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Report

Research Center of Mathematics for Social Creativity at Hokkaido University's Research Institute for Electronic Science × Hitachi Hokkaido University Laboratory

New Research Areas Exploration Symposium 2024

#Carbon Neutral   #Co-creation and Open Innovation   #Regional Revitalization   #Generative AI   #Digital twins/Simulation   #Research & Development

Highlight

Since its opening in 2016 by Hitachi, Ltd. and Hokkaido University as a facility for open innovation, Hitachi Hokkaido University Laboratory has pursued symbiotic urban development that integrates health, industry, and energy. In doing so, its goal is to overcome societal challenges facing Hokkaido through a collaborative approach that transcends the traditional conventions of joint research by collaborating with the community as well as industry, academia, and government.

In a change of format from the Hitachi Hokkaido University Laboratory Forums that have been held over the past four years, the March 2024 symposium was hosted in partnership with the Research Center of Mathematics for Social Creativity, an organization that seeks solutions to problems through mathematics and mathematical sciences and is part of the Research Institute for Electronic Science at Hokkaido University. Under the theme of "New Research Areas Exploration," the symposium was an opportunity to explore new fields of research aimed at creating sustainable communities, addressing this challenge in ways that included mathematics for social creativity, industrial applications of AI, philosophical considerations, and ecosystem building.

The New Research Areas Exploration Symposium 2024 was held at Hokkaido University using a hybrid format that combined offline and online participation.

Opening Address

Hosted by Hitachi Hokkaido University Laboratory and the Research Center of Mathematics for Social Creativity, part of the Research Institute for Electronic Science at Hokkaido University, New Research Areas Exploration Symposium 2024 was held in March at the Sapporo Campus of Hokkaido University using a hybrid format that combined offline and online participation.

In his opening address, Takao Masuda, Executive Director and Vice Dean of Hokkaido University, noted that the symposium would take a different tack from the Hitachi Hokkaido University Laboratory Forums of the past four years, placing a greater focus on academic considerations and addressing new opportunities for collaboration between industry, academia, and government. He had the following to say.

"In seeking to create a sustainable society that delivers wellbeing, Hokkaido University wants to put itself at the forefront of resolving public challenges and achieving social transformation. As numerous people from the private sector, bureaucracy, and municipalities are already helping with efforts to overcome the societal challenges facing Hokkaido, I hope that this symposium can be a vehicle for thinking about the studies that underpin local production for local consumption."

Shinji Nishimura, who heads the Center for Exploratory Research at Hitachi's Research & Development Group, spoke about the work of Hitachi Hokkaido University Laboratory as he expressed his hopes for the symposium.

"Since its opening in 2016, Hitachi Hokkaido University Laboratory has delivered results in the fields of energy and maternal and child health. The topic of this symposium is "New Research Areas Exploration." Along with ongoing work on resolving regional challenges, I hope we can also give thought to the bigger issues and engage in debate aimed at redefining the challenges we face."

Takao Masuda
Executive Director and Vice Dean, Hokkaido University

Shinji Nishimura
General Manager, Center for Exploratory Research, Research & Development Group, Hitachi, Ltd.

First Session: Municipality and Company Perspectives on Challenges

The first half of the symposium was dedicated to two presentations addressing the topics of the region and energy. Entitled "Municipality and Company Perspectives on Challenges," the presentations were given by Makoto Doyashiki, Vice President and Representative Director at Hokkaido Shizen Energy Inc. and a visiting professor of civil and environmental engineering at the Faculty of Engineering, Hokkaido University of Science, and Takashi Takemoto, a guest professor at Hokkaido University's Research Institute for Electronic Science and the acting manager and senior researcher at Hitachi Hokkaido University Laboratory. These are summarized below.

(1) What it Means to Achieve Regional Decarbonization

The government of Japan aims to make renewable energy a major source of power generation by 2030. This means transitioning away from the power systems of the past based on the delivery of electric power from power stations to consumers and moving towards a multi-nodal distributed power system that utilizes renewable energy. This begs the question of how the landscape of Japan will change in response to this shift to distributed generation.

