Department of Intelligence Science and Technology

# Department of Intelligence Science and Technology

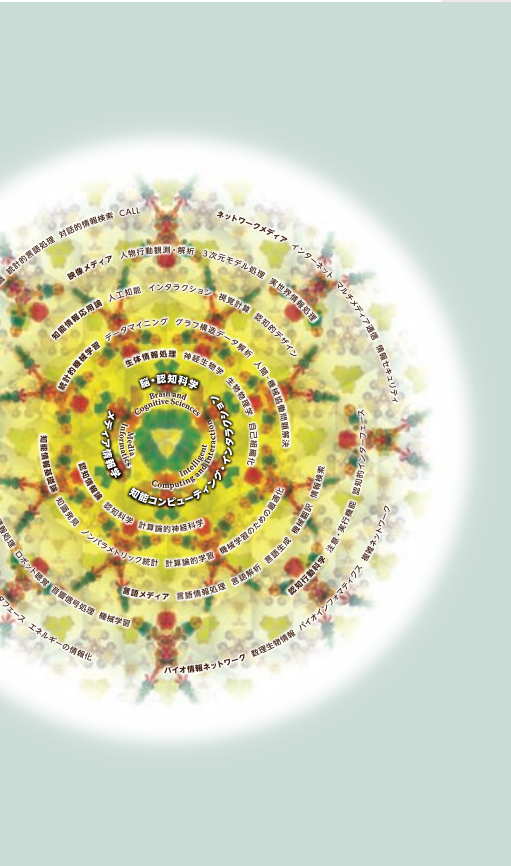
Construction and Elucidation of Intelligence Realization of Flexible, Human-like Information Processing.

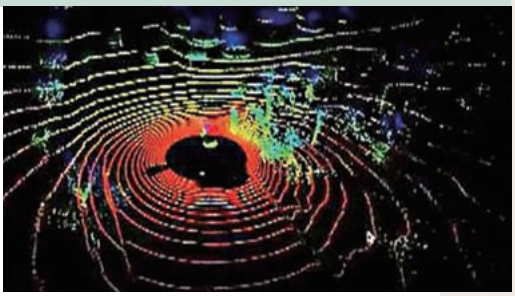
In an advanced information-oriented society, we require information processing with flexible, human-like information capabilities.

Information processing in human and animal organic systems has developed by means of structural and functional adaptation to the environment through a long process of evolution; there is no other high-level processing capacity quite like it.

Intelligence Science and Technology is a multidisciplinary field that aims to clarify the mechanisms of biological- particularly, human-information processing for the development of higher-level information processing.

Welcome to the World of Intelligence Science and Technology.



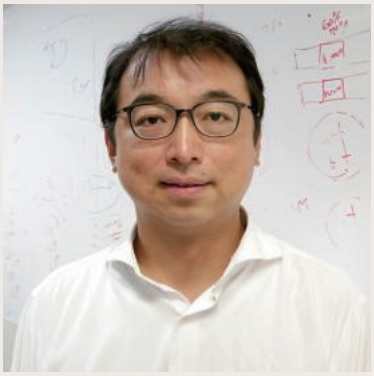





# Welcome to Department of Intelligence Science and Technology

Intelligence Science and Technology is an interdisciplinary research field in which we study sophisticated human information processing and develop new technologies on the basis of an understanding of human intelligence. By “intelligence,” we do not mean simply “`artificial intelligence” but rather a wider scope embracing intelligent aspects of human, systems, and information technology. More specifically, our research and educational activities include (i) basic mechanisms of human beings, such as life, brain, cognition, and behavior, (ii) information media related to language, speech/auditory, and visual information, and (iii) a broad range of topics related to intelligence and informatics, such as interaction between human and intelligent systems, artificial intelligence and machine learning, and software and networks. One of our distinguishing features is integration of these topics under a unique discipline, “intelligence science and technology,” notwithstanding that these topics are also investigated in separate research fields such as neuroscience, psychology, engineering, and computer science. Faculty members and students coming from a wide variety of academic backgrounds devote themselves to cooperating in pursuit of this common goal. We hope that, in this unique academic environment, many young students will engage in this exciting research field, tackle the mysteries of complex human intelligence, and develop new ideas for addressing challenging issues regarding intelligent media and computation.

