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FEATURED TOPIC

Todai Robot Project

INTERVIEW WITH

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Can a Robot Get Into the University of Tokyo? The Challenges Faced by the Todai Robot Project

The Todai Robot Project was begun in 2011 by the National Institute of Informatics in order to reunify the field of artificial intelligence, which has been splintered since the 1980s, and open up new horizons.. Its benchmark targets are to achieve a high score on the National Center Test for University Admissions by 2016, and pass the University of Tokyo entrance exam in 2021. Sub-project director Associate Professor Yusuke Miyao discussed these targets and provided an overview of the project.

Tainaka Could you tell us the objectives of the project?

Miyao We are researching the process of thinking by developing a computer program that will be able to pass the University of Tokyo entrance exam. The program will need to integrate multiple artificial intelligence technologies, such as language understanding, in order to develop all of the processes, from reading the question to determining the correct answer. While the process of thinking is first-nature to people, many of the processes involved in mental computation are still mysteries, so the project will be taking on challenges that previous artificial intelligence research has yet to touch.

Tainaka You're not going to making a physical robot?

Miyao No. What we'll be making is a robot brain. It won't be an actual robot that walks through the gate, goes to the testing site, picks up a pencil, and answers the questions.

Tainaka Why was passing the university entrance exam selected as the project's goal?

Miyao The key point is that what's difficult for people is different than what's difficult for computers. Computers excel at calculation, and can beat professional chess and shogi players at their games. IBM's "Watson" question-answering system*1 became a quiz show world champion. For a person, beating a professional shogi player is far harder than passing the University of Tokyo entrance exam, but for a computer, shogi is easier. What makes the University of Tokyo entrance exam harder is that the rules are less clearly defined than they are for shogi or a quiz show. From the perspective of using knowledge and data to answer questions, the university entrance exam requires a more human-like approach to information processing. However, it does not rely as much on common sense as an elementary school exam or everyday life, so it's a reasonable target for the next step in artificial intelligence research.

Tainaka Elementary school exam questions are more difficult?

Miyao For example, consider the sentence "Assuming there is a factory that can build 3 cars per day, how many days would it take to build 12 cars?" A computer would not be able to create a formula that expresses this in the same way a person could, near-instantaneously. It wouldn't understand the concepts of "car" or "factory", so it wouldn't be able to understand the relationship between them. Compared to that, calculating integrals is far easier.

> What's difficult for people is different than what's difficult for computers

Tainaka The National Center Test for University Admissions is multiple choice, and the second-stage exam is a short answer exam, right?

Miyao Of course, the center test is easier, and it has clear right and wrong answers, making it easier to grade. For the second-stage exam, examinees must give written answers, so during the latter half of the project, we will be shifting our focus on creating answers which are clear and comprehensible to human readers.

Tainaka Does the difficulty vary by test subject?

Miyao What varies more than the difficulty itself are the issues that have to be tackled by artificial intelligence research. The social studies questions, which test knowledge, rely on memory, so one might assume they would be easy for computers, but it's actually difficult for a computer to determine if the text of a problem corresponds to knowledge the computer possesses. What makes that identification possible is "Textual Entailment Recognition"*2, an area in which we are making progress, but still face many challenges. Ethics questions, on the other hand, frequently cover common sense, and require the reader to understand the Japanese language, so they are especially difficult for computers, which lack this common sense. Personally, I had a hard time with questions requiring memorization, so I picked ethics. (laughs)

Tainaka So ethics and language questions are difficult because they involve common sense.

Miyao Similar challenges are encountered with English, other than the common sense issue. For example, English questions include fill-in-the-blank questions, but it's difficult to pick natural conversational answers without actual life experience. Reading comprehension questions test logical and rational thought, but it's not really clear what this "logical and rational thought" consists of. The question, then, is how to teach "logical and rational thought" to computers. Also, for any subject, questions sometimes include photos, graphs, and comic strips. Humans understand them unconsciously, but it's extremely difficult to have computers understand them.

Tainaka Aren't mathematical formula questions easy to answer?

Miyao If they were presented as pure formulas, computers would excel at them, but the reality is not so simple. The questions themselves are written in natural language, making it difficult to map to the non-linguistic world of formulas. The same difficulty can be found with numerical fields, like physics or chemistry, or in fields which are difficult to convert into computer-interpretable symbols, such as the emotional and situational experience of reading a novel. That's what makes elementary school exams difficult.

Tainaka There are a mountain of problems.

Miyao There are many problems that nobody has yet taken on. That's what makes it challenging, and it's very exciting working with people from different fields. Looking at the practical results of this project, our discoveries and developments will be adapted for use in general purpose systems, such as meaning-based searching and conversation systems, real-world robot interfaces, and the like. The Todai Robot Project covers a diverse range of research fields, and NII plans to build an infrastructure, organizing data and creating platforms, and bring in researchers from both inside and outside Japan to achieve our objectives. In the future we will build an even more open platform, creating opportunities for members of the general public to participate as well, and I hope anyone motivated will take part.

A Word from the Interviewer

Over half a century has passed since people first began attempting to provide computers with human intelligence, but it finally feels like all the ducks have been put in a row. The goal of passing the University of Tokyo entrance exam is both clear and appealing. There remain many obstacles, but they feel like surmountable ones. The best aspect of the project is the zeal with which young researchers participate in it. It is certain to act as a catalyst for accelerated AI research in the future.

Madoka Tainaka

NII Today Copy Editor / Editor & Writer

Graduate of Chuo University, Faculty of Law, Department of Law. Former chief editor of the science and technology information magazine Nature Interface, Ministry of Education, Culture, Sports, Science and Technology Council for Science and Technology Information Science Technology Committee Technical Advisor, etc. In addition to being a copy editor at NII Today, she has also written and edited many manuscripts. She co-authored "These Are Numbers, Too?! Car Navigation, Street Maps, and SNS" (Maruzen Library). Her fields include science and technology, urban studies, the environment, and music. She strives to convey the writings of experts in a clear and easy to understand way.

