TUT Research
e-Newsletter from Toyohashi University of Technology

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FEATURE STORY

What's needed for educating students and young researchers

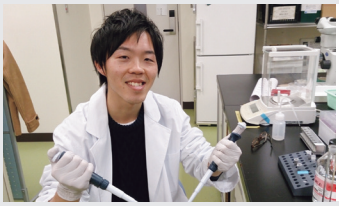
Education at national universities and graduate schools is currently at a turning point. Since the privatization of national universities in 2004, each university has had more autonomy and independence.

Research Highlights : Special Issues – TUT Student Research Awards 2017-2018

This issue features some of the many research awards won by TUT students since 2017.
From a total of 136 awards, we have chosen one award winning representative student from each department.

Smooth Jerk-limited Trajectory Generation and Nonlinear Friction Compensation for Feed Drive Systems

The International Federation of Automatic Control (IFAC) 2017, Application PaperPrize 5



Sensors with chemical "eyes" that visualize neurotransmitters in the brain

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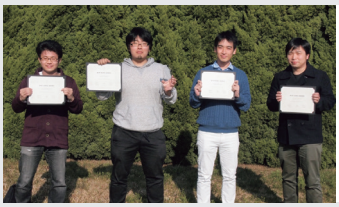

A Body Odyssey

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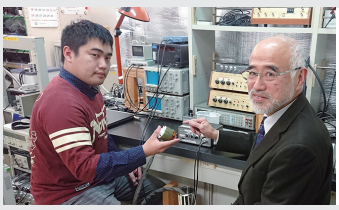

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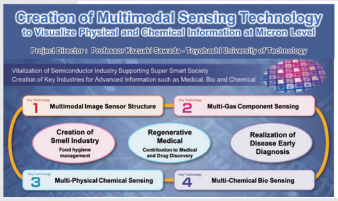

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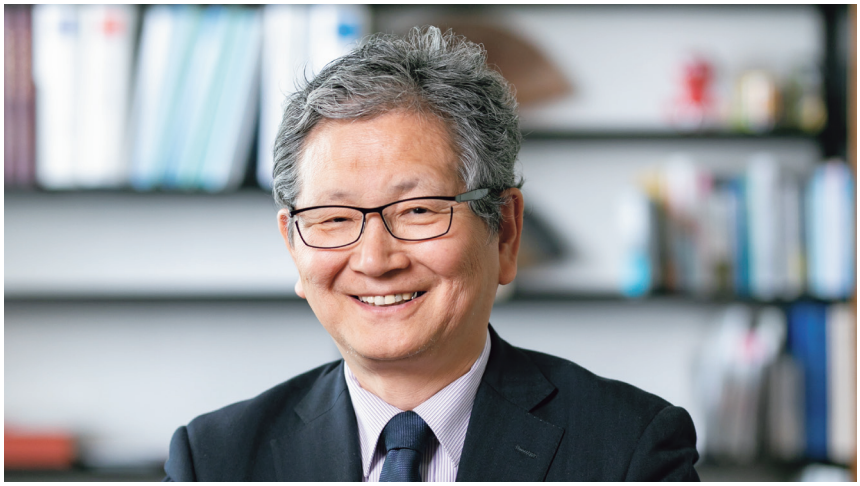
What's needed for educating students and young researchers

Kazuhiko Terashima

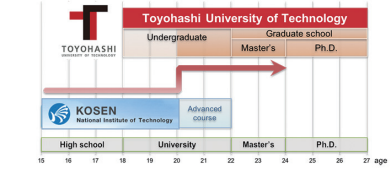


Education at national universities and graduate schools is currently at a turning point. Since the privatization of national universities in 2004, each university has had more autonomy and independence. At the same time, they have faced difficulties because of decreasing grant money for school management and serious competition in obtaining research funding. In this pressurized situation it is hard for universities to remain inventive, which in turn has made it difficult to maintain and keep improving the quality of research and education. Also, the type of person desired in the real world is changing as globalization keeps expanding, and universities and graduate schools are expected to produce graduates who are even more diverse and innovative.

In such a changing environment, what is Toyohashi University of Technology working on? We spoke with Dr. Kazuhiko Terashima, a researcher of robotics and system control and the executive trustee & vice president of the university, who has produced many graduates and instructors and has been actively involved in educational reform for a long time.

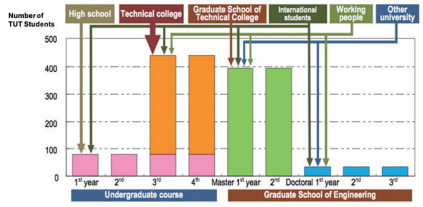
Interview and report by Madoka Tainaka

"The best feature of our institution is that we are truly a science and technology university. Eighty percent of our students transfer to our institution from technical colleges for their junior (third) year. Many of our faculty members and students are great at producing things, programming, and working with their hands.



TUT provides higher education to graduates of KOSEN (Institute of Technology) to foster engineering and research leaders with practical and creative ability

There are many foreign students and working adults attending our school, and in this diverse environment, we are trying to train our students to learn technologies properly, analyze them scientifically, and build theories that can be used universally.



Number of TUT students per grade and multiple admission paths

So, you can say that we are a university with a very unique character," says Dr. Terashima.

This unique character can be seen its university rankings.

① Out of 770 colleges and universities in Japan (according to Asahi Shimbun's 2019 university rankings), the university is ranked third in research grant money, KAKENHI (Grant-in-Aid for Scientific Research) per instructor (among universities established between 1966 to 1980)

② First in the total amount of collaborative research money shared with companies (for research projects under 300 researchers).

③ In the passed years, our university has become champion 6 times in the NHK Student ROBOKON (NHK Student Robot Contest), and won second place in 2018.

We know that this university offers an environment in which students can really focus on their research.

A wide variety of support to cultivate young researchers

Dr. Terashima claims that the university's accomplishments, as seen in its rankings, are all the result of the steady and diverse efforts that are focused on global society and based on the university's strengths.

"We offer a six-week English training course at Queens College in the U.S. to faculty members and a study abroad program, of either one year or three months, to young researchers under the age of 50 in accordance with the 'The Top Global University Project' established by the Ministry of Education, Culture, Sports, Science and Technology."

"Also, we have many researchers who participate in and present at international conferences. On average, each researcher travels abroad once or twice a year. There are many collaborative research projects conducted with domestic and overseas companies and other institutions, and one of our advantages is that we receive a large amount of external funding for research."

Further, the university offers about one million yen in financial support to ten promising, young (up to 38 years old) faculty members for their research. The university has also implemented a "tenure-track system" to provide an environment in which younger researchers can be engaged with their research more independently. About 10 years ago, the university received funding from the Japan Science and Technology Agency (JST) and hired ten young researchers as tenure track faculty members of the univer-

sity's Electronics-Inspired Interdisciplinary Research Institute. The university initially gave the tenure track faculty members 10 million yen, and later another six million yen for an additional five-year period. When the program funded by JST ended, another program was developed in which, every year, one assistant professor in order and per division was supported. They continued with this system for five years and it has just ended. Currently, a whole new program is being developed to hire associate professors on the tenure track.

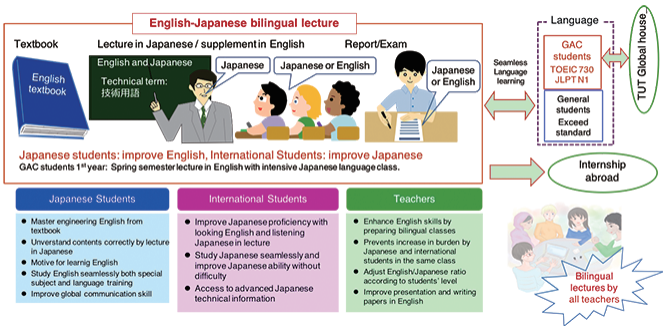
"In addition to this sort of support, we receive research funding from outside the institution. So overall, the research environment we provide is one of the best in the country. For example, we have specialist university research administrators (URA) working at the Research Administration Center (RAC), with whom we are preparing a system to offer strong support for all research."

Enhanced support to develop global talent

Toyohashi University of Technology supports an environment for diverse learning for its students.

"We actively recruit students from overseas and prepare a good environment for them. Our current total student body numbers are around 2,000, and 269 of them, about 13%, are from overseas. These students come from 32 countries, many from Malaysia and other Asian countries, while others come from Germany and France for example. Many of them are pro-active about their experience with us, such as by starting their own venture companies by applying the knowledge they gained here. Naturally this provides a good stimulus to our Japanese students.