Our department welcomes outstanding students from various fields besides those of computer science and engineering. We provide interdisciplinary curricula and research projects. Join us, and enjoy an intellectually exciting experience!



*KAMITANI Yukiyasu*

Professor, Department of Intelligence Science and Technology

1993 B.A., Department of Arts and Sciences, University of Tokyo
2001 Ph.D., Computation and Neural Systems, California Institute of Technology
2008 Head of Department of Neuroinformatics, ATR Computational Neuroscience Laboratories
2015 Professor, Kyoto University

## Outline

### Divisions and Groups

| Division | Group | Research and Education Topics | Professor |
|---|---|---|---|
| **Brain and Cognitive Sciences** | Neuroinformatics | Operating Principles of the Nervous System and the Brain and Basic Principles of Information Processing | KAMITANI Yukiyasu |
| | Psychoinformatics | Human Attention and Executive Function, and Cognitive Interface | KUMADA Takatsune |
| | Cognitive Informatics | Human Sensory and Cognitive Processing | NISHIDA Shin'ya |
| | Computational Cognitive Neuroscience (Adjunct Unit) | Neural Information Processing and Computational Models | NAKAHARA Hiroyuki |
| **Cognitive System** | Computational Intelligence | Information Modeling for Intelligent Information Processing Mechanism | YAMAMOTO Akihiro |
| | Collective Intelligence | Machine Learning and Data Mining | KASHIMA Hisashi |
| | Conversational Informatics | Understanding and Designing Interaction, Human Computer Interaction Using Visual Information | |
| **Intelligent Media** | Language Media Processing | Natural Language Processing, Knowledge Engineering | KUROHASHI Sadao |
| | Speech and Audio Processing | Recognition and understanding of speech, audio and music | KAWAHARA Tatsuya |
| | Computer Vision | Computer Vision, Visual Intelligence | NISHINO Ko |
| **Application of Multimedia (Affiliated)** | Video Media | Human-Computer Interaction through Video Images | |
| | Network Media | Techniques to Realize Multimedia Information Network | OKABE Yasuo |
| | Text Media | Advanced Digital Archiving via Speech and Language Processing | MORI Shinsuke |
| **Bio-system Informatics (Affiliated)** | Biological Information Networks | Bioinformatics, Computational Systems Biology | AKUTSU Tatsuya |

### Graduate Curriculum

#### Courses for the Master's Program

Introduction to Cognitive Science
Introduction to Information Science
Introduction to Bioinformatics
Seminar on Cognitive Science
Computational Cognitive Neuroscience
Computational Learning Theory
Pattern Recognition (Advanced)
Conversational Informatics
Multimedia Communication
Speech Processing (Advanced)
Language Information Processing (Advanced)
Computer Vision
Visual Interface
Statistical Learning Theory
Bioinformatics (Advanced)
Seminar on Intelligence Science and Technology I, II, III, IV
Advanced Study in Intelligence Science and Technology I
Advanced Study in Intelligence Science and Technology II

#### Courses for the Doctoral Program

Seminar on Intelligence Science and Technology, Advanced
Seminar on Brain and Cognitive Sciences, Advanced
Seminar on Cognitive System, Advanced
Seminar on Intelligence Media, Advanced
Seminar on Application of Multimedia, Advanced
Seminar on Bio-system Informatics, Advanced

### Teaching Staff

(M) : Academic Center for Computing and Media Studies

#### Professors

KAMITANI Yukiyasu; KUMADA Takatsune; NISHIDA Shin'ya; NAKAHARA Hiroyuki (RIKEN, Adjunct); YAMAMOTO Akihiro; KASHIMA Hisashi; KUROHASHI Sadao; KAWAHARA Tatsuya; NISHINO Ko; OKABE Yasuo (M); MORI Shinsuke (M); AKUTSU Tatsuya (Institute for Chemical Research)

#### Associate Professors

YAMADA Makoto; NAKAZAWA Atsuhi; YOSHII Kazuyoshi; NOBUHARA Shohei; IIYAMA Masaaki (M); MIYAZAKI Shuichi (M); TAMURA Takeyuki (Institute for Chemical Research)