***1: Watson**

A question answering system developed by IBM. Research and development on Watson began in 2007 as a grand challenge for IBM. In February, 2011, Watson took on two former champions on America's famous quiz show, "Jeopardy!", and won first prize.

***2: Textual Entailment Recognition**

A natural language processing task that determines whether two different texts have the same meaning.

What Impact Will the Todai Robot Project Grand Challenge Have on Society?

The aim of artificial intelligence is to reproduce human thought processes and intelligence on computers. AI technologies have made remarkable progress since the earliest days of computing, after several turning points and major challenges. The Todai Robot Project, which began in 2011, is also drawing attention as a major new challenge which will further advance artificial intelligence technology. We talked with researchers on the frontline of AI about its potential, and their hopes for the project.

The fundamental question of "what is intelligence?"

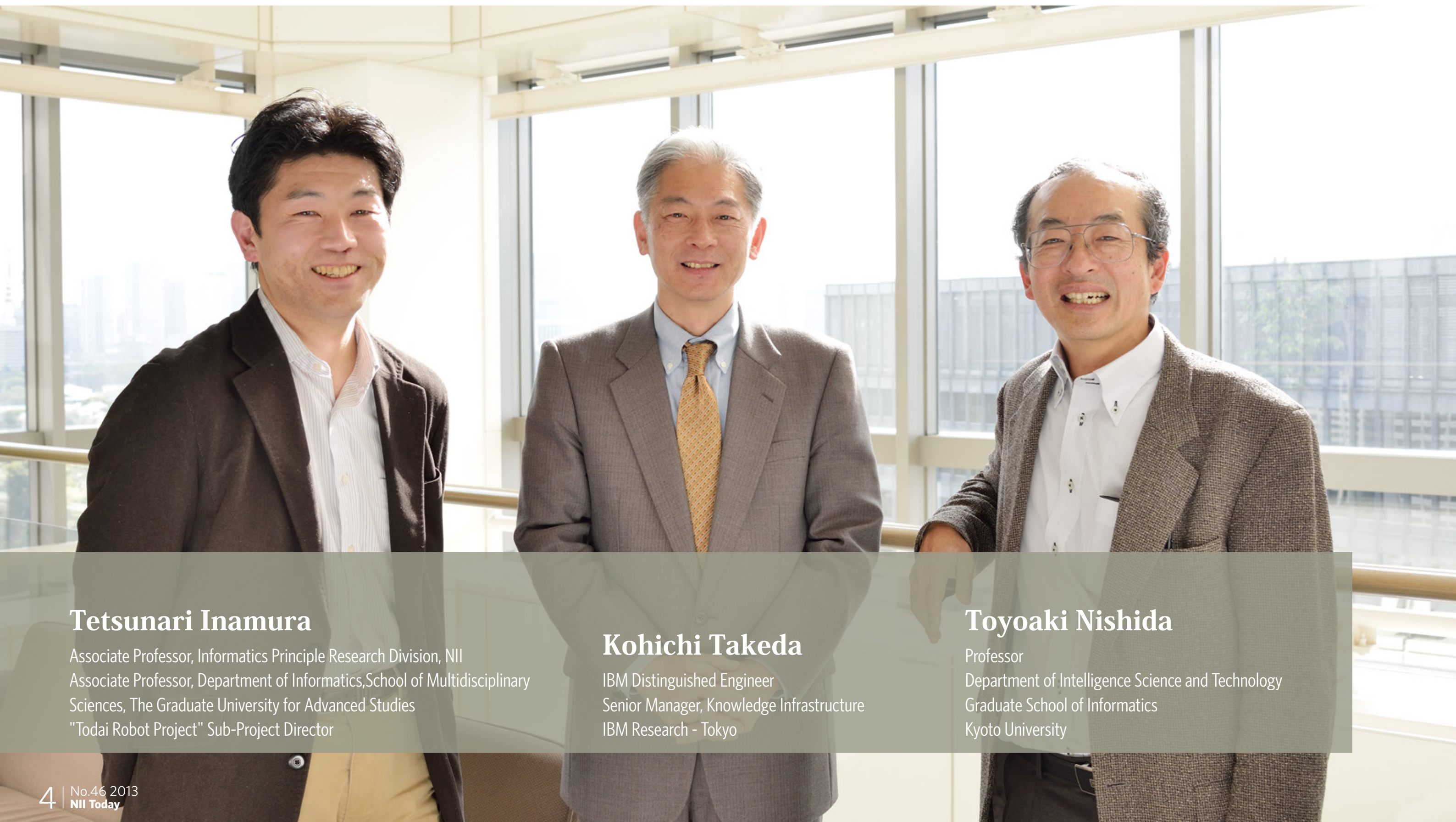
Inamura Artificial intelligence is often thought of as being a young field, but it actually has quite a long history.

Nishid The word "artificial intelligence" was first used at the Dartmouth Conference*1 in 1956. The world's first computer, ENIAC, was developed in 1946, so it would be fair to say that full-fledged research into artificial intelligence began right after computers were invented. Artificial intelligence research since then has undergone a paradigm shift roughly every 10 years. While no artificial intelligences which surpass total human intelligence have been created yet, various elemental technologies, like data mining technology*2, audio and image recognition technology, natural language processing technology, and information retrieval technology, are already in use in society.

Inamura With regards to creating human-like results — which also applies to robots, in the sense of humanoid robots — what do you think about the relationship between artificial intelligence and robots?

Nishida There are two extremes regarding the embodiment. One holds that it is produced by the brain alone, and the other that it is fundamentally dependent on embodiment. I believe the latter. I believe that embodiment is essential to an intuitive understanding of diagrams or spatial relationships, and hence artificial intelligence and robotics share a significant amount of common thoughts, principles and designs.

Inamura I've specialized in robotic engineering since I was a student, so I'm in charge of the physical challenges presented by Todai Robot Project. These physical challenges are typical examples of hurdles that cannot be overcome by cerebral thought alone. Handling real-world phenomena, like throwing a ball, or breaking something by applying too much force, requires the knowledge and direct understanding of physical laws that people absorb through their own physical experiences. Right now, we are using simulators, but in the future I hope that robots will be able to be active in the real world, just like humans, and acquire knowledge through their experiences. However, the engineering hurdles to achieving the functions of the human body are very high, so in the future the issue of how to tie it together to artificial intelligence, in the sense of cerebral functions, will be a major challenge.