Our university provides bilingual Japanese and English education, partly due to our large foreign student body, and partly as one of our stated goals when we were chosen as one of the universities to carry out The Top Global University Project. So, for example, both textbooks and classroom instruction are provided in both languages for global courses. Also, there is a unique program involving about 180 students who are enrolled in our new Global Technology Architects Course (GAC). Under this program, almost all of them live in shared housing in groups of five which have a mix of Japanese and foreign students. It should also be noted that a six-week internship at a corporation is required in the student's senior (fourth) year. As a leading graduate school, Toyohashi University of Technology adopted the "Brain Information Architects" project for its doctoral students. In this program, a two-week trip to Malaysia and a six-month overseas internship are included. There are also double-degree programs available that produce elite education. These programs enable students to earn degrees at both Toyohashi University of Technology and at other institutions overseas, such as the University of Stuttgart in Germany and the University of Eastern Finland.



"These various efforts are resulting in an increased number of foreign students and Japanese students who can succeed globally. Many of our foreign graduates work at Japanese companies or assume the role of connecting Japan and their home countries."

Instructors' attitudes that are essential to education

Dr. Terashima mentions that, in addition to a wide variety of programs already being offered at the university, the the instructors' attitudes to educate students is very important in order to produce promising talent.

"One unique characteristic of science universities in Japan is that a student joins a lab in his or her senior (fourth) year and is involved in research with instructors in a more hands-on environment (like a "temple school" in the Edo period). The concept of the Humboldt's educational model of 'teaching through research' is being truly carried out."
"What I think is essential here is the vision of the instructors. I myself have displayed to my students the roadmaps for five, ten, and twenty years from now for the research fields of robotics and system control. I have always been showing my students what kind of research we need to be involved in so that we can produce the best results in the world."

Another important point is making efforts to motivate the students. Experience in presenting at international conferences as well as domestic while in a master's program not only helps bring students' motivation in research to a higher level, but it also trains them in their presentation skills and broadens their knowledge.

"It is also important to build a character with personality while engaging in self-study and self-learning in a free atmosphere. For this purpose, we need to have our students decide spontaneously their research subjects, research plans, and how to manage their labs on their own. Of course, during such processes, the instructors must provide full support while having constant communications with their students."

Thanks to these supportive education policies, Dr. Terashima's lab has already produced 341 graduates. Out of those graduates, about 30 of them have earned their doctorate degrees, and some have become instructors at universities and technical colleges.

"We are now in the so-called era of the 100-year-life and lifelong learning. Learning while you are young is particularly important. In my twenties, a research paper carrying my name as the first author was published in the world's leading journal. That experience made me want to become a researcher who can build theories of control that can be useful to people. I hope that the students and young researchers who learn at our university will be successful and help Japan and the rest of the world with the knowledge they gain here."

[Reporter's Note]

After the interview, Dr. Terashima showed me "Tera's Sayings" (Teragoroku) titled "50 Tips for Adults." These are some of the tips he wrote while he was sick in bed at home for two days in his mid-forties, which he later posted on his blog. When I took a look at these tips, I read messages such as, "Have your own policies and philosophies about things. Don't be opportunistic," and "Have an area of specialty and deepen it. Nurture it with great care. 'Continuity leads to success.'" These messages were written for young people, but even at my age, I was deeply moved by many of these words. Dr. Terashima himself says with a smile, "I want young people to live freely without being too consumed by these guidelines. But, when they feel confused or stuck, I hope that they can draw some guidance or comfort from the blog." I do hope that many people have a chance to read it.

"Teragoroku"
http://www.syscon.me.tut.ac.jp/teragoroku_e/index.html

学生・若手研究者の教育に必要なこと

現在、国立大学・大学院教育は大きな変換点を迎えている。2004年の国立大学の法人化以降、それぞれの大学に自主性・独立性が求められると同時に、運営交付金の減少や競争的研究資金獲得の厳しさなどを背景に、各大学の創意工夫なくして、研究や教育の質を維持・向上させていくことが難しくなっているのだ。また、グローバル化に伴い社会で求められる人材も大きく変化し、大学や大学院に対して、より多様で、イノベーティブな人材の輩出が期待されている。
そうしたなか、豊橋技術科学大学はどのような取り組みをしているのか。ロボット・制御工学の研究者として、数多くの卒業生や教員を輩出するとともに、長年、大学の教育改革に取り組んできた寺嶋一彦理事・副学長に聞いた。

「本学の最大の特色は、まさに技術科学大学であることに尽きると思います。8割の学生が高等専門学校から3年次に合流する編入生で、ものづくりやプログラミングなど、手を動かすことに長けた学生が非常に多い。

留学生や社会人入学の学生などもいる多様な環境のなか、技術をしっかり身につけ、それらを科学的に解明し、普遍的に使える理論の構築をめざすという、じつに特色のある大学と言えます」と、寺嶋副学長は語る。

そうした特色は、大学ランキングにも垣間見ることができる。日本の全770大学のランキング（朝日新聞大学ランキング2019）で本学は、教員1人あたりの科研費配分額（大学設立年1966～1980年）：第3位、企業との共同研究総額（研究者300人未満）：第1位、またNHK学生ロボコンでは、過去6回優勝し、2018では準優勝するなど、研究に注力できる環境にあることがわかる。

若手研究者育成に向けた多様な支援

ランキングが示すような成果の背景には、本学の特色に根ざしつつ、グローバル社会を見据えた地道で多様な取り組みがあると寺嶋副学長は言う。

「文科省の『スーパーグローバル大学創生支援』事業のもと、教職員に対して、米国・クイーンズ大学にて6週間の英語教育を用意しているほか、50歳までの若手研究者を対象に、1年間もしくは3カ月間の海外留学制度を用意しています。また、本学では国際会議に参加、発表する研究者が多く、平均すると年に1～2回ほど渡航しています。国内外の企業や他機関との共同研究も多数あり、外部資金の獲得額が大きいことも特長でしょう」

さらに、優秀な38歳までの教員、十数名に対して100万円程度の研究費支援を実施しているほか、若手研究者が自立して研究が行える環境整備をめざす「テニュアトラック制」を導入している。10年ほど前に、科学技術振興機構（JST）の補助金を受けて、本学のエレクトロニクス先端融合研究所の若手研究者10名をテニュアトラック教員として採用。スタートアップに際して1,000万円、その後5年間の研究期間に対して600万円の研究費の支援を行ってきた。JSTの制度終了に伴い、毎年順番に、この制度を各系1名の助教に展開して5年が経過し、一応この制度を終了し、この取り組みの発展形として准教授採用へのテニュアトラック制の導入を始めたところだ。

「こうしたさまざまな支援に加え、科研費などの外部資金も併せることで、本学では日本の他大学に比べると恵まれた研究環境を実現しています。また、研究推進アドミニストレーションセンター（RAC）には、専門知識を備えたリサーチ・アドミニストレーター（URA）やコーディネーターがいて、研究を強力にバックアップする体制も整っています」

グローバル人材育成の支援も充実

一方、学生に対しても、多様な学びが得られる環境が用意されている。

「たとえば、留学生を積極的に受け入れ、そのための環境を整備しています。現在、学生約2,000人中269名と、約13%の学生が海外からの留学生です。出身国はマレーシアを筆頭に、アジア各国、さらにはドイツ、フランスなど32カ国にものぼります。留学生の中には、ここで学んだ成果を糧にベンチャー企業を立ち上げるアクティブな人も多く、日本人学生にとっても大きな刺激となっているのです」

留学生が多いこともあり、グローバルコースの授業については、スーパーグローバル事業の一環として英語と日本語の教科書を準備し、バイリンガルで実施している。また、グローバル科学技術アーキテクト養成コースの学生約180名は、原則として全員がシェアハウスに入居し、日本人と留学生が5人1部屋で生活をともにするというユニークな取り組みも行っている。4年次に、6週間もの企業実務訓練（インターンシップ）が必須単位となっていることも特筆すべきだろう。

博士人材に関しては、リーディング大学院として「ブレイン情報アーキテクト」プロジェクトが採択され、その中で2週間のマレーシア体験ができるほか、6カ月の海外インターンシップも用意されている。ドイツ・シュトゥットガルト大学や東フィンランド大学とのダブルディグリー・プログラム、すなわち本学と海外大学の両方で学位が取れるプログラムもあり、エリート教育も充実している。

「こうしたさまざまな取り組みが、留学生の増加につながり、グローバルに活躍できる日本人と、日本企業に就職、あるいは本国との架け橋となるような留学生を多数輩出することにつながっているのです」

教育のために不可欠な教員の心得

こうしたさまざまなプログラムが準備されていることに加え、有為な人材の輩出には、学生を育てる教育者側の心構えが大切だと寺嶋副学長は言う。

「日本の理系の大学で特徴的なのは、4年次から研究室に所属して、寺小屋的な環境のなかで教員とともに研究を行うことにあります。まさに、『研究を通じて教育する』というフンボルト理念が体現されていると言えます。