The current electric power system arose out of societal needs. As the shift from gas to electrical lighting created a need for electricity, a government-controlled system emerged from the 1930s onward. The goal here was to ensure a reliable supply of the electric power that came to underpin industry as more and more factories switched from steam to electricity as their primary source of power. Given the expectation that the ongoing market liberalization of recent years will bring significant changes to this system, it has become necessary for the region to be designed on the assumption that past practices will change.

Makoto Doyashiki
Visiting Professor of Civil and Environmental Engineering, Faculty of Engineering, Hokkaido University of Science
Vice President and Representative Director, Hokkaido Shizen Energy Inc.

The Third National Spatial Strategy published in July 2023 included a provision for increasing regional energy self-sufficiency to ensure availability during disasters. While investment is clearly needed to develop energy resources in the region, revenues from levies aimed at encouraging renewable generation and from the taxation of oil and coal are expected to fall in the future. Ways of making up for this shortfall are therefore currently under consideration. For example, in addition to paying for the costs of CO_2 emissions as called for in the Green Transformation (GX) Promotion Act, it is also expected that the development of rules on government support for companies to decarbonize will go a long way towards getting people to take decarbonization seriously.

Looking at the region, it is vital for municipalities facing regional challenges such as population decline and depopulation to become financially affluent in order to overcome those challenges. The resources they need to address societal challenges will become available if they work within a local economic cycle of production, income, and expenditure, preventing the outflow of money outside the region and pursuing practices that achieve this. What is meant by regional decarbonization is expressed by a formula in which decarbonization × XXX equates to measures for addressing regional challenges. That is, rather than a goal, decarbonization is a means of resolving regional challenges. Whatever initiative fills the "XXX" placeholder will vary from region to region. For example, if practices can be developed that use locally generated energy to keep money circulating within the region, it should serve as a lever for action on regional challenges. Along with our focus on using decarbonization as a means of addressing local issues, Hokkaido Shizen Energy will help to provide residents with inclusive community development.

(2) Social Applications of Mathematical Sciences: Initiative for Local Production of Energy for Local Consumption Featuring Community-based Battery Swapping

While Hokkaido's expansive land area makes it rich in renewable energy resources, a lack of transmission capacity is among the factors holding back greater use of these resources. One option is to build microgrids, autonomous power systems that can operate without a connection to the grid. The difficulty here is that the widely fluctuating output of photovoltaic, wind, and other similar generation methods means that power systems must be of a certain size if they are to keep supply and demand in balance. This makes the installation of regional microgrids both time-consuming and expensive, putting it beyond the reach of most municipalities.

Takashi Takemoto
Guest Professor, Research Institute for Electronic Science, Hokkaido University
Acting Manager and Senior Researcher, Hitachi Hokkaido University Laboratory

In response, Hitachi Hokkaido University Laboratory has been investigating a development model that works in partnership with local industry as it pursues the local production of energy for local consumption in a way that matches demand. This involves locating multiple small autonomous grids (nanogrids) around the region. As well as helping local industry by consuming the electricity this generates locally, the plan for the future is to also use it for freight, transportation, and disaster prevention and to maintain reliable operation, coordinating the transfer of excess power between nanogrids with the help of electric vehicles (EVs), batteries, and other energy storage.

A trial site featuring an autonomous nanogrid that uses a multi-fuel engine to provide balancing capacity was built in Iwamizawa City in 2021 with the assistance of the municipality. Developed by Hitachi's Center for Exploratory Research, the multi-fuel engine is capable of generating electric power from a variety of different fuels. In this case, it runs on gas emitted by local hot springs and its operation is coordinated with photovoltaic power generation. This ensures a steady supply of the required level of electric power even as the photovoltaic output varies.

To assess and verify the utility of distributed energy systems that feature a high level of variability, being made up of multiple nanogrids powered by renewable energy, an evaluation technique was developed through a mathematical collaboration with Hokkaido University. This involved devising an algorithm for satisfying the dual requirements of secure electricity supply and transportation. It worked by solving an optimization problem in a virtual environment subject to multiple constraints, including the weather and demand. This was used to analyze a year's worth of log data on EVs and nanogrid operation.