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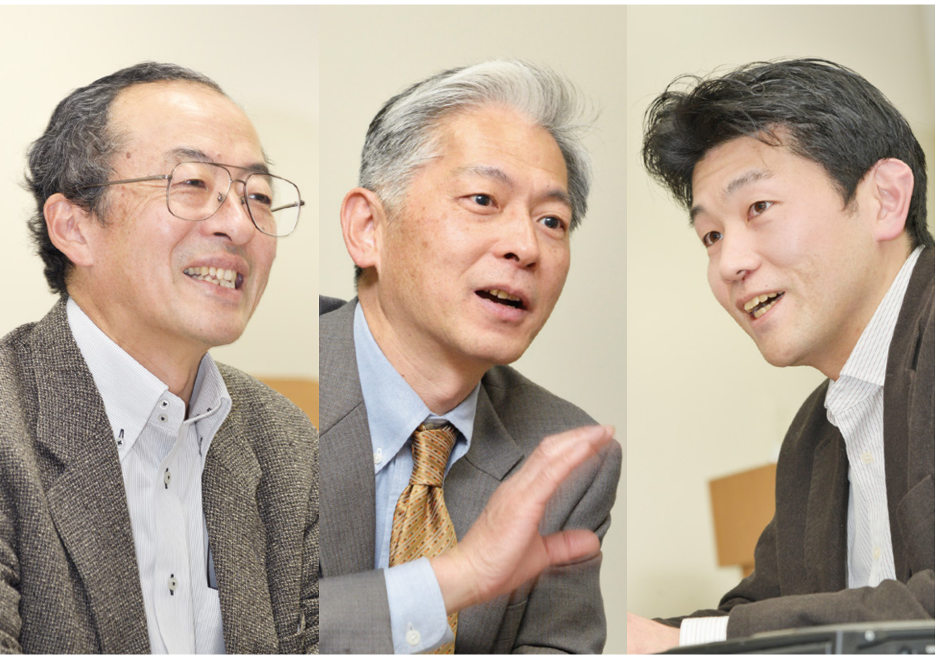


Nishida We also have to think deeply about the fundamental issue of what is necessary to create human-like artificial intelligences and robots. For humans, in addition to intelligence, mind and emotion also play important roles. Creating remarkably sophisticated artificial intelligences and robots requires these types of elements to be included.

Takeda The Watson project, which I took part in, did not include these human elements. We focused exclusively on the ability to compute answers to given questions. For example, we didn't use voice recognition, just voice synthesis when it read back the answers. It is not a system which would listen to a question and respond like a human, either. On the other hand, it does not panic when behind and make incorrect answers. In that sense, Watson is not replacing humans, and instead, it is a system for supporting human intellectual activities by specializing on using a large amount of data to generate potential answers and hypotheses to provide evidence-based answers to questions.

Entering the fields of embodiment and heart

Inamura Just as IBM positioned Watson as a grand challenge, NII has positioned Todai Robot Project as a grand challenge. The objective is to pass the Tokyo University entrance exam, but even if it achieves that, it will be just the first step towards true intelligence. For example, consider this elementary school science problem. "Butter is applied to several locations on a metal rod, and beans are stuck to the butter. If one end of the rod is heated with a candle, in what order will the beans fall off?" Even if the Todai Robot Project were able to pass the Tokyo University entrance exam, it wouldn't be able to answer this question. That's because it cannot be turned into symbols or an equation. However, for a human, even an elementary school student, this can be solved based on just experiential knowledge and common sense. So, how should this type of human knowledge be handled? Right now, we are trying to use advanced programming, but, ideally, in the long term it would be possible to acquire by artificial intelligence on its own. In other words, we will have to move up from Tokyo University to elementary school. That will be really difficult, but it's an area into which robotics and artificial intelligence needs to move. I believe that the Todai Robot Project will be extremely significant as a first step.

Takeda In the latest IBM 5 in 5 - a list of innovations that have the potential to change the way people work, live and interact during the next five years, we discusses a list of innovations to mimic the five human senses. IBM researchers have begun exploring on advances which will help computers to incorporate human senses in their own ways. It will not be easy to convert biological information such as taste or smell into current machine learning and statistical reasoning. However, if it can be done, it might be possible to mimic human-like thinking and intelligence even more. What's more, if physical sensations play a role in the formation of human common sense, as well as affecting feelings and emotions, they would be vital elements in the world of information technology.

Nishida The first-stage objective, scoring highly on the National Center Test for University Admissions, could be achieved to some extent using a Watson-like approach of focusing intently on the ability to handle questions and responses based on large amounts of data. However, answering questions such as Japanese questions on the second-stage exam will require the inclusion of elements such as feelings and emotions. Generating written answers for the second-stage exam requires enough written expressive ability to impress the reader. It would be a great accomplishment if we were able to achieve that. I think what makes the Todai Robot Project such an important and groundbreaking challenge is that it delves deep into emotional understanding and expression as well.

Takeda The very fact that we can take on those challenges shows the tremendous potential of the field.

Nishida As an artificial intelligence researcher, I would love to have a conversation with an intelligence that could pass the second-stage exam.. I think that that by practically searching for answers to challenges in which human intelligence is reflected, we can penetrate into the heart of human intelligence itself. It would certainly increase human creativity and contribute to greater societal progress. I'm looking forward to the future challenges posed by the Todai Robot Project.

(Written by Akiko Seki)

***1: Dartmouth Conference**
Artificial intelligence research conference held in 1956. Its official name is "The Dartmouth Summer Research Project on Artificial Intelligence", and was the first place where the term "artificial intelligence" was used.

***2: Data mining technology**
Technology for identifying information which is useful for people from a large volume of unorganized data.

