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Utilizing FRPs in the construction and reinforcement of buildings and bridges

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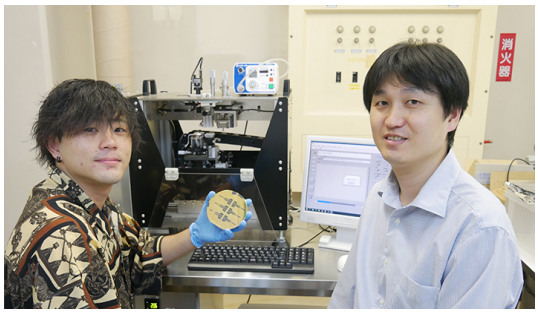
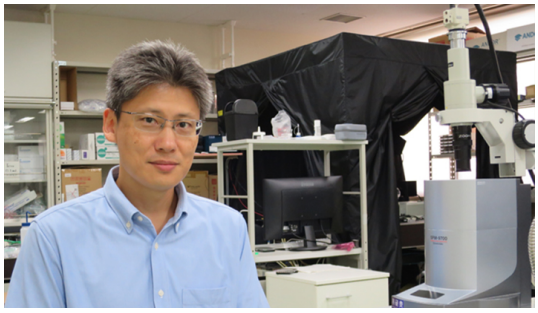


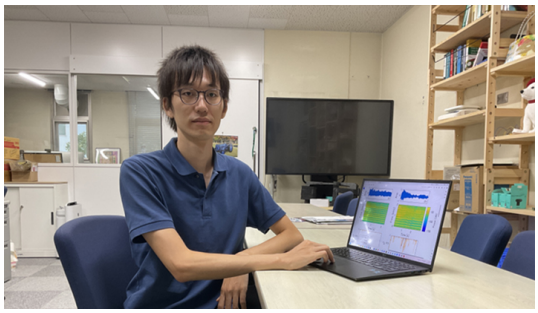
Multisensory information detection using multi-channel electrocorticography film that can be placed over a wide area of the cerebral cortex

Development of electrocorticography device for simultaneous detection of multi-modality information in the mouse brain



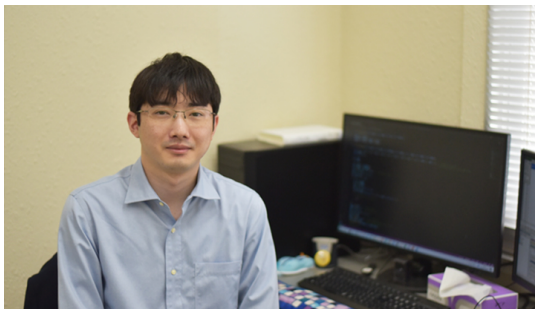
Concentration of cell membrane components with nanocarbon materials

Localization of lipid bilayer domain on graphene oxide



Diagnosis of voice condition from call audio

Toward the development of a dysarthria diagnostic system in telemedicine



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Creating training data from a human body link model without measurements

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Utilizing FRPs in the construction and reinforcement of buildings and bridges

Yukihiro Matsumoto

Professor Yukihiro Matsumoto conducts research on fiber-reinforced plastics (FRPs), which are produced by moding carbon or glass fibers with resin. FRPs are lightweight and durable and have a high degree of freedom in their shape. They are widely used in airplanes and automobiles. Professor Matsumoto is exploring methodologies for utilizing the properties of FRPs in the construction and reinforcement of civil engineering structures such as buildings and bridges. What are the benefits of using FRPs as a material for construction and civil engineering?

Interview and report by Madoka Tainaka

FRPs exhibit both lightness and strength

FRPs were developed in the early 20th century and used partly as a structural material in lifeboats and fighter jets during wartime. At present, they are indispensable in manufacturing automobiles and in other aspects of our lives. However, in the late 20th century, FRPs started gaining attention as a material for building and civil engineering materials. Professor Matsumoto offers the following explanation as his reason behind researching FRPs, which are an uncommon material for construction and civil engineering.

"All materials have advantages and disadvantages, but the biggest advantage of FRPs is their lightness and strength. Furthermore, the main materials of FRP are originally fibers; therefore, they resemble a cloth before being molded with resin, giving them a very high degree of freedom in shape. Another advantage is that they do not corrode as steel does. Although FRPs have not yet become widespread in construction, I believe their unique features can be utilized in many situations."

The biggest significant disadvantage of using FRPs is that we do not yet fully understand these materials or the best way to design and use them. Professor Matsumoto indicates that applications of these materials in construction are not suitable for mass production, unlike with automobiles for example. In addition, we need to learn how to use the material characteristics to achieve maximum strength, which is all important for construction.

"FRPs are materials with variable qualities, and their strength changes depending on the direction of the fibers. The structural property of FRPs has two aspects. The tensile strength, which indicates if the material will tear when pulled, is undoubtedly stronger than that of steel. However, the rigidity, which indicates the extent of deformity when force is applied, is sometimes less than half that of steel. Certain buildings in the world, even in Japan, are made entirely from FRPs. However, realistically, instead of using only FRPs, I think combining them with steel, concrete, and other materials and finding the appropriate material and place to use them will be wiser."

Utilization for seismic reinforcement of joints and steel materials

Professor Matsumoto discusses the reinforcement of steel materials and their joints with carbon-fiber-reinforced plastics (CFRPs) as an example of the combination of FRPs and other materials.

"As you may have seen the brace members in factories, L-shaped components, known as angle irons, are installed diagonally and fastened with bolts to form part of the structure. However, with buildings that were built per old structural design standards, the force and strain of an earthquake on the building can weaken the strength of the bolt holes which will likely cause structural failure. To address this issue, various solutions have been developed and put into practical use, such as reinforcement through welding and additional bolts. However, in reality, limited progress has been made in reinforcement work because of issues at some factories, such as a reluctance to weld due to the risk of sparks, or an inability to shut down for several days for reinforcement work. Therefore, we developed a simple method for affixing the carbon fiber over the bolt, injecting it with resin, and hardening it while it adheres."

According to Professor Matsumoto, the advantage of this method is that no large-scale preparation is required, and there is no need to build scaffolding or carry heavy steel plates. "When we conducted the experiment in several locations, students were able to complete the task in approximately two hours using only a four-legged scaffolding stepladder." As mentioned earlier, FRPs can be wrapped around the shape of an object; therefore, they can be f exibly adapted on-site.

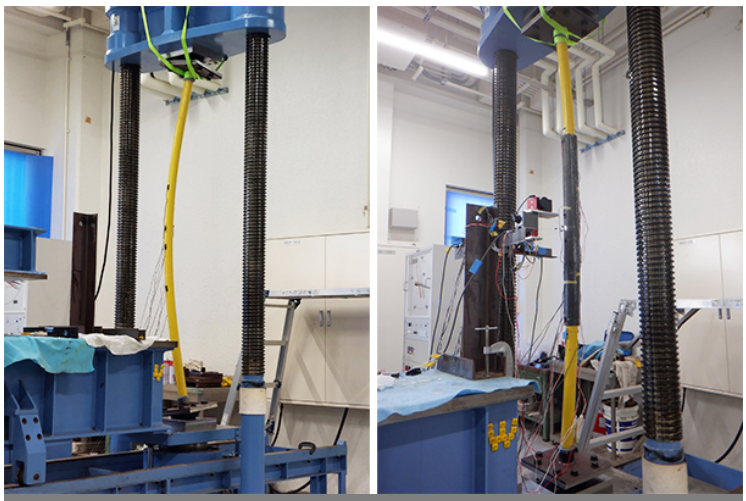
Work at university laboratory by students.