#### Senior Lecturers

HOSOKAWA Hiroshi; MIZUHARA Hiroaki; WU Yang; KASAHARA Hidekazu

#### Assistant Professors

MAEGAWA Shingo; MAJIMA Kei; ICHINOSE Natsuhiro; KOBAYASHI Yasuaki; TAKEUCHI Koh; MURAWAKI Yugo; INOUE Koji; SHIMONISHI Kei; NAKAMURA Eita; KOTANI Daisuke (M); KAMEKO Hirotaka (M); MORI Tomoya (Institute for Chemical Research)

# Brain and Cognitive Sciences

We aim to investigate both the cognitive and the physiological mechanisms of advanced biological, especially human, information processing and to explore possible applications of such mechanisms. For this purpose, we plan to analyze the information processing mechanisms of the nervous system at the molecular, biochemical and physiological levels; to elucidate the underlying principles; and to develop new artificial information processing systems. Moreover, we will analyze the processes of human sensation, perception, learning, memory, thought and inference from both a cognitive perspective and a computational neuroscience perspective in order to examine the mechanisms of these types of information processing.

## Neuroinformatics

*Decoding neural codes*

Brain signals can be seen as “codes” that encode our mental contents. We study methods for modeling brain functions and representations using information science and technology including machine learning and artificial neural networks. Our approach is based on data-driven predictive models that relate brain data and mind states via analysis of massive neural, behavioral, and multimedia data. Using these models, we aim to understand basic principles of neural information processing, and seek to develop real-life applications such as brain–machine interfaces that exploit decoded brain information.

[Professor: KAMITANI Yukiyasu,
Senior Lecturer: HOSOKAWA Hiroshi,
Assistant Professor: MAEGAWA Shingo,
Assistant Professor: MAJIMA Kei]

## Psychoinformatics

*Toward understanding human cognition and applying it to human-machine interface*

Human activities in daily life are supported by basic cognitive functions, such as perception, attention, memory and high-order executive control. We investigate the psychological and neuroscientific bases of these cognitive functions (especially focusing on attention and executive function), using psychological experiments, brain-imaging and computational techniques. We are interested in human behavior not only in well-controlled experimental settings in a laboratory, but also in real-world settings such as IT-equipment use and real car driving. We are also interested in cognitive functions in a wide range of populations, from healthy young adults to older or disabled individuals.

[Professor: KUMADA Takatsune,
Assistant Professor: ICHINOSE Natsuhiro]

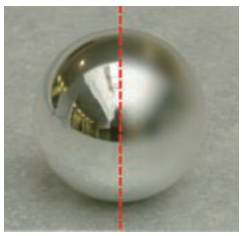
An experiment examining eye and action coordination

## Cognitive Informatics

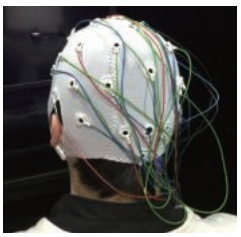
*Understanding Human Sensory and Cognitive Information Processing*

Our lab studies the computational principle and the neural mechanisms of human functions including perception, cognition and language processing, by means of psychophysics, computer simulations and EEG recordings. By comparing human brains with cutting-edge artificial intelligent systems, we attempt to reveal the characteristic nature of the human information processing. We are also interested in leveraging human scientific studies for innovation of information technologies.

[Professor: NISHIDA Shin'ya, Senior Lecturer: MIZUHARA Hiroaki]



Material perception is one of our research topics.



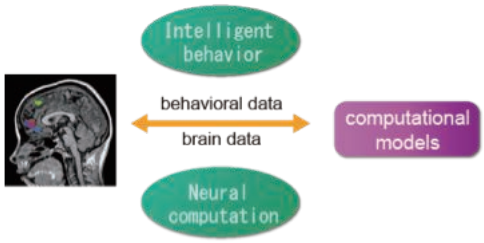
Brain researches by EEG measurements

Outline

## Computational cognitive neuroscience (Adjunct unit)

*Neural information processing and computational models*

We aim to understand the computational principles that underlie the way neural systems realize adaptive behavior and complex minds: e.g., decision-making, reinforcement learning, motivation and emotion, and social behaviors. Our approaches are tightly linked to statistical and information science including machine learning and neural networks, as well as to questions in neuroscience and psychology. To address our questions, we build computational and mathematical models, and develop data analysis methods for linking those behavioral functions and brain signals through computations. We use human fMRI to examine neural signals and computations, combined with those modeling and quantitative methods. We also seek to use our insights to be applied to constructing brain-based intelligence. [Professor: NAKAHARA Hiroyuki]