Solving Mathematics and Physics Entrance Exam Problems with AI Technologies

Current Research and Future Prospects

Using AI technologies to answer mathematics and physics questions presents a different type of difficulty than solving social studies questions. Furthermore, mathematics and physics require both shared and differing methodologies. We talked with Hirokazu Anai, Takuya Matsuzaki, and Hikaru Yokono, who are playing pivotal roles in developing mathematics and physics question answering technologies, about their progress on the challenge, the issues they face, and potential applications of the technologies they are developing.

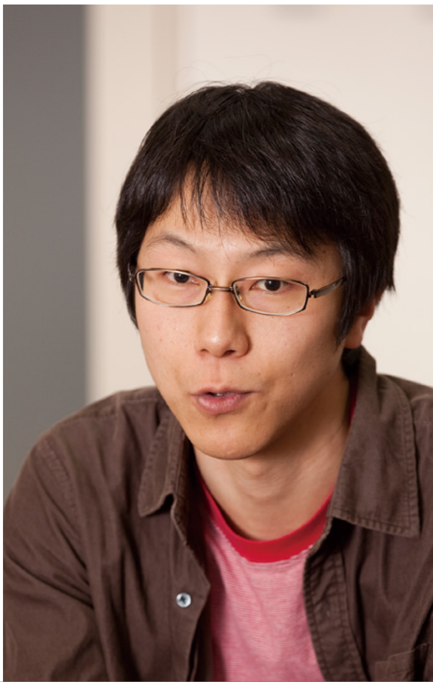
"Math Solvers" and "Physics Simulators"

The first step in solving the math and physics problems with AI is to read and understand the questions. This step is mainly handled using language processing techniques. "Language processing" here refers to converting questions, provided in the form of text, to expressions which the computer can understand. Broadly speaking, this part of the process is identical for both mathematics and physics questions. However, from that point on, the approaches diverge. In the case of mathematics, after the meaning of the question has been determined, a formula is derived from the meaning. For different types of formulas, different reasoning algorithms (solvers) are used. The derivation process of the formula thus bridges the gap between the logical expressions of the question and the logical expressions necessary to calculate its solution.

In the case of physics questions, the problem is also understood using language processing, but the next step is to use "physics simulators". They simulate the physical process described in the problem, and the solution is determined by looking at the results of the simulation. This step thus differs from the mathematics problem-solving approach. NII's Hikaru Yokono, who is involved in the physics question area of the project, explains,

"Humans understand the content of the question, infer the physical laws behind it, and use the formulas which govern those physical laws to solve the problem. Computers, on the other hand, use a physics simulator to actually replicate the situation described in the problem, measure the results, and select the choice which is closest to the simulation results."

For example, to solve a physics question about the relationship between the positions of a spring and a weight, a computer would select the answer by running simulations using various parameters, and choosing the answer which is most similar to the outcome of the simulation.



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Professor, Kyushu University

Steps towards the Goal of the Grand-Challenge

NII's Takuya Matsuzaki, involved in the mathematics area of the project, discusses the goal of passing the University of Tokyo entrance exam.

"We have found approximately 50% of the National Center Test for University Admissions questions can in principle be solved with our current design of the solving process. The basic solution methods and framework for the second-stage exam are the same as for the center test. If we start with questions that are easy for computers, and gradually expand the range of questions that can be solved, I think we'll be able to reach the passing line."

What will it take to accomplish this goal? Hirokazu Anai of Fujitsu Laboratories, a developer of the solvers used for mathematics, explains,

"It all comes down to how to convert text and diagrams into formulas. For example, even if a formula is valid, it will require a tremendous amount of calculation when there are many variables

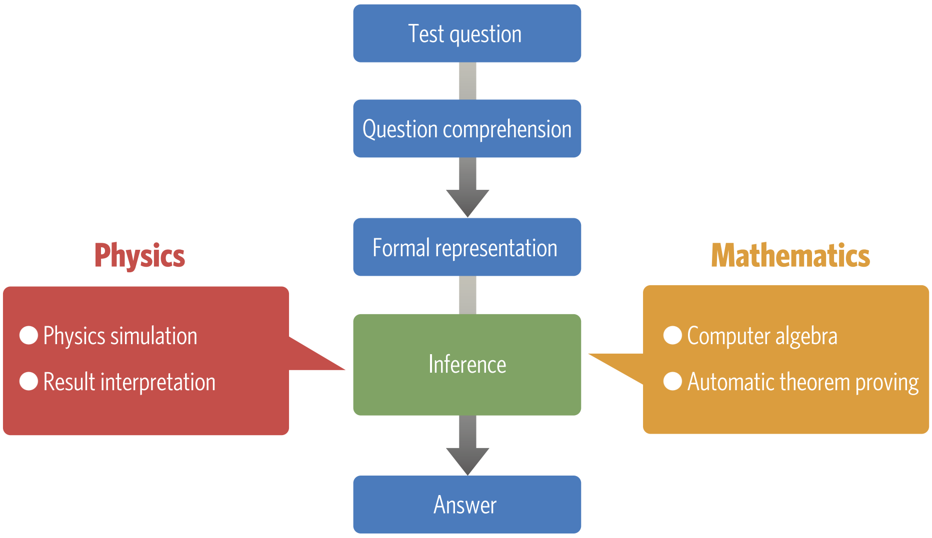


Figure : Approach to solve physics and mathematics entrance exam questions with AI.
The two approaches use different technologies in the inference step.

in it. There are, however, almost no entrance exam problems which could not be solved by a solver if we follow the problem solving approach envisioned by the author of the question. The key to solving exam problems within the allotted time is hence how we derive the formula."

Some questions require multiple solvers to be combined together. Since a formula has to be in a form specified by a solver, it is also important to select the right solvers.

There are also certain types of questions which are still difficult to answer.

"We don't know any algorithm for some questions, and we don't know how humans solve some questions. However, we don't take the approach of investigating the process humans use in actually solving these problems. Instead, we consider how to create a system which would achieve high scores, and if it produces positive results, then it makes sense to compare that approach to human thought processes," says Matsuzaki.