Professor Matsumoto also believes that there is considerable potential for increasing the all important strength of the material. "In the experiments, we deformed the structure horizontally to simulate the horizontal shaking of an earthquake, but the bolt joints did not break even after moving about 120 mm. Without reinforcement, it would have broken at approximately 30 mm and lost its supporting power immediately. However, if reinforced with FRPs, it will continue to maintain its strength up to an extent even after 120 mm, and will not suddenly collapse. This toughness is not due to the strength of the carbon fibers but rather an inherent property of steel. In other words, supplementing the structure with FRPs at its weak points allows us to make the most of the inherent qualities of steel."

Understanding how to get the best out of the variable qualities of FRPs

Owing to their low weight, GFRP bridges using glass fibers have already been developed as pedestrian bridges. Professor Matsumoto however, advises caution when using these "quirky materials".

"In regular FRPs, most of the fibers are in the vertical direction (longitudinal direction). However, if a hole is made perpendicular to the fiber and hooked to a bolt, then that part may act as a trigger and cause the bolt to slide out. In other words, the weakness of FRP is that if used incorrectly, it loses its strength. Therefore, we proposed a method for increasing the strength by tilting the fibers at a 45° angle."



Compression tests of structural pipe member
without strengthening (left) and with unbonded CFRP strengthening (right).

However, if special FRPs with tilted fibers are used in all locations, then productivity will drop and the unit cost of materials will substantially increase. Therefore, to maximize performance, Professor Matsumoto proposed a method for attaching the diagonal-fiber-containing materials only around the bolts.

"Simply affixing FRPs with 0.5-mm-thick fibers diagonally on both sides of a 6-mm-thick regular FRP more than doubles the yield strength. Moreover, even if the structure is broken by an unexpected force, it will not suddenly lose its strength and the diagonal fibers will not fall apart. I think that FRPs can be used most advantageously in situations that make the most of their low weight and strength, such as in seaside pedestrian bridges, which are susceptible to corrosion, bridges in locations where temporary construction using heavy machinery is difficult, and temporary bridges erected during a disaster."

Developing a simple method that does not require adhesives

When reinforcing with FRPs, another drawback is affixing the fibers with adhesives. The performance of FRPs deteriorates if the adhesive peels off. Professor Matsumoto was working on the use of optical fiber sensors for detecting signs of adhesive peeling. However, he realized that there was no need to worry about the adhesives peeling off if no adheres were used. Therefore, he is currently investigating a method for maximizing the material performance without using adhesives.

"Roofs can be made of slender steel pipes, such as the steel three-dimensional truss structure (space frame) used for the festival plaza at the 1970 Osaka Expo. However, if an unexpected force greater than the design force is applied, such a roof might break. To reinforce it, we developed an extremely simple method of wrapping CFRPs around the center of the steel material."

The work is remarkably simple: similar to a plaster cast, the CFRP is fitted like a plaster cast to match the shape of the steel. Furthermore, Professor Matsumoto said that they succeeded in increasing the yield strength of the steel material by 20–30%. CFRPs are light; therefore, the weight increase can be minimized on the structure.

"Even if a compressive force is applied on the column, the CFRP-reinforced parts will not deform, as opposed to the unreinforced parts. This procedure involves covering the material with a semicircular pipe-shaped CFRP, which makes working on roofs very easy. Although the high material costs of the CFRPs themselves are unavoidable, the lightweight nature of these materials renders additional expenses such as a crane or scaffolding unnecessary, as well as not requiring advanced techniques. Therefore, overall, CFRPs can be considered to be more efficient and economical than other reinforcement materials. Moreover, Japanese manufacturers lead the CFRP market as they own the top three carbon fiber manufacturers. Furthermore, I think that the integration of construction technology with Japan's material technology is also an advantage."

Seismic reinforcement of factories and buildings built as per old structural design standards is an urgent issue in Japan, a country prone to major earthquakes. We look forward to the widespread use of the simple seismic reinforcement using FRP developed by Professor Matsumoto and his team.

Reporter's Note

Professor Matsumoto says that he loved playing in the garden since he was a child, making all kinds of things with his hands using garden plants and soil. He wanted to work in building structures; thus, he studied at the Department of Architecture in the National Institute of Technology, Yonago College, and then progressed to the Toyohashi University of Technology.

"Perhaps because of the thriving automobile industry in the Tokai region, I had many opportunities to work with FRPs at the university, and I soon became an expert in FRPs." However, surprisingly, he said that this has not always been easy. "Experiments often fail, and a particularly large obstacle was the adhesive issue with FRPs." He experimented while brainstorming with his students, and after much struggle, he proposed a method that did not rely on adhesives. Failure is said to be the key to success, but perhaps the determination shown by Professor Matsumoto was also a key ingredient.

建物や橋梁の建設・補強にFRPを役立てる

松本幸大教授が研究対象とするのは、ガラス繊維や炭素繊維などを樹脂で固めたFRP（Fiber Reinforced Plastics＝繊維強化樹脂）だ。軽量かつ丈夫で形状の自由度が高いFRPは、飛行機や車などに広く用いられているが、松本教授はその材料の特性を生かして、建築物や橋梁などの土木構造物の建設や補強に役立てるための方法論を探究している。FRPを建築・土木材料に使うメリットとは？

軽さと強さを兼ね備えるFRP

20世紀初頭に開発され、戦時中に救命ボートや戦闘機などの材料に用いられて発展、いまや自動車をはじめ、私たちの生活に欠かせない材料となったFRPだが、建築・土木材料として着目されるようになったのは20世紀末になってから。建築・土木資材としてはあまり一般的ではないFRPを研究する理由を、松本教授は次のように語る。

「どんな材料にも利点と欠点はありますが、FPRの最大の利点はなんといってもその軽さと強さにあります。さらに、もとが繊維なので樹脂で固める前は布状で、形状の自由度が非常に高い。鋼のように腐食しないのも大きなメリットです。まだ、建築分野では浸透していませんが、FRPならではの特長を活かす場面がさまざまにあると思っています」

一方、その最大の欠点は、材料を十分理解して、材料自体を設計して使う難しさにある。建設用途では、自動車などのような大量生産に向かないことが多いうえ、肝心の強度を出すには、材料の特性を踏まえたテクニックが必要だと松本教授は指摘する。