そこで不可欠だと思うのが教員のビジョンです。私自身、ロボット・制御工学の特定研究分野において、5年後、10年後、20年後のロードマップを提示して、世界一の研究成果を出すために、いまどんな研究をする必要があるかを学生たちに常に示してきました」

もう一つ重要なのが、学生のモチベーションを高めるための取り組みだと言う。国内学会はもとより、修士課程のうちから国際学会での発表を経験させることは、研究へのモチベーションを高めるだけでなく、プレゼンテーション能力を養ったり、見聞を広げたりすることにつながる。

「自学、自習を尊重し、自由な雰囲気のなか、個性ある人格を育てていくことも重要です。そのためには、研究テーマや研究計画、あるいは研究室運営などを学生自身にも自主的に決めさせ、実行させていくことが大切です。もっとも、その過程で教員は学生と対話しながら、最大限のサポートをしていかなければなりません」

こうした教育方針の結果、寺嶋副学長は研究室から341名の卒業生を送り出し、うち30名程度の博士を輩出、大学や高専の教員へと育て上げた。

「人生100年時代、生涯学習がうたわれる時代ですが、若いときの勉強はとくに重要です。私自身、20歳代で世界のトップジャーナルにファーストオーサーとして論文が掲載されたことを機に、人々に役立つ制御の理論を構築したいと、研究者の道を志しました。本学で学んだ学生、若手研究者が、ここで得たさまざまな経験を糧に、日本、世界のためにいっそう活躍してくれることを願っています」

（取材・文＝田井中麻都佳）

取材後記

取材の後、「大人のための50箇条」と題した「テラゴロク」（寺嶋語録）なるものを見せてくださった。寺嶋副学長が40代半ばのあるとき、体調を崩して2日ほど自宅で寝ていたときに書き留め、後でブログにアップしたのだという。覗いてみると、「PolicyやPhilosophyを、いろいろなことに対して持て。日和見主義ではダメ」「専門をもち、それを磨け。大事に大事に育てよ。『継続は力なり』」といった言葉が続く。それらは若い人に向けたメッセージだが、この歳になったからこそ、しみじみと感じ入る言葉が多い。ご本人も、「若い人にはゴロクなんかに振り回されずに、伸び伸び生きてほしい。ただ、何か悩んだり立ち止まったりしたときに、ちょっと覗いて、指針にしてくれたら嬉しいですね」と笑う。ぜひ、多くの方に読んでいただきたいと思います。

テラゴロク
http://www.syscon.me.tut.ac.jp/teragoroku/index.html

Researcher Profile

Dr. Kazuhiko Terashima

Dr. Kazuhiko Terashima received his PhD degree in engineering in 1981 from Kyoto University, Japan. Since 1982, he started his career at Toyohashi University of Technology and had been involved in the development of robotics and mechatronics. In this period, he was a visiting researcher at Technical University of Munich in German from 1990 to 1991. Currently Dr. Terashima is engaged in education and research as vice president at Toyohashi University of Technology.

Reporter Profile

Madoka Tainaka is a freelance editor, writer and interpreter. She graduated in Law from Chuo University, Japan. She served as a chief editor of "Nature Interface" magazine, a committee for the promotion of Information and Science Technology at MEXT (Ministry of Education, Culture, Sports, Science and Technology).

Smooth Jerk-limited Trajectory Generation and Nonlinear Friction Compensation for Feed Drive Systems

By SIMBA KENNETH RENNY

The International Federation of Automatic Control (IFAC) 2017, Application Paper Prize

The systems engineering laboratory in the department of mechanical engineering at Toyohashi University of Technology in collaboration with the institute for system dynamics at the University of Stuttgart, has developed methods for generating smooth motion trajectories for feed drive systems for efficient manufacturing and energy saving. The method is based on quintic Bézier curves and the altered bang-bang approach to ensure smooth velocity transitions within the motion trajectory. In addition, a contouring controller with a feedforward friction compensator was applied in order to smoothly track the designed trajectory by canceling out the effect of friction forces.

The result of this study was presented during the 20th World Congress, The International Federation of Automatic Control (IFAC), Toulouse, France, July, 2017 and published by ELSEVIER. Consequently, the researchers of this study were awarded with the IFAC Application Paper Prize (Finalist). The prize is given for outstanding technical contributions at an IFAC Congress in the area of control applications. The IFAC congress is held once in every three years and during the 20th IFAC congress, 2,800 out of 4,267 submissions were accepted for presentation. From the 2,800 accepted submissions, five papers including our paper were selected and awarded as the application paper prize finalists.

Details of the research

Computer numerical control (CNC) machines are widely used to manufacture complex components that are required to be very precise to comply with the rising demand. In order to achieve the desired manufacturing quality, motion trajectories must be traversable without violating systems' constraints such as a permissible acceleration and jerk. Generally, the trajectories have to be at least second order differentiable in order to achieve a continuous velocity and acceleration. Linearly interpolated trajectories have been used for decades due to their simplicity in design and implementation. However, these linear trajectories cause undesired performance, such as stops between trajectories' segments, unnecessary time and energy consumptions and wear on the system parts.

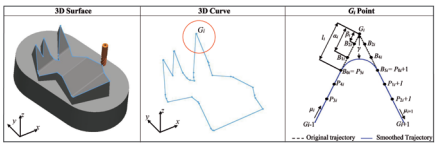


Fig.1 represents a method to generate smooth trajectories using Bézier curves. From the left side, the first figure represents the 3D surface to be machined, the middle figure is the 3D curve extracted from the 3d surface. The last figure is the zoomed portion of the 3D curve (point Gi), where the dashed and solid lines referrer to the original and modified curves, respectively. Points Gi, i = 1, 2,... are the G-code points used to define the original trajectory, γ and μi are the tolerance in the contour error owing to the induced geometrical error and the tangential unit vectors corresponding to the motion direction, respectively. Points P0i to P5i and B0i to B5i, are Bézier control points for each linear trajectory-segment and the inserted curve at the corner to create the modified curve (solid line). αi and βi are the fractions of the length li, and they are used to design the curvature of the inserted curve. The modified curve ensures that the induced geometrical errors do not exceed the allowed tolerance γ.

For improvement of motion trajectories, many methods have been proposed in the literature and most of them focus on smoothing the linear interpolated tool-path points using curve fitting techniques. For densely tool-path points, curve fitting techniques exhibit oscillations in the trajectory because high-order spline curves are numerically unstable. On the other hand, cubic parametric spline curves are used to smoothly interpolate the linear tool-path points. They are infinitely differentiable when used as a single curve, however, their differentiability is limited to first-order when two or more curves are connected.

In this study, a method for generating smooth motion trajectories using quintic Bézier curves and smooth velocity profiles based on the altered bang-bang approach was proposed. The altered bang-bang approach allows for smooth velocity transitions between the spline curves, such that low-velocity values can be used during the motion start and end, and in all areas with high curvatures. Since it is well known that mechanical systems cannot instantly accelerate to high velocities and that the velocity is inversely proportional to the curvature, smooth reference velocity ensures that the motion acceleration and jerk are within the permissible range.

In addition to the velocity profile matter, mechanical systems experience friction forces which vary nonlinearly with velocities. Therefore, on implementing a smooth velocity profile, a contouring controller with a feed forward friction compensator was applied in order to smoothly track the designed trajectory by canceling out the effect of friction forces. Experimental verification was conducted and results showed that the proposed method is effective for improving the performance of CNC systems.

Behind-the-scenes story

We had previously successfully developed a method to automatically generate smooth trajectories for mobile robots based on the assigned via-points. In addition, other members of our laboratory studied and developed a nonlinear motion controller with "a" friction compensator for feed drive systems. The performance of the designed controller was found dependent on the nature of the applied trajectory. Tracking performance was much better if the trajectory is smooth enough to be traversed by the system. On the other hand, poor performance was observed when traversing trajectories with high curvatures. It was in this light that we studied the method previously used for mobile robots and modified it for application to feed drive systems.

Future Research

The research team of this study believe that the proposed method will be adopted for industrial applications to enhance manufacturing performance. In addition, this study can be applied to other motion systems, such as autonomous mobile robots and driverless cars.

This study is partly sponsored by the Japan Society for the Promotion of Science (JSPS).

Reference

Kenneth Renny Simba, Gunter Heppeler, Ba Dinh Bui, Yogi Muldani Hendrawan, Oliver Sawodny, Naoki Uchiyama, Bézier Curve Based Trajectory Generation and Nonlinear Friction Compensation for Feed Drive Contouring Control, IFAC-PapersOnLine, Volume 50, Issue 1, (2017), Pages 1944-1951. https://doi.org/10.1016/j.ifacol.2017.08.388.