Regarding the center test physics questions, Yokono says, "Not all questions can be solved using simulators. There are still challenges to surmount." Center test physics questions tend to concentrate on four areas: dynamics, electromagnetics, waves, and thermodynamics. Existing physics simulations can be used for questions about dynamics and electricity. On the other hand, wave and thermodynamics simulations are complex, yet high school physics level questions do not demand an extremely high level of accuracy. So we need to consider an approach that is not simulation-based.

In the second-stage exam the examinees are requested to describe physical phenomena and the reasons behind them. The project has not yet begun tackling this question type. The key to solving these problems will be to combine the prediction by physics simulators together with other infrastructure technologies.

Hikaru Yokono
Project Researcher
Research Center for Community Knowledge
NII

What contributions will these technologies make in the future?

The solvers developed by Fujitsu have been used as vital tools for finding optimal designs for various products. However, they

are not necessarily easy to use and have not been fully utilized.

"We would like on-site engineers to use the solvers, but unfortunately they haven't achieved widespread use.

Engineers would be far more likely to use the solvers if the project made it possible to feed the solvers a question and have them automatically provide an answer," said Anai, discussing his hopes for the project.

A question solving approach based on language analysis, formula derivation, and inference algorithms would also provide important research seeds for natural language processing and solver technologies. From the perspective of natural language processing, it clearly defines the goal of language analysis in the form of formal representations. From the perspective of solver algorithms, it would systematize the know-how necessary to solve problems.

"Solver usage would increase if we clarify which problems solvers could be used to solve what kind of problems. That would contribute to greater use of mathematical methods, and increase the visibility of computer algebra and other solver technologies," said Anai.

Matsuzaki continued, discussing potential applications after the challenge, " Natural language is a very flexible tool to convey "what to do", while a computer is a very useful tool for things that we know "how to do."—Finding the most effective way of tying these two tools together has been a fundamental challenge in AI, and it is exactly what we need in the automatic math problem solving. The challenge will give us insights on the new relationships between humans and computers."

With regards to the future potential of physics simulator usage, Yokono said, "For example, when someone sees something rolling across a table top, they immediately reach out and keep it from falling off. However, a modern robot wouldn't know that the laws of physics would make the object fall. Advances in AI would make it possible for computers to understand real-world situations, use physical simulations to model changing situations governed by physical laws, and predict future states."

The knowledge generated by this challenge has the potential to contribute to a wide range of fields, such as intelligent robots.

(Written by Akihiko Hoya)

Social Studies Questions Require Understanding, Not Mere Rote Memorization

Social studies exam questions are, for people, purely memorization questions, and might seem easy for computers, with their exceptional memories. However, the reality is that they cannot be answered with rote memorization alone. One of the critical factors in answering social studies questions is how well the computer can understand the question text, and how well it can identify mistakes. The key to accomplishing these successfully is the natural language processing technology "textual entailment recognition".

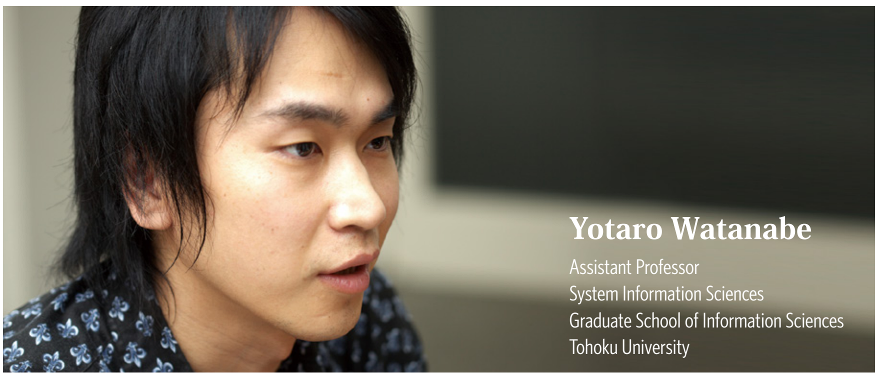
Making computers **understand the meaning of text**

Hiroshi Kanayama
Research Staff Member
IBM Research - Tokyo

Within the entrance exam questions to be tackled by the Todai Robot project, social studies questions, regarding history, geography, modern society, politics, and economics, are especially focused on memorized knowledge. It is tempting to believe that with a large database and search technologies, these questions would be easy for a computer to answer. Reality, however, is not so simple.

"For example, to answer questions such as 'Who was the third shogun of the Edo Shogunate?', a database search would be enough to produce an answer. That's not what entrance exam questions are like, though. The National Center Test for University Admissions test has examinees select the correct statement from a list of statements. If identical statements were found in the database, it could be answered through simple matching, but in reality, statements with the same meaning are expressed in various ways. A simple illustration: are 'Tokyo' and 'Tokyo-to (Tokyo metropolis)' the same, or different? Getting a computer to differentiate between those is no trivial matter," says Hiroshi Kanayama of IBM Research - Tokyo, who was involved in the development of the Watson question answering system.

The key to resolving this issue is textual entailment recognition, an important technology in the field of natural language processing. What kind of technology is it? Assistant Professor Yotaro Watanabe of the Graduate School of Information Sciences at Tohoku University explains, "Natural language processing is, simply put, a technology that enables computers to understand the language we use every day. It takes sentences, which otherwise would be nothing more than strings of characters to a computer, and divides them into individual words, analyzes the structure of the sentence, and then structures it in order to provide it with meaning. Within this process, textual entailment recognition is a technology for determining if there is an entailment relation between two sentences — that is, if two sentences mean the same thing even if they use different expressions.