「癖のある材料というか、繊維の向きによって強さが変わるんですね。また、強さの観点も二つあって、引っ張ったときにちぎれるかどうかという引張強度は鋼よりも断然強いけれど、力が加わったときにどれくらい変形するかという剛性では、鋼の半分以下になる場合もあります。海外ではFRPだけでつくった建物も存在しますし、日本でも一部にFRPを使った建物はあるものの、現実的には、FRPを単体で使うというより、鋼やコンクリートなどと組み合わせて、適材適所で使っていくのが賢いやり方だと思います」

鉄材の接合部の耐震補強に活かす

他の材料とFRPの組み合わせの例として松本教授が挙げるのが、鋼材やその接合部へのCFRP（炭素繊維強化樹脂）による補強だ。

「工場などで見かけたことがあるかもしれませんが、山形鋼といってL字形の部材を斜めに設置し、ボルトでとめて、構造の一部を担っていることがあります。ところが、古い耐震基準でつくられた建物だと、地震などで力が加わって引っ張られると、ボルトの穴で強度が落ちた部分が発端となって、簡単にちぎれてしまうことがあるんですね。これに対して、溶接による補強やボルトの追加など、さまざまな解決策が開発されていて、実用化もされているのですが、工場によっては火花が出る溶接はできないとか、補強のために何日も工場の稼働を止められないといった理由で、補強工事はあまり進んでいないのが実情です。そこで我々は、ボルトの上から炭素繊維を貼り付けて、樹脂を染み込ませて接着しながら固めるという簡便な方法を開発しました」

大掛かりな準備も不要で、足場を組んだり、重い鉄板などを持ち運んだりする必要はないという。「実験で数カ所に実施した際には、学生が馬脚立に乗って、2時間程度で仕上げることができました」と松本教授。先述した通り、FRPは対象の形にそって巻き付けることができるため、現場で臨機応変に対応できるのが大きな利点だ。

肝心の強度も、飛躍的に高めることができるという。
「実験では、地震の横揺れを想定して水平方向に変形させたところ、120 mmほど動いてもボルトの接合部が切れることはありませんでした。補強がなければ、30 mm程度で切れて、一気に支える力がなくなってしまいます。一方、FRPで補強すれば、120 mmを超えてもしばらくは力を保ち続け、一気に支えを失うことはありません。なお、この粘り強さは炭素繊維の力ではなく、鋼がもともと持っている特性なんですね。つまり、構造物の弱いところをFRPで補うことで、鋼本来の性能を活かすことができるというわけです」

FRPの癖を知り、性能を引き出す

一方、歩道橋などの橋梁では、軽さの利点からすでにガラス繊維を使ったGFRP橋が登場しつつある。しかし、松本教授が「癖のある材料」というように、FRPの使い方には注意が必要だという。

「通常のFRPは繊維がほとんど縦方向（長手方向）に入っているのですが、そのまま繊維に垂直に穴をあけてボルトに引っ掛けると、その部分がトリガーになって、ずるっと抜けてしまうことがあるんですね。つまり、使い方を誤ると、FRPが備えるせっかくの強度が出なくなってしまうのが弱点です。そこで、われわれは繊維の向きを45度傾けて、強度を高める方法を提案しました」

ただし、すべての箇所に特殊なFRPを使おうとすると生産性が落ちてしまったり、材料単価が跳ね上がってしまったりしてしまう。そこで、ボルトのまわりにだけ斜めに繊維が入った材料を貼り付けることで、十分に性能を引き出す方法を編み出した。

「6 mm厚の通常のFRPの両側に0.5 mm厚の繊維が斜めに入るFRPを貼り付けるだけで、耐力は倍以上になります。しかも、想定外の力がかかって壊れたとしても、一気に耐力を失うことはなく、斜めの繊維が引っ掛ってバラバラになったりしない。腐食が心配な海辺の歩道橋や、重機による仮設が困難な場所での橋梁、災害時などに一時的に設置される仮設橋など、軽さと強さを活かして適材適所にFRPを使っていくことができると思います」

接着剤を使わない簡便な方法を開発

もう一つ、FRPの弱点と言えるのが、FRPで補強を行う際に、繊維を接着剤で貼り付けるのだが、接着剤自体が剥がれてしまうと、性能が出なくなってしまうことだ。松本教授は、接着の剥離の兆候を光ファイバセンサでセンシングする方法も手がけるが、そもそも接着剤を使わなければ、剥がれる心配をしなくてもいいことに気づいたという。そこで現在、松本教授は接着剤を使用せずに、材料の性能を最大限に引き出す方法を追究している。

「1970年の大阪万博のお祭り広場に採用された鉄骨立体トラス構造（スペースフレーム）のように、棒状の鉄材を骨組みにした屋根がありますが、設計で想定した以上の力が加わることで、折れてしまうことがあるんですね。その補強として、鉄材の中央部分にCFRPを巻きつけるだけ、というきわめて簡便な方法を開発しました」

作業はじつに簡単で、鋼材の形状に合わせてCFRPをギブスのようにはめるだけ。そのうえで、鋼材の耐力を20～30%アップさせることに成功したという。CFRPが軽いため、重さの増加は数%程度なので、補強による構造への影響も非常に少ない。

「柱を押しつぶすような力が働いても、CFRPで補強した箇所は変形しないので、補強していない部分が変形するにとどまるんですね。半円のパイプ状のCFRPをかぶせるだけなので、屋根の上などの作業も簡単です。CFRPは材料費の高さがネックですが、軽い部材なのでクレーンを使ったり足場を組んだりする必要もなく、作業に高度なテクニックもいらないため、総合的に見れば、他の補強方法よりも効率的かつ経済的と言えます。しかも、炭素繊維メーカーの御三家と言うように、CFRPは日本のメーカーが大きなシェアを占めていて、我が国の材料技術と融合した建設技術というのもメリットと言えるのではないでしょうか」

地震災害の多い日本において、旧耐震の工場や建物の耐震補強は喫緊の課題だ。松本教授らが開発した、FRPによる簡便な耐震補強の普及に期待したい。

（取材・文＝田井中 麻都佳）

取材後記

幼い頃から庭遊びが好きで、手を動かしながら庭木や土を使っていろいろな物をつくっていたと松本教授。将来は構造物をつくる仕事をしたいと、米子高専の建築学科を経て、豊橋技術科学大学へ進学した。

「東海地方は車産業が盛んなせいか、大学ではFRPに触れる機会が多く、気がつけばFRPの専門家になっていました」。もっとも順風満帆ではなかったという、意外な言葉が。「実験で失敗するのはしょっちゅうですし、特に大きな壁にぶち当たったのがFRPの接着問題です」と松本教授。学生と議論しながらさまざまな方法を試し、苦労の末に接着剤に頼らない方法にたどり着いた。失敗は成功のもとと言うけれど、諦めることなく手を動かし続けてきたからこそ、つかむことができた成果にちがいない。

Researcher Profile

Yukihiro Matsumoto

Yukihiro Matsumoto received PhD degree in 2007 from Toyohashi University of Technology, Aichi, Japan. He started his career at National Institute of Technology (KOSEN), Yonago College as an assistant. Since he started his career at Toyohashi University of Technology as an assistant professor in 2009, had been involved in structural engineering including FRP materials for building and civil structures. He is currently a professor at Institute for Research on Next-generation Semiconductor and Sensing Science (IRES^2).