## Cognitive system

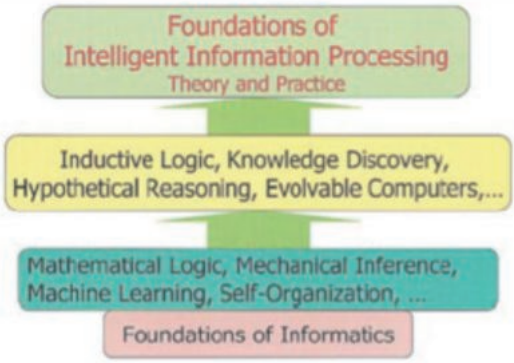
Our goal is to develop flexible and intelligent information processing. We will identify the basic components and structures of information, as well as study extraction, recognition, understanding, and representation of information. We are developing new approaches of intelligence information research including advanced data analysis, reasoning, inference, and interaction.

## Computational intelligence

*Formulation of principles to support intelligent information processing*

We will formalize the intelligent information processing seen in human activities and conduct studies on the basic principles that underlie these processes, as well as realization methods. Specifically, this will involve education and research relating to artificial intelligence information processing such as inductive logic, knowledge discovery, hypothetical reasoning, and evolvable computers, using mathematical logic, inference procedures, machine learning theories and self-organization.

[Professor: YAMAMOTO Akihiro,
Assistant Professor: KOBAYASHI Yasuaki]

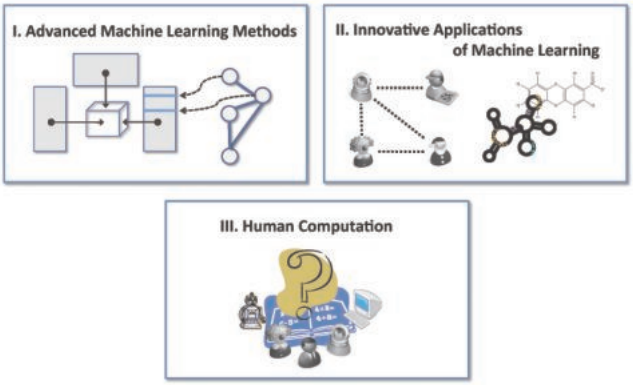


## Collective intelligence

### *Data Analysis That Matters*

Our research focus is on advanced data analysis methods such as machine learning and data mining, and on their applications to important real-world problems in various fields including marketing, healthcare, and industrial systems. Our research interest also includes human-computer cooperative problem solving for hard problems computers alone cannot solve.

[Professor: KASHIMA Hisashi,
Associate Professor: YAMADA Makoto,
Assistant Professor: TAKEUCHI Koh]