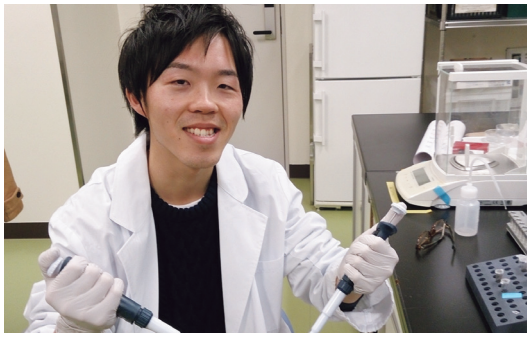
Sensors with chemical "eyes" that visualize neurotransmitters in the brain

Aiming for the early diagnosis of diseases and contributions to drug creation

By Hideo Doi The Institute of Electrical Engineers of Japan (IEEJ) "35th Sensor Symposium" October 2018, IGARASHI Award

A research group at the Department of Electrical and Electronic Information Engineering in Toyohashi University of Technology and a research group at the Faculty of Medicine in Yamanashi University worked together to successfully visualize the neurotransmitter ATP (Adenosine-5'- triphosphate) released from brain tissue slices using a semiconductor image sensor modified with a biomaterial detection film. This sensor enables real time observation of in-solution ATP diffusion without implementing labels (specifically, fluorescent labels), by using an enzyme that recognizes ATP and converts it into hydrogen ions. By placing brain tissue or other biological tissues and organs on top of the sensor, the two-dimensional distribution of extracellular responses can be acquired directly as visual information.

The results of this research were presented at The Institute of Electrical Engineers of Japan (IEEJ) "35th Sensor Symposium" held in Hokkaido on October 2018 and the presenter, Hideo Doi was awarded the IGARASHI Award, which is given to young researchers under the age of 35 who gave the best presentation at each symposium.



Motivation for this research

The reason I first started this research was that I became interested in the semiconductor image sensor developed in Professor Sawada's laboratory, which enables the visualization of a chemical phenomenon that is invisible to human eyes. This sensor enables us to obtain visual information about the movement of ions that are present in our bodies. By applying the technology used in this sensor, we are working on the development of new sensors that can visualize chemical phenomena in the brain that no one has ever seen before. I was also attracted to the fact that this project was done in collaboration with researchers from the department of Medicine of another university. Currently, we are working on the development of image sensors for medical applications with a research group lead by Professor Koizumi from the Faculty of Medicine in Yamanashi University.

Struggles in research

The biggest struggle in this research was investigating membrane-forming technology for the detection membrane to be used in ATP imaging. We experimented with various quantities of substance and membrane thickness for the detection membrane in order to find the right balance to achieve faster detection at a higher sensitivity and to achieve better imaging on top of a square array sensor measuring approximately 5 mm on each side. As a result, we were able to control membrane thickness even with a small amount of dripping solution by chemically treating the hydrophobic surface of the sensor.

By performing analysis on the measured data while focusing on the detection speed of the sensor, we experimentally demonstrated that a membrane thickness of about 100 nm is optimal for detecting ATP (with detection sensitivity being enhanced up to the theoretical detection limit). Although it often took 30 hours from preparation for just one sample to result analysis, we carefully collected and analyzed the data to be ready for biological experiments in Yamanashi University, and through this, we achieved improvements in the sensor's performance.

Meanwhile Yamanashi University, from the process of repeatedly conducting the biological experiments, had the idea of using an acute type that does not need culturing of the hippocampus. This was based on the theory that scars (which serve as armor-like layers) which formed on the cells at the surface of the hippocampus slices during the culture process might inhibit the release of neurotransmitters. As a result of proceeding with this suggestion, we were able to capture a clear image of the hippocampus itself, which eventually lead to capturing images of released ATP.

Impressions after receiving the award

At first, I was simply happy to have received an award, but after being congratulated by my mentor, Professor Sawada, that nobody in our research group had received this award since it was awarded to a faculty member around 20 years ago, I realized that this was a prestigious award and felt very honored to have received it.

I was glad that my effort was well-received given that I had been working on the speech, and thinking how to promote my research, right up until just before the presentation. This experience has encouraged me to work even harder in the future.

Details of the research

It is suggested that glial cells, which attract attention as active cells in the brain, release a neurotransmitter called ATP outside the cells in order to regulate the activity of neuronal cells (synaptic transmission, synapse structure: 1–2 μm), and glial cells play a major role in regulating brain functions. To this end, imaging and analysis of extracellular ATP in local parts such as synapses is required at a high spatial resolution. However, conventional bioluminescence methods that use the light of fireflies only have approximately 200 μm in spatial resolution, which is larger than a cell size, thus a problem arose that the release sites of ATP couldn't be visualized.

In response to these circumstances, our research group developed an ATP image sensor created through modification with an enzyme that selectively detects ATP on top of a previously developed ion image sensor with a spatial resolution of 40 μm. By using a chemical reaction between ATP and the enzyme, this sensor converts ATP into hydrogen ions and thereby enables the detection of ATP.

In addition, we found that by chemically treating the surface and by regulating the thickness of the detection membrane to about 100 nm, ATP can be detected at a high sensitivity around the sensing area. After actually attaching a hippocampus to the sensor and conducting biological experiments, the output images changed in accordance with electrical stimulation, and we confirmed that these signals originated from ATP. This is a world-first example of successfully visualizing ATP discharged from brain tissue without the use of fluorescent or other labels.

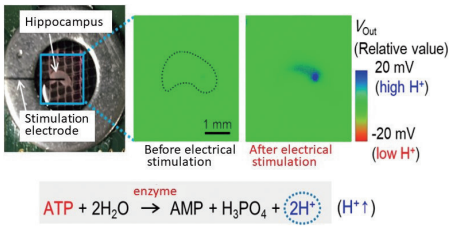


Fig.1 Results of analyzing images of ATP release through electrical stimulation. (Left) Optical image of hippocampus placed on the ATP detection membrane. (Right) The output images before and after electrical stimulation.

Since the communication between neurons and glial cells in the hippocampus are presumed to be the elementary process of processing and dispatching information for memory and learning, this research can be expected to contribute to the elucidation of the true mechanisms behind the processing and dispatching of information in the brain. In order to realize this, it is also necessary to achieve imaging and analysis of the temporal and spatial distributions of extracellular neurotransmitters released by neurons and glial cells (which are 10 times greater in number than neurons).

Prospects

The research teams in Toyohashi University of Technology and Yamanashi University succeeded in imaging ATP released from brain tissue. This was achieved using information on ions obtained from a sensor with a spatial resolution of 40 μm, created by improving technology on ATP detection membranes. The research group that developed this sensor at Toyohashi University of Technology, to which I belong, also succeeded in developing an image sensor with a high spatial resolution of 2 μm, approaching the size of a synapse.

By using this sensor with this newly developed ATP detection membrane, it will become possible to visualize ATP released from local areas in cells. In addition, multiple and simultaneous imaging of interactive processes between ATP and other neurotransmitters or different types of ions could bring new information leading to novel insights with physiological significance. Such results could be beyond the scope of those achievable by conventional optical information, such as that from fluorescent microscopes.

This research was supported by Japan Science and Technology Agency (JST) CREST Grant Number JPMJCR14G2.

A Body Odyssey

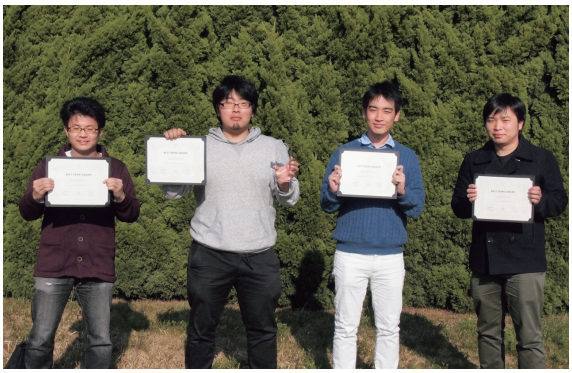
Virtual-reality experience for learning digestive organs

By Satoshi Fujisawa

The "Augmented Human 2017" international conference at Silicon Valley, Best Demo Award

A research team led by Satoshi Fujisawa, a graduate student of Department of Computer Science and Engineering at Toyohashi University of Technology has developed a system for experiencing a virtual trip in human digestive organs as a food by user's crawling. The system contributes to enhancing learning and understanding on mechanisms of digestive organs because users have fun to experience the system as they are transformed to a food.

This system was presented in an international conference Augmented Human 2017 at Silicon Valley, CA, USA, 16th – 18th March 2017, and awarded "Best Demo Award."