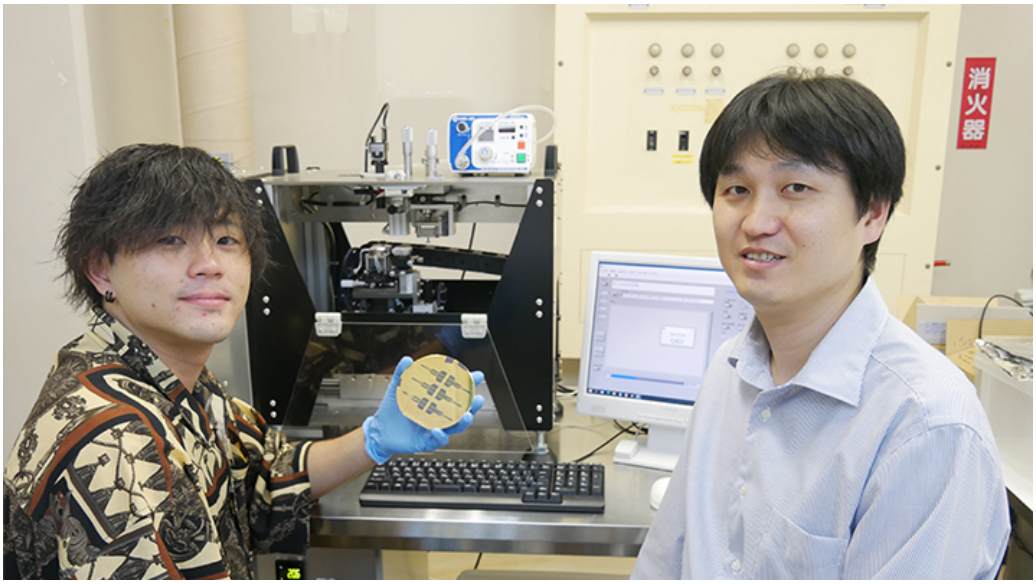
Reporter Profile

Madoka Tainaka
Editor and writer. Former committee member on the Ministry of Education, Culture, Sports, Science and Technology Council for Science and Technology, Information Science Technology Committee and editor at NII Today, a publication from the National Institute of Informatics. She interviews researchers at universities and businesses, produces content for executives, and also plans, edits, and writes books.

Multisensory information detection using multi-channel electrocorticography film that can be placed over a wide area of the cerebral cortex

Development of electrocorticography device for simultaneous detection of multi-modality information in the mouse brain

Hiroto Sekiguchi



Prof. Hiroto Sekiguchi (Right) and Ryota Kanda (Left)

A research group led by Associate Professor Hiroto Sekiguchi from Toyohashi University's Department of Electrical and Electronic Information Engineering, along with Assistant Professor Susumu Setogawa and Associate Professor Noriaki Ohkawa from Dokkyo Medical University's Comprehensive Research Facilities for Advanced Medical Science (Associate Professor Setogawa is currently a Specially Appointed Assistant Professor at Osaka Metropolitan University), have developed a flexible electrocorticography (ECoG) (Note1) film for simultaneous detection of multisensory information (Note2) from multiple regions of the cerebral cortex by placing neural electrodes over a wide area of a mouse brain surface.

Researchers believe that the human brain achieves cognitive functions such as attention, learning, and memory through the simultaneous processing and integration of various sensory information across multiple regions of the cortex. In order to understand the neural information processing mechanisms underlying these cognitive functions, researchers required a device capable of simultaneously recording neural activity from a wide area of the cerebral cortex in rodents such as mice and rats, including the temporal region responsible for processing diverse sensory information. However, the device itself was difficult to install in the temporal region of rodents because it is obstructed by the skull and surrounding temporal muscles.

Therefore, in order to successfully position an ECoG recording device in the temporal and deep regions of the cerebral cortex of mice, it was crucial to develop a device and establish a technique which allows recording electrodes to be placed in the narrow gap between the skull and the surface of the cerebral cortex. Our research group achieved two significant advancements: (1) Development of a cortical ECoG device composed of an appropriate film capable of both the flexibility and rigidity to adhere to the brain. (2) Establishment of a surgical technique for effectively attaching the device to the temporal region of the brain. This measurement technique using a new ECoG measurement device has achieved a wider range of neural activity measurement than existing measurement techniques, and is expected to lead to the development of large-scale ECoG research to clarify the mechanisms of interaction between brain regions in the future.

The results of this research were published online in the scientific journal *Molecular Brain* on May 3, 2023. This research was supported by the Japan Science and Technology Agency (JST) Strategic Basic Research Promotion Project PRESTO (JPMJPR1885), the Casio Science Promotion Foundation, the Toyoaki Scholarship Foundation, the Foundation of Public Interest of Tatematsu, the Research Foundation for Opto-Science and Technology, the Takeda Science Foundation, the Naito Foundation, the Astellas Foundation for Research on Metabolic Disorders, and the Tochigi Industrial Promotion Center (the Grant-in-Aid for World-Class Technological Research and Development).

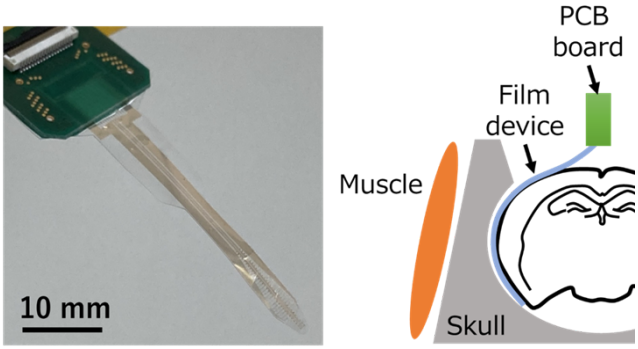
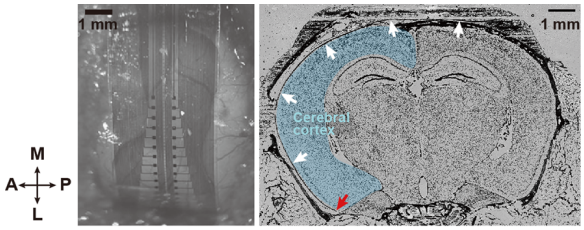


Photo of the developed multichannel electrocorticography device (left). Schematic diagram of the electrocorticography method for a wide area of the brain using the developed device (right).