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Developing textual entailment recognition technologies NTCIR RITE

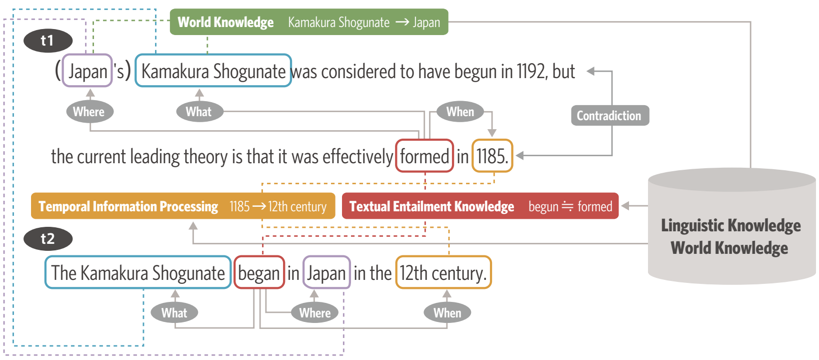
Textual entailment recognition can be thought of as a technology whose aim is to enable computers to understand human language, not on just the individual word level, but on the text level as well. It has drawn attention recently for its potential to make more advanced natural language processing possible.

In Japan, NII sponsors the NTCIR international workshop, whose objective is the improvement of natural language processing and information access technologies. In 2011, a new NTCIR task called RITE was created, focused on textual entailment recognition. In RITE, teams apply their own unique approaches to textual entailment recognition evaluation data in order to evaluate their methodologies. Various evaluation data is used, but one example of a RITE task would be to determine whether there is an entailment relation between the following two sentences.

t1 The Kamakura Shogunate was considered to have begun in 1192, but the current leading theory is that it was effectively formed in 1185.

t2 The Kamakura Shogunate began in Japan in the 12th century.

"For us humans, it's easy to determine that if t1 is true, t2 is true as well. However, to get a computer to understand it, you must first have it analyze the semantic structure, 'The Kamakura Shogunate was established (in) 1185.' Furthermore, you must use knowledge regarding language, and knowledge regarding the real world, to have it absorb differences in expressions and supplement the statements with information which can be inferred based on common sense knowledge, in order to infer the relationship between the two sentences," said Assistant Professor Watanabe (see figure).



It is hoped that RITE, which uses different methods for these processes, comparing and evaluating the methodologies, will accelerate the advancement of textual entailment recognition technology.

"In my case, I was able to produce good RITE scores using my logical inference-based approach, which also shares some aspects of my past mathematical research. However, the difficulty with using logic is the diversity of natural language expressions. It is extremely difficult for a computer to evaluate whether the meanings of two statements are fundamentally the same, and just use different expressions. On the other hand, that's also one of the most interesting aspects of this research," said RITE participant and NII Project Researcher Ran Tian.

Deepening the world of **human knowledge**

One of the materials which can be used to test the results of NTCIR RITE are the social studies exam questions to be answered by Todai Robot Project. In the first stage target, the center test, the Todai Robot Project will have to understand the meanings of questions, and determine whether individual statements in a list of choices are correct or incorrect. This can be done by determining whether the choices have the same meanings as statements in a collected body of knowledge, such as a textbook or Wikipedia, and using inference and textual entailment recognition. Cutting-edge textual entailment recognition technology is now able to correctly answer over 50% of the center test knowledge-testing questions. There are still many questions it cannot answer, and researchers are trying to improve recognition accuracy.

There is, however, more than one potential approach.

"We tested another method, besides textual entailment recognition, by seeing if Watson, a system which was developed to answer quiz-style questions, could answer center test world history true/false questions that had been translated into English. We looked at a sentence requiring a true/false decision, and, considering keywords within it as potentially false, asked the question answering system what word made the statement true. Using this technique, sometimes the computer could automatically confirm what knowledge is required for examinees in the center test," explained Kanayama.

Correctly answering university entrance exam questions is a major milestone for natural language processing technologies such as textual entailment recognition, but is not the ultimate objective. Expectations are high for this challenge to produce various technologies that will improve our daily lives.

Kanayama said, "by gaining knowledge out of large volumes of data, I hope to create technologies that support human intellectual activities." Assistant Professor Watanabe expressed his hope to "organize the massive volume of disordered information on the web along the lines of specific objectives, tying it together with true/false determination systems." Project Researcher Tian said, "What I ultimately hope to achieve is the realization of human-like thought processes on computers." Each researcher has their own goals, but the advances they will achieve in the field, and the deepened natural language comprehension their research will provide computers with, is certain to make the world of human knowledge an even more profound one.

(Written by Akiko Seki)

NTCIR

NTCIR is an evaluation workshop whose objectives are the advancement of research into text processing technologies such as information retrieval, text summarization, and information extraction. The goal of RITE, part of NTCIR, is the identification of implications [inference], rephrasing [identical meaning] and contradiction, issues faced widely throughout natural language processing and information access research.

For more information on NTCIR, please see NII Today No.48 P4-P7.
http://www.nii.ac.jp/userdata/results/pr_data/NII_Today/48/p4-7.pdf

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The Younger Generation Discusses Their Hopes for the Todai Robot Project

What does the next generation of researchers, which has not experienced the past setbacks in the AI field, think of the Todai Robot Project? We talked with Yasuhiro Matsumura, who passed the Tokyo University entrance exam last year, and Hiroyoshi Komatsu, a high school student who is participating in the Todai Robot Project, about what interests them in the project, and their hopes for its future, from their respective perspectives as an impartial observer and someone directly involved in the project.

Would a robot pass the mathematics section but struggle with the Japanese section?

Arai I heard the other day from an acquaintance at Tohoku University that when they asked engineering department students what project they'd like to take part in the future, several answered "Todai Robot Project". A lot of people are interested in the project, not just students majoring in natural language processing or mathematics. Today, I'd like to get the opinions of the younger generation on this project. How did you two first hear about the Todai Robot Project?

Matsumura I'm part of a newspaper club at University of Tokyo, and I found out about it in a news release but, to be honest, I wasn't particularly interested when I first heard about it. I read an interview with you, Professor Arai, in a mathematics journal in 2011, and I found your approach of putting science and mathematics questions into words to be very close to my own interests. It made a big impression. Then this spring, when I interviewed you for the University of Tokyo Newspaper, I heard more about the project, and realized how interesting it was.