Fujisawa (2nd from left) and his co-winners

Motivation for this research, struggles in research, and impressions after receiving the award

Satoshi Fujisawa wanted to develop an intuitive and enjoyable learning system to teach about health and physical education. His motivation for this came from his sense of regret that he had not been so interested in these topics during his school days. Since there were no previous studies relating to this field or to similar virtual-reality systems, the development was a gruelling process of trial and error. During their demonstration at the Augmented Human 2017 conference for example, the team experienced hardware trouble, which limited the effectiveness of their presentation. Naturally then, his team members were very surprised to hear that they had won the award for best demo.

Fig.1 Demonstration in AH2017 (Left), and Award's certificates (Right).

Details of the research

Children study physical structure and the mechanisms of the human body using text books and anatomical body models as a part of Science or Health and physical education in elementary school and junior high school. However, these subjects are not interesting for children. Thus, Satoshi wanted to make a virtual-reality (VR) system to allow people to experience the inner body by themselves so that they can learn about digestive organs enjoyably.

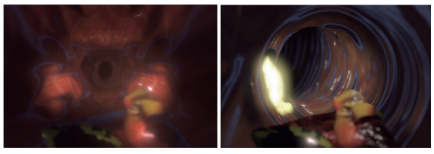


Fig.2 Images of esophagus (left) and duodenum (right).

The narrative of the developed VR experience is the journey of food, which becomes an avatar of the user. The food is eaten by a person, and travels through several digestive organs while getting digested. The food is digested gradually and the internal images of digestive organs are presented with 3-D information on a head-mounted Display (HMD), and users can look around them. Six digestive organs (esophagus, stomach, duodenum, small intestine, large intestine, rectum) were created in details based on text books, and specific movements of each organ were implemented. Users moved in the VR inner body by crawling, that was detected by pressure sensors on a soft matt. Four vibrators presented tactile sensations for improving the perception of self-motion. Headphones created 3-D sounds to accompany the movements of the digestive organs and heart beats.

Participants who experienced the system and said, 'I enjoyed the sense of movement through the inner body', 'I became interested in the structure of the body' and 'I want to try other internal organs'. Thus, it is suggested that the VR system could contribute to enhancing scientific interest in the inner body and improving science learning.

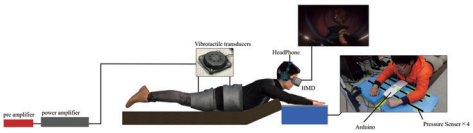


Fig.3 Schematic structure of the developed VR system.

Prospects

Satoshi, the team leader said, "I would like to create more VR systems, and provide novel and unimaginable experiences to many people."

Reference

Fujisawa, S., Hamada, T., Kondo, R., Okamoto, R., and Kitazaki, M. (2017). A body odyssey: exploring the human body as digested food. The 8th Augmented Human International Conference (AH '17), Silicon Valley, CA, USA, March 16-18 2017. [Best demo award] Proceedings of the 8th Augmented Human International Conference (AH '17), Article 39.

DOI: https://doi.org/10.1145/3041164.3041209.
Youtube video demonstration: https://youtu.be/mrMd7e1rTMQ

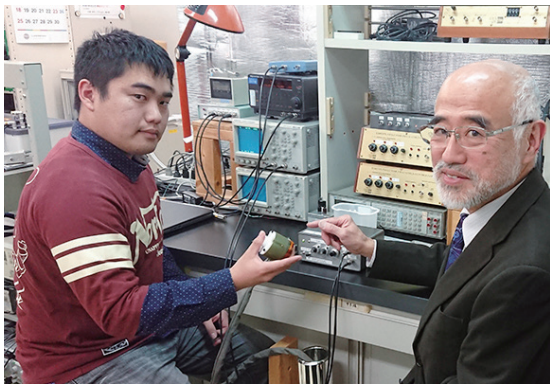
Chasing small magnetic fields

One application of SQUIDs, superconducting magnetic sensors

By Moriki Kabasawa The High-Temperature Superconductors in High Frequency Field (HTSHFF) 2018 Yamagata, Best Student Poster Award

The Applied Sensing Technology Laboratory at the Department of Environmental and Life Sciences in Toyohashi University of Technology is working on the research and development of a non-invasive device for measuring brain functions by using SQUIDs (Superconducting Quantum Interference Devices), or superconducting magnetic sensors. Superconducting magnetic sensors are known to have the highest sensitivity among magnetic sensors. By releasing small magnetic markers in the bloodstream and detecting these magnetic markers in the brain with SQUIDs, blood flow in the brain can be studied in a non-invasive manner. In addition, it is possible to measure the direction and speed of blood flow in detail by using multichannel SQUIDs.

The results of this research was presented at HTSHFF 2018 Yamagata in June 2018 and received the Best Student Poster Award. This award is given to the student who gives the best poster presentation in English as a young researcher in the field of high temperature superconductor research.



Moriki Kabasawa (left), and Professor Saburo Tanaka

Motivation for this research, struggles in research, and impressions after receiving the award

The Applied Sensing Technology Laboratory that I belong to is working on the production, assessment, and measurement of superconducting magnetic sensors called SQUIDs (Superconducting Quantum Interference Devices). The multi-channel SQUID that we are currently using is designed with three channels in one element. The production of these elements involves many processes, and it takes about one week to make a single element.

I had a hard time making enough elements for use in measurement. Since my research can only begin after making these elements, I had to overcome various difficulties in assembling the device, improving it, and finding a suitable measurement method. I could not have made progress in my research nor received this award without the advice of Professor Saburo Tanaka, as well as the help from other members in the laboratory. I am very grateful to Professor Tanaka and to my laboratory members who all supported me throughout my research.

Details of the research

Various methods have been used in research to measure brain functions in a non-invasive manner, including magnetoencephalography and electroenceohalography. Depending on the purpose of measurement, methods were either selected individually or combined together in order to measure brain functions. The focus of our research is on a non-invasive method of measuring blood flow in the brain by injecting extremely small magnetic markers called magnetic nanoparticles into the blood that flows to the brain, and performing measurements with SQUIDs, highly sensitive superconductive magnetic sensors. Rodent models, as a step prior to application on humans, are used as subjects, and we can expect the research to further advance the field of brain research.

The SQUIDs that I produced can measure a magnetic field at $1/10^5$ of the magnetic flux quantum Φ_0 (2.07×10^{-15} Wb). The extremely small magnetic signals from a small number of magnetic nanoparticles moving in a magnetic field can be detected with SQUIDs. In order to study the direction and speed of blood flow by performing measurements on magnetic nanoparticles inside blood, there was the need to create a multichannel system using multiple SQUIDs so as to understand the relationships between magnetic signals obtained from different channels. To solve this problem, measurements were performed repeatedly with a variety of different movement paths in samples and different directions for the applied magnetic field. Through these measurements, I was able to find the signal waveforms derived from relationships between the position of the SQUIDs, the movement path of the magnetic nanoparticles, and the direction of the applied magnetic field.

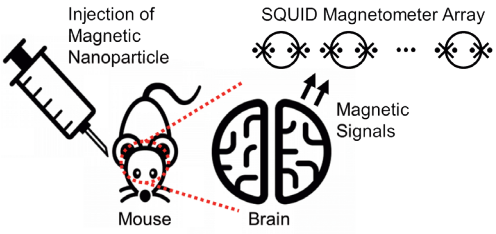


Fig.1. Image of measurement method

Prospects

In our current measurements, experiments are being conducted using samples that are modeled on the flow of blood in the brain, and signal waveforms are studied under known measurement conditions. In the future, we hope to enable conclusions to be made in unknown measurement conditions on the basis of previously measured waveforms. We will proceed with measurements using mice and other small animals, with the ultimate aim of establishing a non-invasive method for studying the brain.

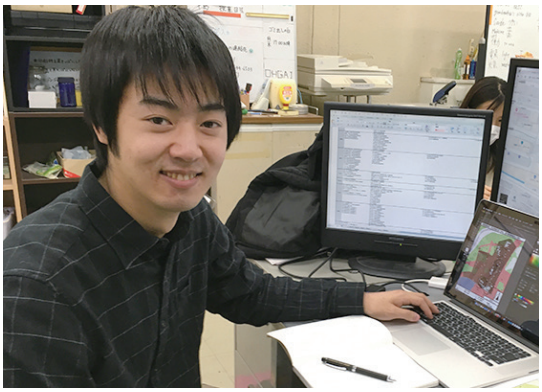
Gathering facilities and people

Consolidating public and welfare facilities through government and the private sector

By Iku Kawano Architectural Institute of Japan 2017, Outstanding Young Researcher Presentation Award

Iku Kawano, a graduate student at the Department of Architecture and Civil Engineering in Toyohashi University of Technology, shed light on the method of creating focal locations in city centers through the consolidation of public and welfare facilities, by looking at developments currently made in city center areas. There are three different types found in the consolidation of public and welfare facilities: "consolidation by function," which gathers facilities with multiple purposes together; "consolidation by scale," which gathers small scale facilities together; and "consolidation by location," which gathers dispersed facilities together (Fig. 1). Through investigating projects conducted in city centers in terms of the intended usage, total floor area, and distance from major facilities, I found that I could categorize the projects into the following types: those that attempt to create a new focal location at the city center, those that attempt to enhance an existing focal location, and those that have little influence on the existing focal location.