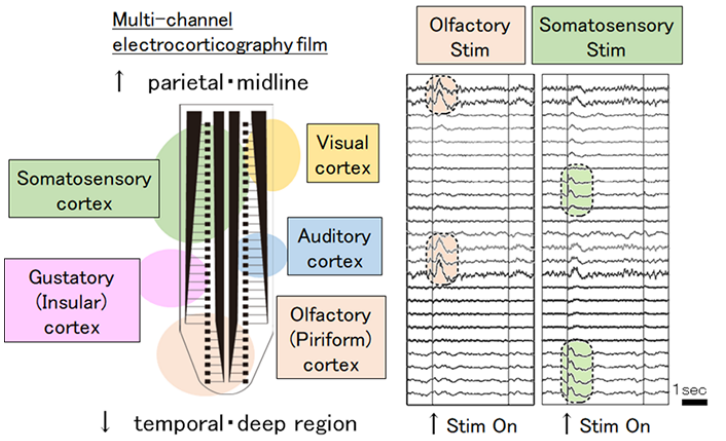
The total number of patients related to mental disorders such as dementia, schizophrenia, and developmental disorders is on the rise. One contributing factor to these diseases is impaired cognitive function due to the failure of information integration systems in the brain. However, the precise mechanisms by which the brain integrates diverse sensory information obtained from various environments are still not fully understood. In order to deepen our understanding of these information integration systems, it is necessary to develop biometric techniques to simultaneously monitor the activities of multiple brain regions governing diverse sensory information that are distributed across the cerebral cortex. To understand the mechanisms of the neural circuits of cognitive functions, neuroscience research has been conducted in rodents such as mice and rats, where state-of-the-art tools can be applied, and large-scale measurement techniques covering the parietal and temporal regions of the rodent cerebral cortex have been sought. However, the conventional microscope-based large-scale calcium imaging (Note3) and electrophysiological techniques (Note4) for measurement of brain activity in rodents have been limited to the parietal area of the rodent head due to the hindrance caused by the thick skull and surrounding temporal muscles. Therefore,there has been a need to develop a new device that can simultaneously detect multisensory information over a wide area of the cerebral cortex, including the temporal region, and to develop a technology to install such a device.

The research group aimed to realize a multi-channel ECoG measurement device that could be placed over a wide area of the brain, and conceived the idea of inserting the device into the narrow gap between the mouse skull and the dura mater. In order to insert the device into the narrow site and place it on the brain surface, it was necessary to maintain both flexible and rigid properties that would allow it to adhere closely to the brain. The research group successfully addressed this challenge by selecting the appropriate width and thickness of parylene film (Note5), which serves as the base of the device, and by establishing a surgical technique for placing the film in the temporal region. As a result, the research group was able to successfully position multi-channel electrodes across a wide area extending from the somatosensory cortex to the deepest part of the cerebral cortex, known as the olfactory cortex. Furthermore, by using an ECoG device equipped with 64-channel recording electrodes, the group successfully obtained ECoG measurement from a wide area of the cerebral cortex of awake and anesthetized mice. The research group also confirmed that the developed device, along with its placement technique, can detect neural responses evoked by both somatosensory and olfactory stimuli in the same mouse, thereby enabling simultaneous detection of widely distributed multisensory information in the brain.



Placement of the developed electrocorticography device on the mouse brain surface.
Left: Photo of the electrode array placed from the parietal region to the temporal region (device inserted into an even deeper region of the cortex).
Right: Photo of the device placed on the brain and brain surface (white arrow = device, red arrow = device tip).

The multi-channel ECoG device technology developed in this study, which can be applied to a wide area of the mouse brain, is a new measurement technology that expands the scope of ECoG recording in the cerebral cortex of rodents. Until now, ECoG measurement from the cortical surface of the temporal region was only possible with humans and monkeys. However, this innovative technology will enable electrocorticogram measurement even in mice across a wide range from the parietal region to the temporal region. There are a variety of animal models of pathological conditions in rodents that have been created using genetic engineering technology, and the newly developed measurement technology will make it possible to compare human cases with the results of research on animal models. Further understanding of the mechanisms of the brain system that integrates diverse information in rodents is expected to lead to the elucidation of pathological mechanisms of human neurological and psychiatric diseases and the development of new therapeutic techniques.



Detection of multisensory information from the same mouse using the developed electrocorticography device.

Explanation of Terms

Note1: Electrocorticography

A method of measuring neural activity in which part of the skull is surgically removed and a sheet with multiple electrodes is placed on the surface of the brain in order to electrically measure the activity of the cerebral cortex.

Note 2: Multisensory information

Refers to multiple senses such as somatosensory (touch), visual, olfactory, auditory, and gustatory. The human brain perceives phenomena by combining these multiple senses.

Note 3: Calcium imaging (method)

A method of obtaining spatiotemporal information of neural activity as image data by converting neural cell activity into fluorescence using dyes and proteins that emit fluorescence when bound to calcium ions.

Note 4: Electrophysiological technique

A method of recording electrical information (potential/current) of cells by placing glass or metal electrodes on neural cells. Examples include electroencephalograms, electrocardiograms, and electromyograms.

Note 5: Parylene film

A general term for paraxylylene-based polymers. Known as a biocompatible material. An extremely thin film can be formed using vapor deposition. Parylene film can be used as a coating material for biomedical devices such as pacemakers.

Reference

Susumu Setogawa, Ryota Kanda, Shuto Tada, Takuya Hikima, Yoshito Saitoh, Mikiko Ishikawa, Satoshi Nakada, Fumiko Seki, Keigo Hikishima, Hideyuki Matsumoto, Kenji Mizuseki, Osamu Fukayama, Makoto Osanai, Hiroto Sekiguchi, Noriaki Ohkawa, "A novel micro-ECoG recording method for recording multisensory neural activity from the parietal to temporal cortices in mice", *Molecular Brain*, 16, Article number:38(2023).
https://doi.org/10.1186/s13041-023-01019-9

脳広域に設置可能な多点脳波計測フィルムで多感覚情報を検出

マウス脳のマルチモダリティ情報を同時検出できる皮質脳波計測デバイスを開発

関口 寛人

豊橋技術科学大学 電気・電子情報工学系 関口寛人准教授と獨協医科大学 先端医科学統合研究施設 瀬戸川将助教（現・大阪公立大学 特任助教）、大川宜昭准教授らは、マウスの脳表面の広範囲に神経電極を配置し、大脳皮質広域の複数の領域から多感覚情報（注1）を同時検出できるフレキシブルな皮質脳波計測（注2）フィルムを開発しました。

我々の脳では、複数の大脳皮質の領域が多様な感覚情報を同時に処理して統合することによって、注意、学習、記憶等の認知機能を達成していると考えられています。このような認知機能の神経情報処理の仕組みの理解に向けて、マウスやラット等のげっ歯類を対象とした多様な感覚情報を司る側頭部を含む脳の広範囲から脳波を同時検出できるデバイスが求められていました。しかし、げっ歯類の側頭部は頭蓋骨とその周囲の側頭筋に妨げられるため、デバイスを設置すること自体が困難でした。

マウスの大脳皮質側頭部・深部へ脳波記録デバイスの設置を実現するためには、頭蓋骨と大脳皮質表面の狭い隙間に記録電極を設置できるデバイス開発と手技の確立が必要でした。今回、本研究グループは、（1）脳に密着できる柔軟性と剛性の両方の性質を維持する適切なフィルムでできた皮質脳波計測デバイスの開発と、（2）脳側頭部へとデバイスを挿入する手術手技の確立によって、体性感覚と嗅覚への刺激によって誘発される大脳皮質の脳活動の検出に成功しました。新たな皮質脳波計測デバイスを用いたこの計測手法は、既存の計測技術よりも広範囲の神経活動計測を実現したことから、今後、脳領域間の相互作用のメカニズムを明らかにする大規模な皮質脳波研究の発展が期待されます。