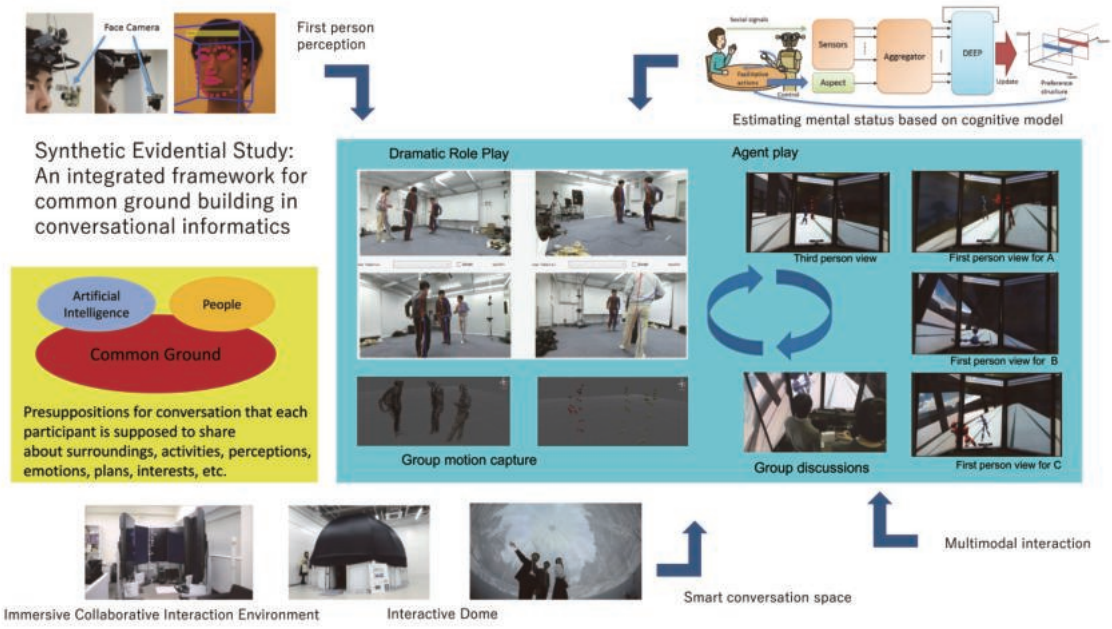



## Conversational Informatics

### *Design and understanding of social intelligence and interaction*

People converse with each other for many reasons: to exchange information, to discuss an issue, to resolve a conflict, to increase mutual understanding, to compose a joint story, or just for fun. Conversation will remain as a vital means for people to communicate with other people and autonomous agents in the emerging human-agent symbiotic society. Our group centers on understanding and augmenting conversational interactions. We are keen to provoke and support empathic conversation in which participants are engaged in a game-like activity to make tacit thoughts explicit and organize them into a larger discourse in a very effective trial-and-error fashion. Building and management of common ground consisting of a shared knowledge and belief among participants is a key issue to make it happen. We take a data-intensive approach to acquire and utilize data entailing how participants interact with each other, what information to be shared, and which aspects of the environment are relevant. We aim at building a computational framework for sharing and cultivating wisdom through enhancing conversational interactions and facilitating conversational content in a community. The primary theoretical backbone is conversation quantization that characterizes conversation as a series of conversational quanta, each of which packages information about relevant participants, references to the objects and events discussed in the discourse, a series of verbal and nonverbal utterances exchanged by the participants, commitments to previous discourse (themes), and new propositions in the discourse (rhemes). We focus on smart conversation space, conversation capture, conversation production, cognitive approach, and synthetic evidential study.

[ Associate Professor: NAKAZAWA Atsushi ]



Outline

# Intelligent Media

The Intelligence Media Division deals with language, speech, and visual information, which are the fundamental media that represent, accumulate and communicate information. Research and education conducted at the Division cover a wide range of topics in theory and application, including analysis, recognition and understanding of information contents represented in these media, as well as media generation/editing to effectively represent and communicate information.

## Language Media Processing

*Making computers that can understand language*

Language is the most reliable medium of human intellectual activities. Our objective is to establish the technology and academic discipline for handling and understanding language, in a manner that is as close as possible to that of humans, using computers.

■Fundamental studies on text understanding

By analyzing over 10 billion sentences collected from the Web using a computer cluster, we are conducting research on automatic learning of predicate-argument structures, inter-event relations, as well as knowledge-based sentence understanding.

■Application of language processing

Through cooperation with various institutions that possess real data, we are working on ways to apply language processing in a real world context.

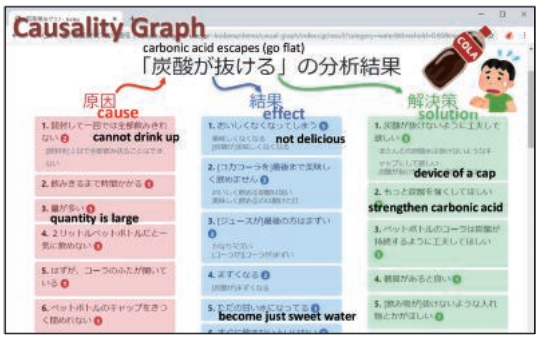
・Advanced information aggregation from SNS texts, contact center inquiry logs, etc.

・Structuring and knowledge processing of medical texts for development of medical AI

・Construction of a dialogue system as a new communication channel between governments and citizens

・Research into practical use of machine translation (simultaneous translation of lectures at universities, etc.)