The results of this research were presented at the Architectural Institute of Japan and I was awarded the Outstanding Young Researcher Presentation Award (in the category of urban planning research at academic conferences), which is given to young researchers who delivered an excellent presentation.



Struggles in research

My research focused on analyzing 24 projects across 13 cities involved with the consolidation of public and welfare facilities, and these projects were operated by a variety of organizations, such as local governments, redevelopment unions, and private companies. For this reason, I had to contact the organizations that managed each project, and thus gathering information required a lot of patience. The most difficult experience I faced was when gathering information from redevelopment unions. Once the target project was up and running, the redevelopment unions were dissolved and I had no way of contacting them. As a result, I needed to contact the construction and community-planning companies that were involved in the projects, which required several extra steps.

Details of the research

In this country, where the population is declining and aging, the industrial hollowing-out of city centers is becoming prominent due to various factors, such as the suburbanization of large shops and an increase in motorization. As such, there is a growing importance placed on revitalizing city centers. In response to these circumstances, local governments have been formulating basic plans for revitalizing city centers as an ongoing process since around 2006. It is especially important to improve public and welfare facilities in rural cities with little private investment. Consolidation is significant in that it creates a hub in the city center, which serves to create a center for activity.
In this research, I shed light on the method of creating focal locations at city centers through the consolidation of public and welfare facilities in city centers.

There are many types of projects for consolidating public and welfare facilities. Projects have different influences on the city center based on a combination of different factors including the organization leading the project, the intended usage, the total floor area, and the location. Projects were categorized into three types with regard to the method of creating focal locations at city centers as follows:

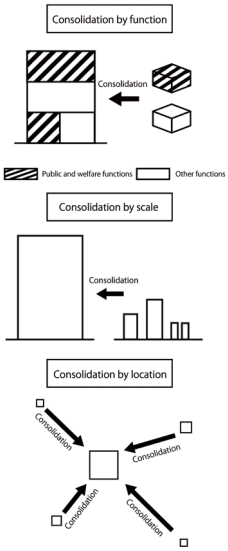


Fig.1 Concepts of consolidation

1. Projects that create a new focal location by building facilities with a total floor area of 10,000m^2 or above that are at least 100 meters away from a train station or a city office.
2. Projects that enhance the surroundings of an existing focal location by building facilities with a total floor area of less than 10,000m^2 that are less than 100 meters away from a train station or a city office.
3. Projects that build facilities with a total floor area of less than 10,000m^2 at least 100 meters away from a train station or a city office, but that do not create a new focal location nor enhance an existing focal location.

Furthermore, these projects were also divided into two types based on the effect on population flow as well as their main purposes: projects with welfare and commercial purposes that pull population flow towards them, and projects with residential purposes that push population flow away from them. By looking at the data with the methods of creating a focal location on one axis and the effect on population flow on a second axis, I found that there were six methods of creating focal locations as follows and shown in Fig. 2.

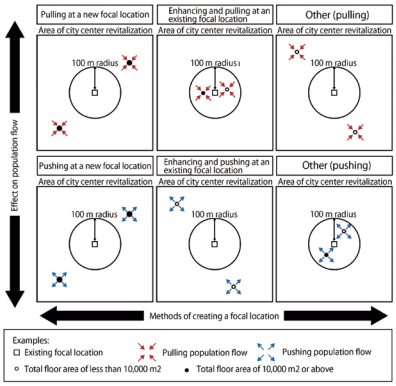


Fig.2 Types of methods for creating focal locations

1. Pulling at a new focal location.
2. Pushing at a new focal location.
3. Enhancing and pulling at an existing focal location.
4. Enhancing and pushing at an existing focal location.
5. Other (pulling).
6. Other (pushing).

Prospects

Currently there are many public and welfare facilities that are deteriorating and require renewal in municipalities across Japan. However, renovations require significant costs. Thus, consolidation of public and welfare facilities is needed through greater collaboration between government and the private sector. In order to gather population towards a city center, services that are closely related to our everyday life, such as medical services, welfare services, and childcare, become vital. Therefore, it is also important to combine uses when consolidating facilities.

産業機械駆動系の加々速度制限を考慮した滑らかな動作軌道生成と非線形摩擦補償

International Federation of Automatic Control (IFAC) 2017, Application Paper Prize

シンバ ケニス レニー

豊橋技術科学大学機械工学系システム工学研究室とドイツのシュトゥットガルト大学システムダイナミクス研究所は、効率的な生産と省エネルギー化のための産業機械駆動系の滑らかな動作軌道生成法を提案しました。提案法は5次のベジエ曲線とバンバン型の加々速度に基づき滑らかな速度遷移を保証します。さらに、その軌道への動作追従のためにフィードフォワード型の摩擦補償を適用しました。

本成果は、20th World Congress, The International Federation of Automatic Control (IFAC), Toulouse, France, July, 2017に報告し、Elsevier社の論文に採択されました。さらに、制御応用分野の論文を対象としたIFAC Application Paper Prize (Finalist)として表彰されました。The IFAC World congressは3年に一度開催される制御分野の世界的な会議であり、20回目を迎える今回は4,267の投稿論文のうち2,800件が採択され、本論文を含む全部で5編の論文が同賞を受賞しました。

研究内容の詳細

日本の代表的な産業分野の一つであるCNC工作機械などの産業機械装置は世界中の工場で広く利用され、製造する製品の高度化に伴い、一層の高速高精度が期待されています。このために、加速度や加々速度の制限を満たしつつ、駆動系が追従可能となるよう産業機械の動作軌道を生成することが必要です。動作軌道は駆動系の速度および加速度が滑らかになるよう、少なくとも2階時間微分可能となることが望まれます。しかしながら、軌道設計や実装の容易性の点から線形補間軌道も多く用いられており、急な加減速等による動作効率の低下、消費エネルギーの増大、機械磨耗等の点から改良が必要とされます。

動作軌道の改良法についての研究が進められ、多くの場合にはカーブフィッティングの応用が検討されています。しかしながら、例えば高次のスプライン曲線は数値的に不安定であり、振動的な軌道の発生が指摘されています。また、3次のスプライン曲線では滑らかな補間が可能ですが、軌道を接続するときに微分可能性が制限されます。

そこで私たちの研究チームでは、5次のベジエ曲線とバンバン型の加々速度に基づく手法を提案しました。これは、速度軌道の滑らかな接続を可能にします。また、機械装置では瞬時の大きな加減速や、曲率の高い箇所での高速動作は望ましくないため、本提案では加速度および加々速度制限を満たしつつ、動作始点／終点あるいは曲率の高い箇所での速度抑制が可能な構成となっています。

摩擦力は一般に動作速度に関して非線形性を有しますが、産業機械の高精度動作に対して支配的な外乱となるため、滑らかな速度軌道の実装に伴い、フィードフォワード型の摩擦補償をさらに応用しました。これにより、非線形摩擦力の影響を制御的にキャンセルでき、より高精度な軌道追従が可能になります。実験により産業機械の動作性能の改善が確認されました。

開発秘話

本研究に先立ち、私たちは与えられた経由点を滑らかに移動する車輪ロボットの動作軌道生成法を提案していました。また、研究室のメンバーが産業機械駆動系のための摩擦補償を有する非線形制御法について研究していました。これらの研究を通じて、制御性能が目標動作軌道の性質に大きく依存することを確認していました。すなわち、目標動作軌道が十分滑らかであれば、より優れた制御性能が得られます。一方、高い曲率を有する目標動作軌道では、制御性能が低下します。この点から、先に提案した車輪ロボットのための動作軌道生成法を産業機械駆動系へ応用するアイデアを思いつき検討を行いました。

今後の展望

私たち研究チームは、今回の提案法が産業機械の生産性能向上のほか、自律移動ロボットなど多くの機械駆動装置への適用を期待しています。

脳内神経伝達物質を可視化する化学の目を持つセンサ

病気の早期診断や創薬貢献に向けて　電気学会　「第35回センサ・マイクロマシンと応用システム」シンポジウム 五十嵐賞 受賞 (2018年10月)