本研究成果は、2023年5月3日に科学誌「Molecular Brain」にオンライン掲載されました。また、本研究は、科学技術振興機構（JST）戦略的創造研究推進事業 さきがけ「生命機能メカニズム解明のための光操作技術」研究領域 研究課題名「生体光刺激のための侵襲型LEDデバイスの革新」（JPMJPR1885）、カシオ科学振興財団、豊秋奨学会、立松財団、光科学技術研究振興財団、武田科学振興財団、内藤記念科学振興財団、アステラス病態代謝研究会、栃木県産業振興センター「世界一を目指す研究開発助成事業」からの支援により行われました。

日本では、認知症や統合失調症、発達障害等の精神疾患に関する総患者数は増加傾向にあります。これらの疾患の要因の1つとして、脳内での情報統合システムの障害による認知機能の破綻が挙げられていますが、ヒトや動物が多様な環境から多様な感覚情報を知覚したあと、脳内でどのように情報の統合がなされるのか、その仕組みは十分には明らかになっていません。脳がこれらの情報を統合するシステムの理解を深めるには、大脳皮質に広がって分布する多様な感覚情報を司る複数の領野の活動を同時に捉えるための生体計測技術の開発が必要です。このような認知機能の神経回路の仕組みの理解に向けて、最先端ツールが適用可能なマウスやラット等のげっ歯類を対象とした神経科学研究が進められており、げっ歯類の大脳皮質の頭頂部から側頭部をカバーする大規模な計測技術が求められていました。しかし、げっ歯類での従来の顕微鏡を用いた大規模なカルシウムイメージング（注3）や電気生理学的手法（注4）による脳波計測手法は、厚い頭蓋骨とその周囲を取り囲む側頭筋が邪魔となり、計測範囲が頭頂部に限定されていました。そのため、側頭部を含む大脳皮質の広範囲の多感覚情報を同時検出できる新たなデバイスの開発とその設置技術が求められていました。

本研究グループは、脳広範囲に設置可能な多点の皮質脳波計測デバイスの実現を目指し、マウスの頭蓋骨と硬膜の狭い隙間に滑らせて挿入することで、脳波計測デバイスを大脳皮質上に設置することを発案しました。デバイスを狭い部位へと挿入して脳表に設置するためには、脳に密着できる柔軟性と剛性の両方の性質を維持する必要がありました。目的の条件を満たすように、デバイスの基盤となるパリレンフィルム（注5）の幅と厚さを適切に選び、側頭部へと設置するための手術手技を確立することで、体性感覚野から大脳皮質の最も深部に位置する嗅覚野までの広範囲に多点電極を設置することに成功しました。また、64チャネルの記録電極を搭載した皮質脳波計測デバイスを用いて、覚醒下及び麻酔下におけるマウスの大脳皮質広域からの脳波計測を実現しました。さらに、開発した本デバイスとその設置手技によって、同一のマウスの体性感覚と嗅覚の刺激によって誘発される神経応答を検出できることを確認し、脳の広範囲に分布する多感覚情報を同時検出できることを実証しました。

本研究で開発されたマウスの脳の広範囲に適用可能な多点皮質脳波計測デバイス技術は、げっ歯類の大脳皮質における脳波計測領域をこれまでより拡大する新たな計測技術です。これまで側頭部の皮質表面からの脳波計測はヒトやサルに限定されていましたが、今回の技術によってマウスでも頭頂部から側頭部までの広範囲から脳波計測が可能になります。げっ歯類には遺伝子工学技術によって作出された多様な病態モデル動物が存在しており、今回開発した計測技術を活用することで、ヒトの症例と病態モデル動物の研究結果とを照らし合わせることが可能になります。今後、げっ歯類において多様な情報を統合する脳内システムの仕組みの理解が進めば、ヒトの神経疾患や精神疾患などの病態メカニズムの解明や、新たな治療技術の開発につながることが期待されます。

用語解説

注1：多感覚情報
体性感覚（触覚）、視覚、嗅覚、聴覚、味覚といった複数の感覚のことである。これらの複数の感覚を脳内で組み合わせることで様々なものを認知することができる。

注2：皮質脳波計測
脳活動計測の手法の1つで、外科的処置によって頭蓋骨を外し、脳表に複数の電極が並べられたシートを配置することにより大脳皮質の活動を電気的に計測する手法である。

注3：カルシウムイメージング（法）
カルシウムイオンと結合して蛍光を発する色素やタンパク質を用いて神経細胞の活動を蛍光に変換することで、画像情報として神経活動の時空間的情報を得る手法である。

注4：電気生理学的手法
ガラス電極や金属電極を神経細胞に設置することで、細胞の電気的情報(電位・電流)を記録する手法のことである。一例として、脳波計測や心電図、筋電図などがある。

注5：パリレンフィルム
パラキシリレン系ポリマーの総称であり、生体適合性材料として知られる。蒸着法により成膜することで極薄のフィルムを形成することができる。ペースメーカーを始めとする生体医療機器のコーティング材料として活用されている。

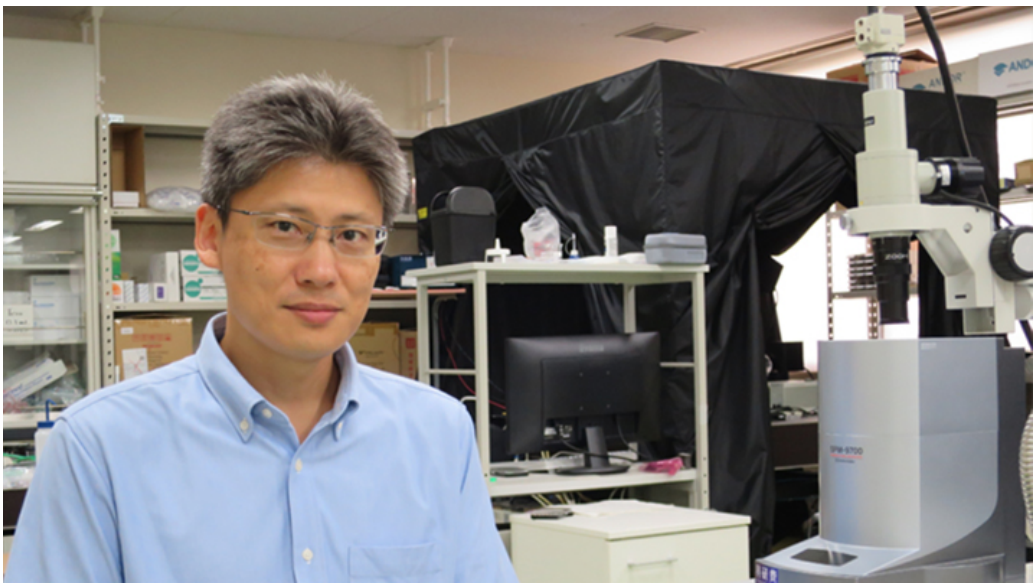
Researcher Profile

Name	Hiroto Sekiguchi
Affiliation	Department of Electrical and Electronic Information Engineering
Title	Associate Professor
Fields of Research	Light-Emitting Device / Semiconductor Engineering