[Professor: KUROHASHI Sadao,
Assistant Professor: MURAWAKI Yugo]

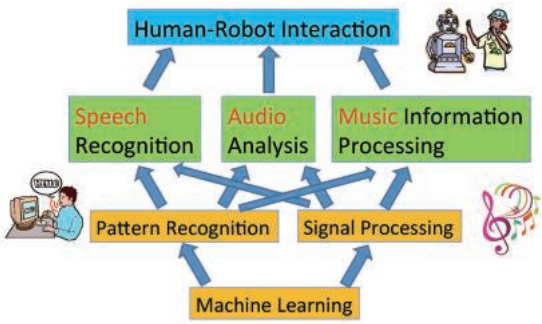



## Speech and Audio Processing

*Recognition and understanding of speech, audio and music*

Speech communication plays a key role in human intelligence. We are studying the intelligent processing of speech, audio and music as exchanged by human beings for automatic recognition, understanding and interaction systems, specifically (1) automatic speech transcription of meetings and lectures, (2) analysis of audio scenes and music signals composed of multiple sound sources, and (3) humanoid robots capable of natural interaction by combining non-verbal information.

[Professor: KAWAHARA Tatsuya,
Associate Professor: YOSHII Kazuyoshi,
Assistant Professor: INOUE Koji,
Program-Specific Assistant Professor: NAKAMURA Eita]



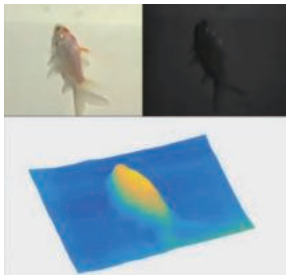
## Computer Vision

*Making Computers See*

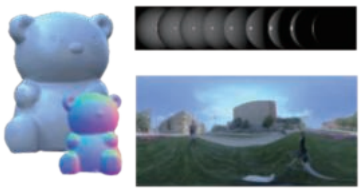
Neural substrates dedicated to vision is said to occupy about 40 percent of the cerebral cortex. Realizing computer vision as a truly intelligent perceptual modality is fundamental for artificial intelligence, and would also inform our understanding of human visual intelligence. Towards computational visual intelligence, our research is focused on establishing the theoretical foundations and efficient implementations of computational methods for better understanding people, objects and scenes from their appearance in images and video, as well as the development of novel computational imaging systems that can see beyond what we see.

[Professor: NISHINO Ko, Associate Professor: NOBUHARA Shohei, Program-Specific Senior Lecturer: WU Yang]

Tracking People in Crowds



Shape from Water



Reflectance and Natural Illumination from a Single Image

## Application of Multimedia (Affiliated)

Multimedia processing with computer devices has new and great potential for expression, information gathering and real-time dialogue processing. We aim to teach and study the technology of multimedia applications through the construction of educational environments in which we can make use of multimedia consisting of images, texts, sound, etc. In this way, students can engage in their studies while creating something of practical use in university courses.

## Video Media

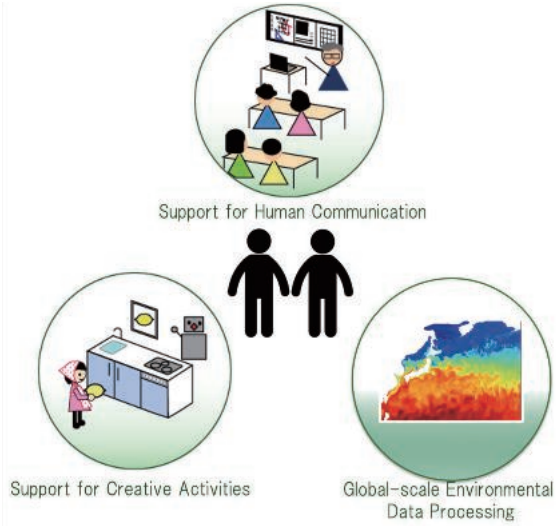
*Human-centric artificial intelligence environment through video media*

Computers act as "information media" to support human activities and communication. Understanding human activities and recognizing the environments in which humans function are necessary for developing such information media.

We study intelligent information technologies for human-centric AI environments and apply them to various fields, such as education, tourism, culinary activities, and primary industries.

- Understanding student behavior for an adaptive education system.
- Smart kitchen system that understands and supports culinary activities.
- Tourist behavior and attribute recognition for recommending optimal activities in light of urban congestion.
- Global-scale environmental data processing for supporting people in primary industries.