Komatsu When the project first began, I saw it covered on the news, both on TV and in newspapers, as well as NHK Special, and was amazed that this kind of world existed. I'm in 11th grade now, but I started programming when I was in 7th grade. In 9th grade I grew interested in artificial intelligence research and began working on natural language processing, so I wanted to work on the Todai Robot Project, if possible. Actually, after about a month of studying natural language processing, I wanted to join the Association for Natural Language Processing, but my parents objected (laughs). But I kept studying on my own, joining the next year, which led up to my involvement in Todai Robot Project.

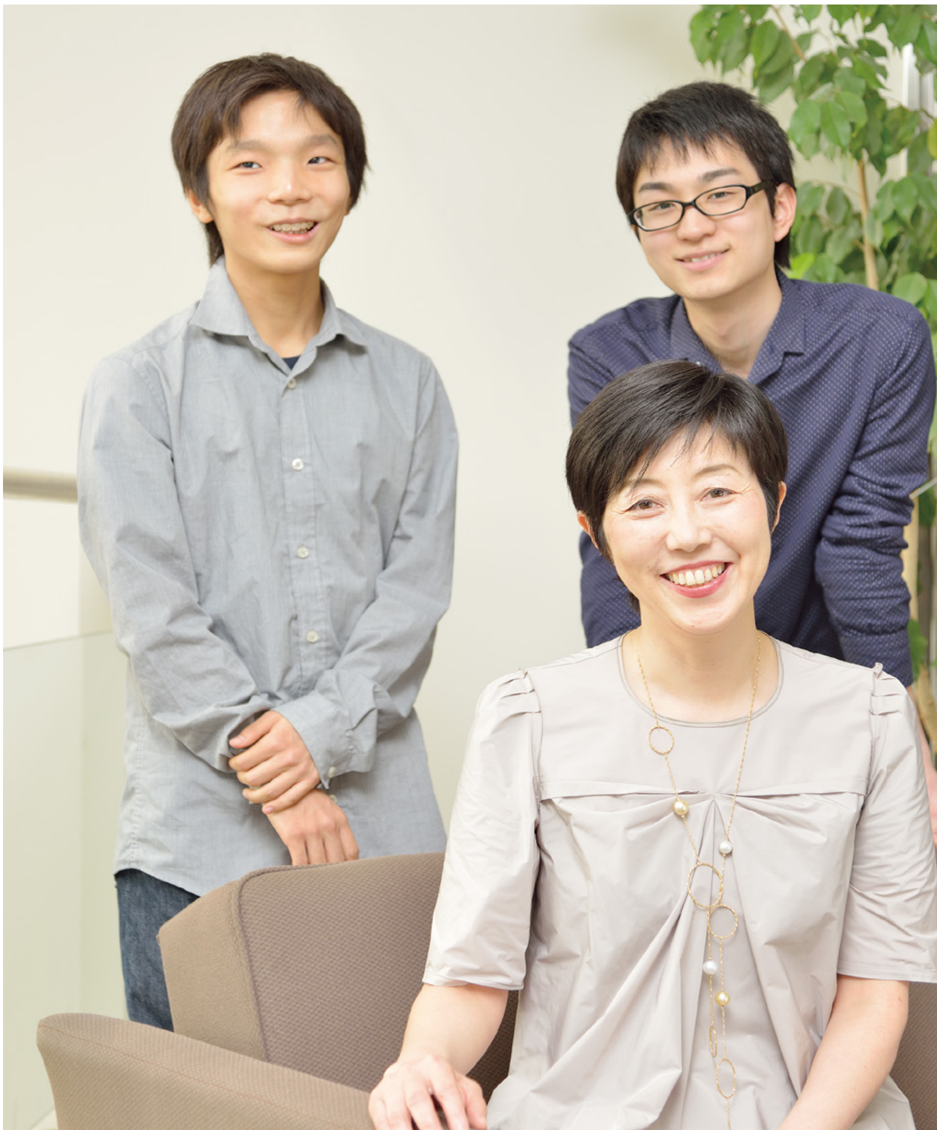
Arai The computing power, data, modules, and other things needed for programming are now available in open source form, so anyone who wants can get started, right? So it's not unusual for a high school student such as yourself to participate. Not in this modern age of the web.

—— Matsumura, you passed the University of Tokyo entrance exam just last year. Do you think a robot could pass the test?

Matsumura I think so. I'm not sure about Japanese, but the mathematics section isn't that hard if you understand the patterns.

—— As a member of the project, what do you think, Komatsu?

Komatsu One of the reasons I got involved in the project was that I hoped it might boost my own test grades, but I have to say that it hasn't particularly helped me with my






own studies (laugh). I think that Todai Robot Project's ability to reach its objectives on the 2016 National Center Test for University Admissions will vary depending on the subject. It's hard to come up with approaches for solving questions on sections like the Japanese section.

Arai There are a lot of challenges for each section, but I think that believing the objectives are possible is important. I think that the reason so many researchers think that it might be possible this time is because the conditions that would make passing possible are gradually falling into place.

The allure of artificial intelligence research is its insights into the human mind

—— What aspects of Todai Robot Project are you interested in?

Matsumura Artificial intelligence research consists of quantitative linguification of the question, "what does it mean for a person to think?", which I think is interesting.

Arai The question of how much of humanity's mental activities can be replicated mechanically has been discussed from a philosophical standpoint since the days of Descartes and Hobbes. During the early 20th century, when Turing developed the logic on which computers are based, this question became divorced from its philosophical underpinning, and a framework was created for considering it as an engineering problem. Artificial intelligence research made many advances, but in the 1980s began faltering. At the time, computing power was still low, there was little data, and the environment itself was not yet robust. The issue of artificial intelligence was broken down into smaller segments, but I think every 30 years these need to brought back together, and used to accomplish whatever is possible with the technologies of the time, leading into the next age of AI research. In this project, I hope to integrate and consider these technologies, and identify what can and cannot be accomplished. What cannot be accomplished can be set aside for 30 years down the line.