As depopulation leads to a wider geographical separation between suitable sites for renewable generation and the places where the electricity is used, work is also underway on developing portable alternating current/direct current (AC/DC) batteries that can deliver temporary electric power to locations such as farms that have land but are unable to supply electricity. This includes studying a model whereby the batteries are removed from electrical farm machinery when not in use and taken to worksites scattered across the community to serve as a low-cost means of supplying the energy they need. Consultations are being held with municipalities and people in the agricultural industry and the trial will be conducted through joint development with the companies concerned. As actual deployment requires investigation of both short-term and long-term considerations, simulations that run in a virtual environment based on equipment and map information will be used to develop systematic evaluation techniques, including determining whether battery delivery and charging and discharging can be aligned with demand. The demonstration project will commence in 2024.

Second Session: "Seeds" from the Private Sector and Universities

The second half of the symposium featured four speakers on the topic of "Seeds from the Private Sector and Universities" (where "seeds" are the ideas and know-how that go into a new venture). They presented research and applications of leading-edge technologies such as the highly topical field of generative artificial intelligence (AI). These are summarized below.

(1) Where Next for a Composite Society in which Humans and Machines are Equal? – Considering AI in Terms of Industrial Applications

At Laboro AI, we work on applications for AI in a variety of industrial sectors. Today, I would like to draw on the perspective this work provides to share some ideas with you on where innovation might be headed in an AI future.

The concept of a composite society in which humans and machines are equal was proposed by Professor Emeritus Toru Nishigaki of the University of Tokyo in his book, Fundamental Informatics. While I do not work in academia, coming from the standpoint of an AI venture business, I have believed for some time in the value of innovations coming out of Japan gaining global traction. Unfortunately, I also have my doubts as to how realistic this is in a Japan that is said to have fallen behind since the rise of the Internet. Amid all the interest currently being garnered by generative AI, it is true that the Japanese government has allocated funding to related technologies such as large language models (LLMs). But is it really enough for us merely to follow behind the current generation of AI that is driven by huge investments from Europe and America? If we assume that the answer is no, do we then need to place our bets on pursuing the next generation of AI? In other words, shouldn't we be engaging in initiatives and addressing problems that look beyond the AI of today?

Tetsuo Shiihashi
CEO and Representative Director, Laboro AI, Inc.

Generative AI has been characterized as a major breakthrough. From a practical standpoint, however, what I believe is needed are AIs that can achieve a given objective by first working out for themselves how best to go about doing so. What I mean by this is techniques that are equipped with formulas for assessing goals and the extent to which they are achieved, and that devise ways of working based on progressively improving themselves by interacting with the environment and "learning how to learn." The AIs of today are not yet capable of this.

Traditional software works in ways that are explicitly designed by humans. Present-day AIs represent the next step, being pre-trained on data to inductively determine their rules of operation. I would count generative AI and foundation models as successful examples of this. Extrapolate this one step farther and what you get are algorithms that learn progressively based on a predetermined design, striking a balance between exploration and actual work. Go farther still and what I expect you will come to are autonomous techniques that optimize how they learn as they are learning, with only the goal function being specified in advance.

If the next generation of AIs are to be capable of flexible learning by trial and error in a way that closely mimics the natural intelligence of living things and incorporates techniques for working out for themselves how to achieve their goals, then they will need an architecture that is fundamentally different from the AIs of today. My belief is that the development of technology in this new field will require the combination of machine learning with models that incorporate existing knowledge as well as a fusion of various different fields, including established methods from the field of optimal search along with reinforcement learning, new forms of computing, and more.

(2) Task Efficiency Improvement and Optimal Strategy Design Using Reinforcement Learning Strategies

Our work applies the mathematical and social sciences to a variety of measures that are aimed at using urban development as a means of regional revitalization and the improvement of wellbeing, including energy management and community empowerment.