土井 英生

豊橋技術科学大学電気・電子情報工学系の研究チームと山梨大学医学部の研究チームは、生体物質検出膜を修飾した半導体イメージセンサ用いて脳組織切片から放出された神経伝達物質ATP (アデノシン三リン酸 Adenosine Triphosphate) の可視化に成功しました。このセンサは、ATPを認識する酵素を応用することで水素イオンに変換して溶液中のATP拡散を非標識（蛍光標識無し）でリアルタイムに観察可能です。センサ上に、脳組織のような生体組織や臓器を乗せて計測することができ、細胞外応答の2次元分布を画像情報としてダイレクトに得ることが可能です。

本研究の成果を2018年10月に北海道で開催された電気学会の「第35回センサ・マイクロマシンと応用システム」シンポジウムにおいて発表し、五十嵐賞を受賞しました。これは、最も優秀な発表をした35歳以下の若手研究者に贈られるものです。

本研究に取り組んだきっかけ

私がこの研究に取り組んだきっかけは、澤田教授の研究室で開発された"目に見えない化学現象を可視化できる半導体イメージセンサ"に興味を持ったからです。このセンサは私たちの体の中に存在する"イオン"の動きを動画像情報として得ることができます。本センサを応用してこれまで誰も見ることのできなかった脳内の化学現象を可視化するセンサ開発に取組んでいます。また、医学部の先生や研究所の方々と連携して研究を進めるプロジェクトに惹かれたこともきっかけの一つです。現在は、山梨大学医学部　小泉教授の研究グループと共同で医療応用を目指したイメージセンサの開発に取り組んでいます。

研究の苦労話

最も苦労した点は、ATPイメージングに向けて検出膜の成膜技術を検討したことです。約5mm x 5mm のアレイセンサ上でより早く高感度に、そしてきれいにイメージングするために、検出膜材料の物質量や膜厚を追求しました。その結果、疎水性のセンサ表面を薬品処理して滴下溶液の量が少なくても膜厚をコントロールできるようになりました。センサの検出速度に着目して測定データを解析した結果、膜厚を100nm程度にすることがATP検出に最適であることを実験的に示しました（理論検出限界まで検出感度を向上）。1 sampleの準備から実験結果の解析に30時間を要することも多々ありましたが、山梨大学での生物実験に向けて緻密にデータを取得し、解析することがセンサ性能の向上に繋がりました。

また、山梨大学で生物実験を幾度と重ねる過程では、海馬は培養過程で切片表面にできる細胞の瘢痕（鎧のような層）が原因で神経伝達物質放出の妨げになるのではないかと考え、培養しない急性タイプを提案しました。その結果、海馬自体の明瞭な画像が撮れるようになり、最終的には放出されたATPの画像取得に繋がりました。

受賞に関するエピソード

初めは受賞できてうれしいという率直な気持ちが大きかったのですが、指導教員の澤田教授から、この受賞は本研究グループではOO先生以来20年ぶりの快挙だよ！と伝えられ、名誉のある賞を頂けたんだなと改めて受賞の実感が湧いてきました。また、論文執筆の段階から発表直前まで研究成果発表での話し方や魅せ方を工夫していたので、評価して頂けたことに喜びもひとしおでした。これを糧に今後の研究にも一層注力していきたいと思っています。

研究内容の詳細

脳内において活動的な細胞として注目されているグリア細胞がATPと呼ばれる神経伝達物質を細胞外に放出し、神経細胞の活動（シナプス伝達、シナプスの構造：1-2μm）を制御することで脳機能制御に大きな役割を果たしていることが示されつつあります。そのため、シナプスのような局所部位における細胞外ATPを高い空間分解能でイメージング及び解析することが求められますが、ホタルの光を利用した従来の生物発光法は空間解像度が200μm程度と細胞レベル以上であることからATPの放出部位を可視化できないという問題がありました。

そこで、私たち研究チームは、これまで開発してきた40μmの空間分解能を有するイオンイメージセンサ上にATPを選択的に検出する酵素を修飾したATPイメージセンサを開発しました。本センサは、ATPと酵素の化学反応を用いることにより水素イオンに変換してATPを検出します。また、センサに化学的な表面処理を施し、検出膜を100nm程度に制御するとATPをセンシングエリア近傍で高感度に検出できることがわかりました。そして実際に海馬をセンサ上に密着させて生物実験した結果、電気刺激依存的に出力画像が変化し、ATPに由来した信号であることを確認しました。これは、蛍光標識などのラベルを使用せずに脳組織から滲み出てきたATPの可視化に成功した世界初の例になります。

海馬に集積している神経細胞とグリア細胞によるコミュニケーションは、記憶や学習における情報処理・発信の素過程であることが推測されていることから、本研究は真の情報処理・発信のメカニズム解明に繋がることが期待されます。さらに、神経細胞とその10倍も数の多いグリア細胞による細胞外情報伝達物質の時空間分布をイメージング及び解析することは脳機能の解明に必要不可欠であると考えています。

今後の展望

豊橋技術科学大学と山梨大学の両研究チームは、ATP検出膜の成膜技術を改善することにより、40μmの空間分解能を持つセンサ上でイオン情報を元に脳組織から放出されたATPの画像化に成功しました。センサを開発する私の所属する豊橋技術科学大学の研究グループはシナプスサイズに迫る2μmの高空間分解能を有するイメージセンサも実現しており、このセンサに開発したATP検出膜を応用することで、細胞の局所から放出されるATPを可視化できることが期待されます。さらに、ATPと他の神経伝達物質や種々のイオンなどとの相互作用を複数同時にイメージングすることにより従来の蛍光顕微鏡のような光情報では得ることのできなかった生理学的意義の解明に繋がる新たな情報を得ることが期待されます。

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食物の旅

バーチャルリアリティによる消化器の学習体験　国際会議Augmented Human（拡張人間会議）2017, Best Demo Award受賞

藤澤 覚司

豊橋技術科学大学情報・知能工学専攻大学院生藤澤覚司率いる研究開発チームは、自分が食物となり、ほふく前進で身体内部の消化器を巡る旅を体験するバーチャルリアリティ体験システムを開発しました。このシステムを使うことで、自分の体験として消化器を学び、楽しく理解が促進されることが期待できます。

本研究の成果を、2017年3月16日から18日までアメリカのシリコンバレーで開催された国際会議Augmented Human 2017（拡張人間会議）においてデモ展示し、Best Demo Awardを受賞しました。

本研究に取り組んだきっかけ、研究の苦労話、受賞時のエピソード等

開発のきっかけは、私自身が興味を示せなかった保健体育の授業をVRでより直感的で面白いものにしたいと考えたことからでした。開発時は、先行研究や関連コンテンツがほぼなかったため、手探りでの開発となりとても苦労しました. デモ展示当日は、機材トラブルに見舞われ受賞はないだろうと諦めていたので、受賞アナウンスで作品名が読み上げられた時は、驚きました。

研究内容の詳細

学校教育では、教科書や人体模型をつかって理科や保健体育として人体の仕組みを学びます。しかし、それは子ども達にとってあまり面白い単元ではありません。そこで、バーチャルリアリティ（Virtual Reality；以下VR）を用いて、自分で身体内部を体験して、楽しく消化器を学習できる作品を作りたいと思いました。

ストーリーとしては、自分が食物となり、食べられてから徐々に消化され、排泄されるまでの旅を実現するものとしました。自分が食物になった様子や、移動中の消化器は、頭部搭載型ディスプレイに立体映像として提示され、見回すことができました。体験する消化器として、食道、胃、十二指腸、小腸、大腸、肛門を、参考書に基づき自らモデリングし、それぞれの消化器に特徴的な運動（蠕動運動など）も実装しました。体内の移動には、ほふく前進を用いました。圧力センサをつけたクッションの上で体験者が腕のほふく動作をすると、それを検出して前進するようにしました。移動時には、消化器の運動に伴う振動を4つの振動刺激装置から提示し、移動感を増幅しました。また、消化器の運動や心臓の鼓動を3D音響としてヘッドホンから提示しました。

本システムを利用した体験者は、「実際に体内を移動している感じがして楽しかった」、「身体構造に興味を持った」「他の臓器も体験してみたい」などの感想を示し、このシステムが身体内部の科学的興味、学習に貢献する可能性が示唆されました。

今後の展望

チームリーダの藤澤は、今後もさまざまなVRシステムを開発して、多くの人に普段体験できないような体験を提供していきたいと考えています。

小さな磁場を追う

超伝導磁気センサSQUIDの応用として

樺澤 守力

豊橋技術科学大学環境・生命工学系、バイオセンシング応用研究室は、超伝導磁気センサSQUIDを用いて、脳の働きを非侵襲で測定する装置の研究・開発を行っています。超伝導磁気センサは最も高感度な磁気センサとして知られています。血流に小さな磁気マーカーを流し、SQUIDで脳の血管を流れる磁気マーカーを検出することで脳を流れる血流を非侵襲で調べることが可能となります。加えて、測定に利用するSQUIDをマルチチャンネルにすることで血流の詳しい方向や速度の測定が可能となります。