Concentration of cell membrane components with nanocarbon materials

Localization of lipid bilayer domain on graphene oxide

Ryugo Tero



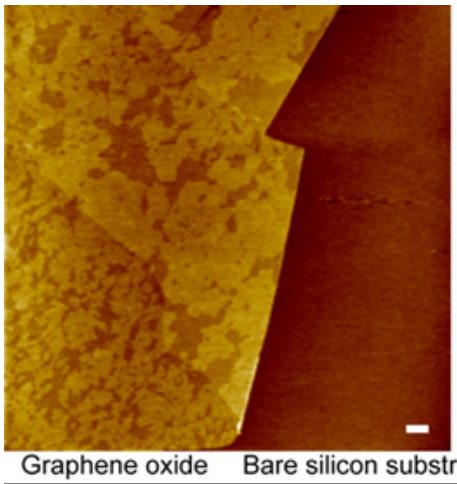
A research team from the Department of Applied Chemistry and Life Science at Toyohashi University of Technology (Professor Ryugo Tero et al.) discovered a phenomenon in which specific lipids are concentrated on graphene oxide in multi-component lipid bilayers, a model for cell membranes. They also clarified the mechanism by which the components of "lipid rafts" (where important cell membrane reactions such as neurotransmission and metabolism occur) gather, owing to the surface characteristics of graphene oxide. This is expected to be useful as a fundamental technology for the concentration and separation of lipids and membrane proteins in cell membranes, which are important research targets in the fields of medicine and drug discovery.

All the transportation of substances, information, and energy inside and outside the cell that is necessary for vital activities is carried out through the cell membrane. These transportations are deeply involved in neurotransmission, metabolism, and viral infections, making them important research targets in the biology, medicine, and drug-discovery fields. The basic structure of the cell membrane is a lipid bilayer, in which specific lipids and membrane proteins are assembled through diffusion and aggregation of molecules within the membrane to control and improve the efficiency of reactions occurring in the cell membrane. Such regions are called lipid domains, a typical example of which is "lipid raft", which is rich in sphingolipids and cholesterol. New technologies for controlling and arranging the positions of lipid domains on a solid substrate are demanded for the biosensing and screening of lipids and membrane proteins.

This research team fabricated an artificial lipid bilayer on a graphene oxide monolayer deposited on a silicon substrate. They discovered for the first time that the lipid domains are concentrated on graphene oxide. Graphene oxide has a structure in which hydrophilic oxygen functional groups are added to graphene (a monoatomic sheet material of carbon).

In a two-component lipid bilayer consisting of two types of phosphatidylcholines with different fluidities, the majority of the low-fluidity gel phase domains in the lipid bilayer membrane gathered on the graphene oxide. In a three-component mixed lipid bilayer membrane of sphingolipids, cholesterols, and phosphatidylcholine, many lipid raft components were present on the graphene oxide.

Professor Ryugo Tero, the leader of the research team, explained as follows: "Regardless of the lipid composition, the less fluid lipid domains clustered on the graphene oxide. This is due to the presence of a mixture of hydrophilic and hydrophobic regions on the graphene oxide surface on a nanometer scale. The initial process of the domain formation in the lipid bilayer occurred preferentially in the hydrophobic regions of the graphene oxide."



Localization of lipid domains on graphene oxide. Atomic force microscope image of the two-component lipid bilayer formed on the graphene oxide deposited on a silicon substrate. Gel phase domains are concentrated on the graphene oxide (left) and are not observed on the silicon substrate (right). Scalebar: 500 nm.

By controlling the position of lipid domains on a solid substrate, membrane proteins with high affinity to the lipids can be placed in the same location, which is expected to be useful as an elemental technology for biosensors and screening technologies targeting membrane proteins. Furthermore, the research team believes that the same method can be used to collect biochemically important lipid components such as glycolipids as well as the lipid raft. They expect that this will be useful in the development of techniques for concentrating and purifying the rare lipids and membrane proteins in cell membranes.

Reference

Ryugo Tero, Yoshi Hagiwara and Shun Saito (2023). Domain Localization by Graphene Oxide in Supported Lipid Bilayers, International Journal of *Molecular Sciences,* 24 (9), 7999.
https://doi.org/10.3390/ijms24097999

ナノカーボン材料で細胞膜の成分を濃縮する

脂質二重膜内ドメインの酸化グラフェン上への局在化

手老 龍吾

豊橋技術科学大学応用化学・生命工学系の研究チーム（手老龍吾教授ら）は、細胞膜モデルとなる多成分脂質二重膜内において、酸化グラフェン上に特定の脂質が濃縮される現象を見出しました。また、神経伝達や代謝などの重要な細胞膜反応がおきる場である「脂質ラフト」の成分が、酸化グラフェンの表面特性によって集められるメカニズムを明らかにしました。このことは、医療・創薬分野の研究対象として重要視される細胞膜内の脂質や膜タンパク質を濃縮・分離するための要素技術として役立つことが期待されます。

生命活動に必要な細胞内外での物質・情報・エネルギーのやり取りは全て、細胞膜を通して行われています。これらは神経伝達や代謝、またウイルス等の感染などに深く関わることから、生物学・医療・創薬分野での重要な研究対象です。細胞膜の基本構造は脂質二重膜であり、膜内での分子の拡散・凝集を通して特定の脂質や膜タンパク質が集まることで、細胞膜で起きる反応の制御や効率化がなされています。このような領域を脂質ドメインと呼び、その代表例がスフィンゴ脂質やコレステロールに富んだ「脂質ラフト」です。脂質や膜タンパク質を対象としたバイオセンシングやスクリーニングのためには、固体基板上に脂質ドメインの位置を制御して配置する技術が求められています。

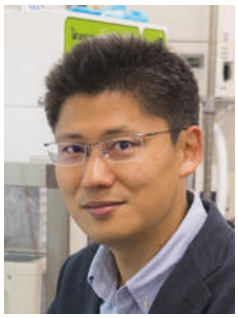
研究チームは、単層の酸化グラフェンを担持したシリコン基板上に人工脂質二重膜を作製することで、酸化グラフェン上に脂質ドメインが濃縮されることを初めて見出しました。酸化グラフェンは、炭素の単原子シート状材料であるグラフェンに親水的な酸素官能基が付加した構造を持ちます。

流動性の異なる2種類のフォスファチジルコリン(phosphatidylcholine)を混合した脂質二重膜では、流動性の低いゲル相のドメインの多くが酸化グラフェン上に集まりました。スフィンゴ脂質、コレステロール、フォスファチジルコリンの3成分混合脂質二重膜の場合には、「脂質ラフト」の成分が酸化グラフェン上に多く存在しました。