One of the challenges of community empowerment is that it is difficult to identify which aspects of the individuals, groups, and organizations that make up a community have been improved by the empowerment measures chosen. Accordingly, we are investigating how best to determine, with a minimum of trial and error, which measures are the most effective when putting wellbeing assessment criteria and wellbeing policies (options) in place.

Komatsuzaki Tamiki
Professor, Institute for Chemical Reaction Design and Discovery and Research Center of Mathematics for Social Creativity, Research Institute for Electronic Science, Hokkaido University

The multi-armed bandit algorithm is a reinforcement learning technique that works by trial and error. It addresses the problem of how best to allocate a fixed set of resources across competing options to maximize the expected benefits. Normal practice for determining which methods work best involves testing, with the number of tests depending on the number of available methods or combinations of methods. Conclusions are then drawn from the results. In contrast, the multi-armed bandit algorithm determines which combination of methods is best as the testing progresses. As the algorithm can obtain an optimal solution based on the specified options and payoffs, it is already in widespread use for applications such as cancer treatment.

Unfortunately, people determine their preferences and opinions in ways that are unconnected with these payoffs. As the views of stakeholders such as residents and municipalities play a part in measures for addressing regional challenges, these do not translate simply into numbers. Nevertheless, use of this method is recognized academically as having great value in this application.

This has led us to look closely at democratic AI. This approach works by defining virtual players that represent people's ideas and preferences and then having the AI autonomously devise optimal strategies for a given set of conditions. When applied to the public goods game, for example, the algorithm was able to determine an optimal result that satisfied all players, taking account of factors such as the players' assets and changes in the amount of investment. We believe that such techniques will prove useful in areas like consensus-building when considering how to address regional challenges.

We are currently engaged in opinion gathering, including by conducting surveys of various industries around the world to study target applications for the deployment of virtual AI. In the future, we intend to continue engaging in industry-academia collaboration to discover and create new fields of study and uncover useful topics.

(3) Superposition of Self and Others and Intermediation: Research Fusing Philosophy with AI

The first issue to consider when thinking about community empowerment is: what is a community? People who travel by the same train do not constitute a community. A collection of individuals does not necessarily form a community, nor does a community exist in anything other than a collection of individuals. In other words, the elements that form a community are not its individuals but their communication. There exists a cyclical relationship where the community arises out of communication and the community in turn sustains this communication.

For this reason, we believe that, as long as communication remains effective, a community can form even if AIs, rather than humans, participate in this communication. In exploring the relationship between AI and community, we are researching the relationship between self and others (social cognition) that lies at the foundation of any community.

One such relationship is the superposition of self and others. Consider how you find yourself moving your feet unintentionally while watching a soccer game. Such experience of 'overlapping oneself with others' (in the sense of "putting yourself in the other person's shoes") is nothing special. Rather, it occurs naturally and is something that we believe is fundamental to social cognition. While theory-theory (TT) and simulation-theory (ST) provide a theoretical framework for the study of social cognition, both approaches presuppose a division between self and others, without considering how this division is formed.

Shigeru Taguchi
Director, Center for Human Nature, Artificial Intelligence, and Neuroscience (CHAIN)
Professor, Faculty of Humanities and Human Sciences, Hokkaido University

In response, based on insights from the field of philosophy, we hypothesized that the concepts of self and other are acquired through learning. We then ran simulations using an AI. We created an AI agent that learns visual predictions in a virtual environment to be able to predict what will happen next in a given situation. We implemented into this model a 'superposition mechanism' that divided the same input into two and overlaid them. As a result, the agent became capable of predicting visual events from the perspectives of others simply by accumulating first-person experiences.

We are also conducting research on community empowerment through AI intervention. Indicators for measuring the activation level of communication include the frequency of contact, duration, amount of conversations, number of questions, and intensity of behavior. In addition to these objectively measurable criteria, it is also necessary to consider the awareness of the members who make up the community.

To this end, we are considering an experiment where an AI chatbot is included in an online community to examine how the presence and type of AI intervention affects the activation level of communication. This involves analyzing cases where AI intervenes and cases where it does not, across multiple sessions of multiple groups, measuring to what extent different types of AI interventions activate human conversations. In the future, we also plan to study the impact of AI intervention on consensus-building within groups.