本研究の成果を2018年6月、HTSHFF 2018 Yamagataにおいて発表し、Best Student Poster Awardを受賞しました。これは、将来の高温超伝導研究分野を担う若手の研究者である学生によって英語で行われるポスター発表の中から、最優秀と認められる研究成果発表を行った者1人に対して贈られる賞です。

本研究に取り組んだきっかけ、研究の苦労話、受賞時のエピソード等

私が在籍しているバイオセンシング応用研究室では超伝導磁気センサSQUID (Superconducting QUantum Interference Device)の作製や評価、測定を行っています。現在使用しているマルチチャンネルSQUIDは1つの素子に3チャンネルあるデザインとなっています。素子の作製にはいくつもの工程があり、1つの素子を作製するのに1週間程度必要となります。測定において十分な素子を作製するのに苦労しました。また、素子が完成してからが研究のスタートでもあるため、装置の組み上げや改良、測定方法で様々な困難がありました。しかし、本応用研究室の田中三郎教授のアドバイスや、研究室の仲間たちの助けもあり研究を進めることができました。このアドバイスがなければ賞を受賞することはできませんでした。私を支え、助けてくれた田中三郎教授や仲間に感謝しています。

研究内容の詳細

脳の働きを非侵襲で調べる方法として脳磁図や脳波計など様々な方法が研究に利用されています。これらは測定する用途によって適切に測定方法を選択または組み合わせて利用されています。我々は脳を流れる血流に磁性ナノ粒子と呼ばれる非常に小さい磁気マーカーを入れ、高感度な超伝導磁気センサSQUIDで測定することで、脳を流れる血流を非侵襲で測定する方法を研究しています。また、測定対象をヒトではなく研究の前段階で利用されるげっ歯類としており、脳の研究のさらなる発展が期待されています。

私が作製したSQUIDは単位磁束量子Φ_0 (2.07×10^{-15} Wb)の$1/10^5$磁場を測定することができます。磁場中を移動する少量の磁性ナノ粒子からの非常に小さな磁気信号を、SQUIDを利用することで検出することが可能となります。血中を流れる磁性ナノ粒子を測定し流れる方向や速度を調べるためには複数のSQUIDからなるマルチチャンネルを使用し、各チャンネルで得られる信号の関係を知る必要がありました。この問題を解決するために、様々なサンプルの移動経路や磁場の印加方向などを変更した測定を繰り返すことで、SQUIDの位置、磁性ナノ粒子の移動経路、磁場の印加方向の関係から得られる信号波形を知ることができました。

今後の展望

現在の測定では脳を流れる血流を模したサンプルを使用し実験を行っており、既知の測定条件のときの信号波形を調べています。今後は測定によって得られる波形から未知の測定条件を決定可能にしていきたいと考えています。最終的には、マウスなどの小動物を用いた測定を進めていき、脳を非侵襲で調べる新たな方法を確立していきたいと考えています。

施設を集め、人を集める

行政と民間による公共公益施設の集約化　日本建築学会　若手優秀発表賞（学術講演会・都市計画部門）　2017年9月

河野 壱玖

豊橋技術科学大学、建築・都市システム学大学院学生の河野壱玖は、中心市街地整備の現況を見ることで、中心市街地における公共公益施設の集約化による拠点形成手法を明らかにしました。公共公益施設の集約化は、複数の用途を集める「機能による集約」、小規模施設を集める「規模による集約」、分散した施設の立地を集める「立地による集約」の3パターンが挙げられます（Fig.1）。中心市街地内で実施されている事業を、内包用途、延べ床面積、主要施設の距離からみると、中心市街地内で新たに拠点形成を図る事業や既存の拠点の強化を図る事業、拠点への影響が少ない事業があることがわかりました。

本研究の成果を2017年9月に日本建築学会において発表し、若手優秀発表賞（学術講演会・都市計画部門）を受賞しました。これは、優秀な発表をした若手研究者に贈られるものです。

研究の苦労話

公共公益施設の集約化を図っている13市24事業に着目して分析を行いましたが、事業主体は自治体や再開発組合、民間企業等、様々ありました。資料収集する際には、各事業主体へ問い合わせが必要であり、資料収集には根気が必要でした。その中でも、一番苦労したのは再開発事業を行う再開発組合に資料収集をした時です。対象とする事業が実施され、しばらく時間が経っている場合は、再開発組合が解散し、問い合わせをすることができません。その際には、事業を行った施工会社やまちづくり会社に問い合わせる必要があり、いくつかのプロセスを踏む必要がありました。

研究内容の詳細

人口減少や高齢化が進んでいる我が国において、大型店舗の郊外立地やモータリゼーションの進行等の様々な要因から中心市街地の空洞化が進み、中心市街地の活性化が重要になってきています。その中で、平成18年から各自治体において中心市街地活性化基本計画を策定できるようになり、中心市街地の活性化が進められてきています。特に、民間投資が少ない地方都市では、公共公益施設の整備は重要となります。また、同時に集約化するということは中心市街地内に核をつくるということであり、賑わいの中心を生むことにつながります。

そこで、本研究では、中心市街地における公共公益施設の集約化による拠点形成手法を明らかにしました。

公共公益施設の集約化を行う事業には、様々な種類があります。事業により事業主体や内包用途、延べ床面積、立地等様々であり、これらの組み合わせにより、中心市街地に与える影響は異なります。拠点形成の方法としては、鉄道駅や市役所から100m以上離れた位置で延べ床面積10,000m^{2}以上の施設を整備することにより新たに拠点を形成する事業、鉄道駅や市役所から100m未満の位置で延べ床面積10,000m^{2}未満の施設を整備することにより既存の拠点周辺を強化する事業、鉄道駅や市役所から100m以上離れた位置に延べ床面積10,000m^{2}未満の施設を整備しているが拠点の形成・強化ともに図られていない事業に分類できました。

さらにこれらの事業は、人流への効果として、主要用途から公共公益・商業用途によって人口を吸引する事業と、居住用途によって人口を放出する事業に分けることができました。このようなことから拠点形成の方法と人流への効果の二軸から見ると、拠点形成手法には、新規拠点形成吸引型、新規拠点形成放出型、既存拠点強化吸引型、既存拠点強化放出型、その他（吸引型）、その他（放出型）の6つがあることがわかりました（Fig. 2）。

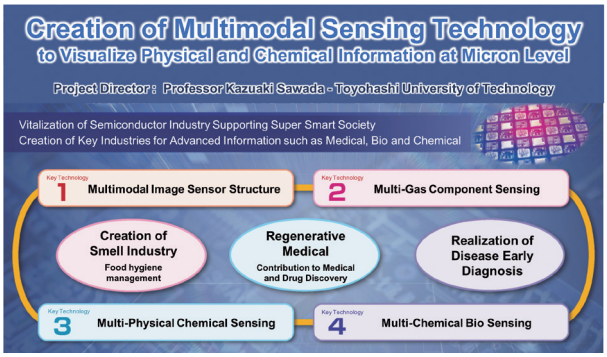
今後の展望

現在全国の市町村には、老朽化が進み更新が必要な公共公益施設が多く存在しています。しかし、新たに整備するには多くの費用が必要です。そのため、今後はこれまでより行政と民間が連携し、公共公益施設を集約することが必要になってきます。また、中心市街地に人を集めるには、医療や福祉、子育て等の生活に密着した用途も重要となるため、集約する用途の組み合わせも重要になっていくと考えられます。

Pick Up

TUT Accelerates Social Implementations of Technology through Large National Investment Projects

Social implementation of technology is the main mission of Toyohashi University of Technology. We promote a range of industry-academia collaborative projects with the goal of accelerating the social implementation of technologies we have developed in-house. Some of these projects have been adopted by national large investment projects, such as OPERA, NEDO and SIP.



OPERA: "**O**pen Innovation **P**latform with **E**nterprises, **R**esearch Institute and **A**cademia" promoted by Japan Science and Technology Agency (JST).

TUT promotes and leads the "Creation of multimodal sensing technology to visualize physical and chemical information at micron level"

NEDO: "**N**ew **E**nergy and Industrial Technology **D**evelopment **O**rganization" promotes "Strategic Energy Saving Technological Innovation Program"

TUT jointly proposed the "Development of 'Hetero-nano' super high strength copper alloy material contributing to energy conservation strategy"

SIP: "Cross-ministerial **S**trategic **I**nnovation **P**romotion Program" promoted by Japan Science and Technology Agency (JST).

TUT plays a key role in the "Development of outdoor wireless power supply technology".

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