Komatsu What's interesting about artificial intelligence is that creating it gives you a greater understanding of people. Even for problems which are extremely easy for people, we still don't understand the thought processes involved. I'm also studying neuroscience and cognitive science, and I hope that by working to create artificial intelligence, I can also shine some light on those fields. Even if I fail, I can use what I have learned to keep moving forward.

Matsumura Plus, if the Todai Robot Project reaches its center test objectives, it will prove that the capacity of artificial intelligence is improving. I expect that this can be applied to a wide range of fields, producing results that benefit society.

A challenge perfectly suited for Japan - using small data to improve accuracy

Matsumura I'm not sure whether I want to focus on mathematics or physics in the future, but in the case of physics, modeling is used to provide an approximate answer to a question, while mathematics provides complete and immediate answers to stated questions. I find that very alluring.

Arai That's one of the cool things about mathematics. I call the Todai Robot Project a "risk hedge project". When trying to provide machines with artificial intelligence that corresponds to the learning abilities of humans, one can only improve accuracy in logarithmic relation to the amount of data, so big data is required for accuracy improvements. However, it's difficult for academic institutions inside Japan to collect the big data they need. That's why there needs to be research into how to improve accuracy using small data. Even if we collect all the entrance exam data for the last twenty years, it only constitutes a small amount of data. The approach of making accurate inferences based on small data goes against the prevailing worldwide research current, but it's extremely important. And cool. I hope that young people get to experience that.

Matsumura Artificial intelligence research won't result in the perfect replication of the human mind within the next 100 years, but I wonder what AI will be like a century from now, and whether it will have exceeded human intelligence.

Arai As artificial intelligence research continues, it will further illuminate the nature of humanity itself. I hope that the upcoming generation, which has not experienced AI's former setbacks, takes on this project with a fresh, new mindset. It is an open platform project, so anyone can participate. Komatsu, you downloaded entrance exam questions to work on the project, right?

Komatsu Yes. Right now I'm thinking exactly how to approach the research. I'd like to make programming improvements that are not subject-specific, like information retrieval improvements.

Arai Let's take on the challenge together.

(Written by Yuko Sakurai)

Yasuhiro Matsumura (Right)
Natural Sciences I , The University of Tokyo

Hiroyoshi Komatsu (Left)
Tokai University Bosei Senior High School

Noriko Arai
Director, Research Center for Community Knowledge
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"Todai Robot Project" Project Director

NII Essay

The Experience of "Understanding"

Kyo Kageura

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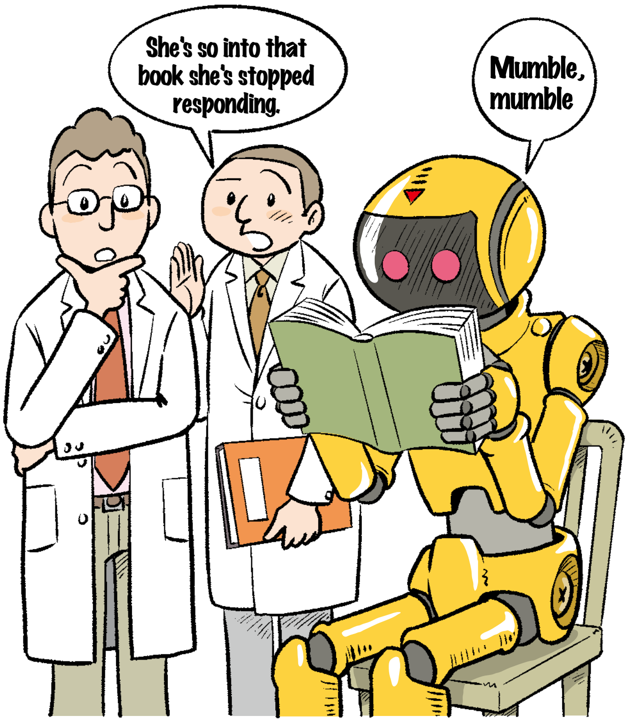

As everyone would agree, there is a qualitative difference between reading about a restaurant or a dish and thinking it would be delicious, and actually eating the dish and experiencing this delicious flavor. Likewise, everyone would recognize that "understanding" the flavor refers to the latter. While the distinction is not as obvious as for food, probably most people would also agree that reading a review of a movie is not the same thing as understanding the movie.

However, when it comes to so-called "knowledge" and the books that convey it, we tend to think that if we read an explanation of a book, we "understand" the original book. Even though the difference could be the same as that between eating a dish and reading a description of the dish, in the case of books we may confuse the two because the medium for experiencing "understanding" and the medium for providing the explanation are identical — words.

Thinking about it this way clarifies a few things. First, the instant of "understanding" — that is, of "comprehending" — is an experience, different from receiving or manipulating information. The second is that when people "understand" something, they often go through the process of becoming absorbed in it. In other words, people absorb universal knowledge by so-called "overfitting ".

Given that, it would be difficult to give computers the same "understanding" as people while avoiding overfitting and trying to achieve generalization by using machine learning methods to handle the language used to convey knowledge. To avoid giving up and claiming "comprehension" as a special right that only humans can enjoy, which cannot be replicated by computers, and to instead try to achieve computer "understanding", one must approach towards "comprehension" as much as possible. For example, from a conceptual standpoint, how to handle computer replication of the process of "absorption" — quite apart from the methods involved — is an extremely important issue.

As "understanding" is an intellectual experience, we must regard the process of "absorption" not as an emotional process but as a logical process. The most exciting aspect of NII's "Could a Robot Get Into the University of Tokyo?" challenge is not whether it succeeds in creating a robot that can actually enter the University of Tokyo — partly because some say that sufficiently advanced information processing would be sufficient to achieve this. Rather, the most exciting point is to what degree it can clearly advance "understanding" towards "comprehension", without merely reducing it to information manipulation and processing.

Weaving Information into Knowledge

NII

Cover Illustration

A robot is halted by security guards in front of the Red Gate, a famous landmark of the University of Tokyo. The goal of the "Could a Robot Get Into the University of Tokyo" Project is not to actually have a robot walk through the red gate and take the entrance exam, but to carry out research that advances the cybernetics development.

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