Through these experiments, we aim to explore the potential of community empowerment through AI intervention. By learning from the ways AI intervenes, we will also seek hints for effective human intervention.

(4) Small Models and Large Reality: Public Perceptions of what Mathematics is for

If we are to attempt to use mathematical models to address societal challenges, then an understanding of the nature and characteristics of these models is also needed among the people calling for these solutions. Accordingly, I would like to talk today about what mathematical models are, their purpose, and what they tell us about the real world.

I will start with two examples from the history of science that express the relationship between mathematical models and reality.

Columbus was the victim of two errors when he departed Spain in 1492 in search of India. The first error was to calculate the nautical distance to travel based on a belief that Japan was to the west of Spain and that India lay farther still to the west. The second error was to underestimate the size of the globe based on the writings of geographers and astronomers from ancient times. Nevertheless, despite basing his decision to embark on the voyage on a calculation of the distance from Spain to Japan that derived from these erroneous assumptions, he instead reached the continent of America.

The complexity of the real world is too great for anyone to measure or perceive it in its entirety. This is why people use models to understand, predict, and in some cases intervene in a complex reality. Because models are so much smaller than the large and complex real world, the correspondence between models and theory on one hand and reality on the other will necessarily be imperfect. While Columbus' success was a matter of luck, his story in this sense can serve as an extreme example of the relationship between mathematical models and the real world.

Another example is the contention between the heliocentric and geocentric world views. While everyone now knows the geocentric world view to be invalid, if you compare the two models in terms of their ability to explain and predict the data, both are capable of doing so with exactly the same accuracy. Both models are obliged to approximate cyclical functions with a Fourier series, with only the level of complexity and number of parameters being different. Which is to say, invalid models can still be extremely useful for explaining and predicting reality and have proven so in practice.

If the goal is to make predictions rather than to learn the truth, then an incorrect model is not a problem. What sometimes happens when researching an issue, however, is that a critical voice suggests that solving the problem will require a more complex model that is closer to reality. The result in this case is often that it becomes an impediment to communication and the problem ends up not getting solved.

If the people seeking solutions to problems, namely local residents or companies, have an understanding of the principles and mechanisms used in mathematical models, they will be able to devise solutions for themselves, also allowing the researchers working on the models to come up with more effective ideas. If such a problem-solving cycle is to be established, then I believe that improving literacy regarding mathematical models will have an important part to play. We intend to persevere with discussion of how this can be brought about.

Masanori Takezawa
Professor, Faculty of Humanities and Human Sciences, Hokkaido University

Closing Address

In his closing address, Professor Tsuyoshi Setoguchi of the Faculty of Engineering at Hokkaido University referred to his own background, specializing in architecture and regional planning, and had the following to say about the symposium program.

"If the community empowerment and other concepts discussed at today's event can be applied to regional societies, I believe they will prove a valuable means of providing communities facing falling populations with safe and secure infrastructure for living. As well as looking forward to further progress in these joint studies, we at Hokkaido University will also be working to resolve societal challenges not only in Hokkaido, but also in the rest of Japan and the wider world by deepening collaboration between people in government, the private sector, and the community."

Tsuyoshi Setoguchi
Professor, Faculty of Engineering, Hokkaido University

Next to speak was Shinji Yamada, who heads the Hitachi Hokkaido University Laboratory, Center for Exploratory Research, Research & Development Group, Hitachi, Ltd. He wrapped up the symposium with the following comments on the work of the laboratory since its opening in 2016. "Over the roughly eight years of its existence, Hitachi Hokkaido University Laboratory has engaged forthrightly in work on resolving societal challenges, not only proposing solutions, but also putting them into practice. Moreover, we intend to continue working energetically and collaborate with our partners to explore new fields of study. I hope that all of you who attended today will come away with some insights and useful suggestions from these presentations."

Shinji Yamada
Laboratory Manager of Hitachi Hokkaido University Laboratory, Center for Exploratory Research, Research & Development Group, Hitachi, Ltd.

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