[Associate Professor: IIYAMA Masaaki, Program-Specific Senior Lecturer: KASAHARA Hidekazu, Assistant Professor: SHIMONISHI Kei]



Outline

## Network Media

*Towards a ubiquitous networking world*

In a ubiquitous networking world, everything is capable of computing and networking, enabling constant Internet connectivity. Our research goal is to achieve just such an environment. To that end, we are working on fundamental research issues pertaining to the next-generation Internet, including IPv6 architecture and programmable networks, operation technologies such as automatic network configurations, platform technologies that support various services, such as identity federation, and security. We are also working on technologies for integration of information, communication through application of Internet protocols and algorithms such as routing, matching, reservation and interruption, and power management. We also work on design and analysis of algorithms for combinatorial optimization problems, and on proving the intractability of problems.

[Professor: OKABE Yasuo,
Associate Professor: MIYAZAKI Shuichi,
Assistant Professor:KOTANI Daisuke]

Demonstration of on-demand power network

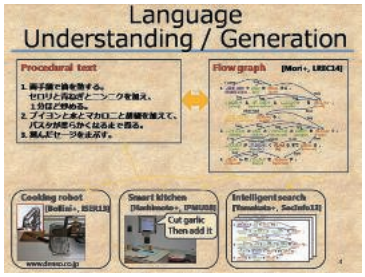
## Text Media

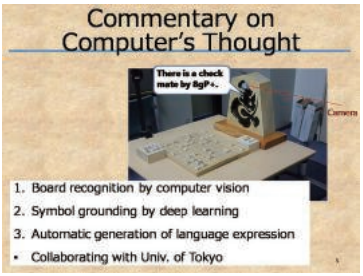
*Speech and Natural Language Processing for Multi-media Archives*

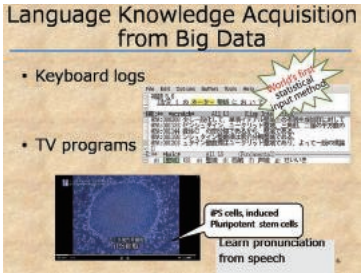
Since time immemorial human knowledge has been recorded as text. The research activities of this group focus on computers capable of understanding these texts and describing new knowledge. As a basis we are studying fundamental natural language processing. And we are studying natural language generation to explain data analysis and future prediction by computer or to describe other media such as video and speech.

Specifically, we deal with real-world media, including procedural texts such as cooking recipes with execution videos, academic knowledge such as history/geography research, and game/data analysis by computers.
We also try to expand human knowledge based on our research results.

[Professor: MORI Shinsuke,
Assistant Professor: KAMEKO Hirotaka]



# Bio-system Informatics (Affiliated)

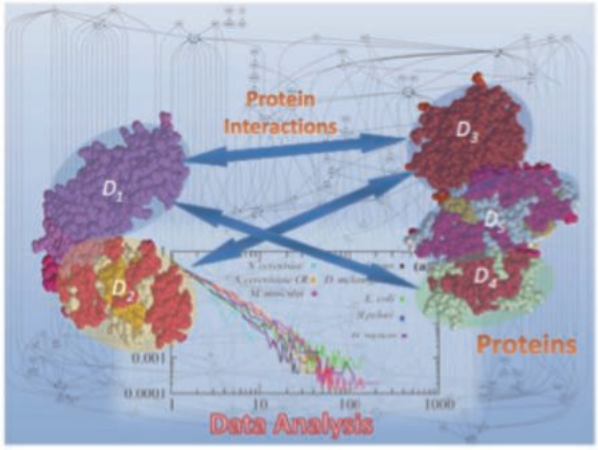
Biological systems and creatures are ineffably complex systems in which many kinds of chemical structures, proteins, genes and other objects interact with one another. We examine these as interactive networks to implement education and research aimed at elucidating and understanding the system, mainly from the perspective of information science.

## Biological Information Networks

*IT for analysis of biological information*

We develop algorithms for inferring interactions among genes, proteins and chemical structures, and for analyzing their interactive networks based on mathematical methods. We also develop algorithms and software tools for other problems in bioinformatics, including sequence analysis and inference of higher-order structures and functions of protein.

[Professor: AKUTSU Tatsuya,
Associate Professor: TAMURA Takeyuki,
Assistant Professor: MORI Tomoya]




Analysis of three-dimensional structures and interactions of protein