「脂質の組成にかかわらず、流動性の低い方の脂質ドメインが酸化グラフェン上に集まります。これは、酸化グラフェンの表面には親水性領域と疎水性領域がナノメートルスケールで混ざって存在していることが原因です。脂質二重膜内にドメインが作られる最初のプロセスが、疎水性領域で優先的に起きるのです。」と研究チームのリーダーである手老龍吾教授は説明します。

固体基板上で脂質ドメインの位置を制御することで、その脂質と親和性の高い膜タンパク質も同じ場所に配置することができ、膜タンパク質を対象としたバイオセンサやスクリーニング技術の要素技術として役立つことが期待されます。また、研究チームは、「脂質ラフト」の成分だけでなく、糖脂質など生化学的に重要な脂質のドメインも同じように捕集できると考えており、細胞膜内に含まれる希少な脂質や膜タンパク質を濃縮・精製する技術の開発にも役立つと期待しています。

Researcher Profile

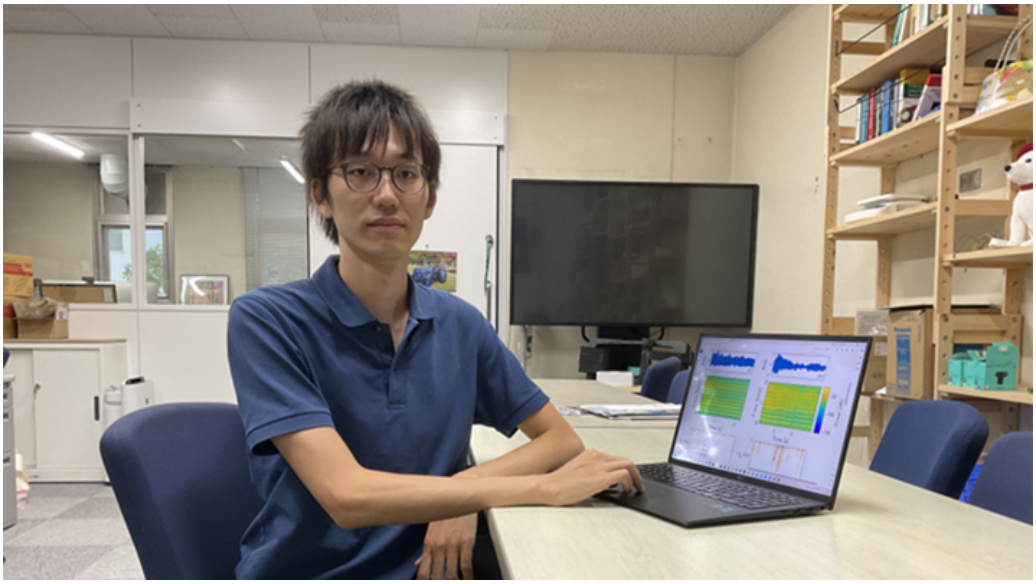


Name	Ryugo Tero
Affiliation	Department of Applied Chemistry and Life Science
Title	Professor
Fields of Research	Surface Physical Chemistry

Diagnosis of voice condition from call audio

Toward the development of a dysarthria diagnostic system in telemedicine

Yuya Hosoda



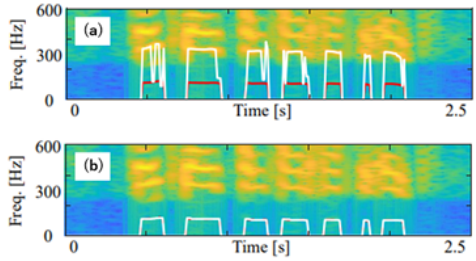
Assistant Professor Yuya Hosoda of the Center for IT-Based Education (CITE), Toyohashi University of Technology developed a method for estimating the pitch of vocal cord vibrations of humans from call audio. In this method, the pitch is estimated by integrating the feature quantities extracted from the amplitude and phase spectra of speech on the complex plane. Through experiments, we have demonstrated that the proposed method is not only efficient for calls where the frequency band is restricted by communication standards, but also works robustly in an environment with background noise.

Early diagnosis of dysarthria, which is an early symptom of neurodegenerative illnesses such as Parkinson's disease, can help to reduce the severity of such diseases. Dysarthria is characterized by tremors in the voice and disturbed breathing. Although clinical tests diagnose symptoms from the patient's voice, they are time consuming and labor intensive. Additionally, conducting face-to-face interviews in remote locations such as mountainous areas is difficult. Therefore, in this research, we aim to develop a system that automatically diagnoses dysarthria through telemedicine by performing ward rounds via communication devices.

In patients with dysarthria, abnormalities occur during vocalization wherein the voice is produced by vocal cord vibrations generated by air released from the lungs in the throat and oral cavity. In this study, our purpose is to estimate the vibration period (pitch) to diagnose the condition of these vocal cord vibrations. Prior to this new technique, pitch measurement methods that were robust against background noise were devised based on features related to the amplitude spectrum obtained by frequency analysis of speech. However, due to communication standards, call audio via telemedicine may lack some of the desired amplitude spectrum. Extracting feature quantities from an amplitude spectrum in such cases can lead to errors in pitch estimation.

In this research, we propose a method to extract additional feature quantities from the phase spectrum, a by-product of frequency analysis, in addition to the amplitude spectrum. Deriving a relational equation between the phase shift and pitch in the time and frequency directions, we have verified that pitch can be estimated by applying the observed phase shift to the relational equation. Based on this finding, we extracted new feature quantities from the phase spectrum to quantitatively evaluate the degree of fit to the relational equation. Finally, by integrating the feature quantities extracted from the amplitude spectrum on the complex plane, we compensated for the lack of feature quantities occurring in the pitch estimation of call audio while maintaining robustness against background noise.

The figure shows the pitch estimation results for a call audio. In previous studies that used only the amplitude spectrum, since the amount of information was reduced by band limitation, the pitch was estimated to be higher than the original value. However, in the proposed method, the pitch is accurately estimated from call audio using the feature quantities related to the amplitude and phase spectra. Further, the gross pitch error (GPE), an evaluation index that indicates the percentage of segments where errors occurred, improved to 9.5% in the proposed method, compared to 42.2% in the previous study. In addition, even for call audio with background noise, this method achieved a GPE of 15.2%, demonstrating robustness.



Pitch estimation results for call audio.
The red and white lines indicate the measured and estimated values, respectively.
(a) Prior studies (b) Proposed method

Although this study focused on pitch estimation to detect abnormalities in vocal cord vibrations, respiratory and oral abnormalities also cause dysarthria. To detect these symptoms, methods that extract feature quantities from the amplitude spectrum have been devised. However, the use of the phase spectrum has not been sufficiently validated. In the future, we will work on extracting relevant feature quantities from the phase spectra for the other cases as well. Further, by comprehensively analyzing these feature quantities, we aim to develop a dysarthria diagnostic system that can function effectively with telemedicine.

Reference

Yuya Hosoda, Arata Kawamura and Youji Iiguni, "Complex-Domain Pitch Estimation Algorithm for Narrowband Speech Signals," IEEE/ACM Transactions on Audio, Speech, and Language Processing, vol. 31, pp. 2067-2078, 2023.
https://doi.org/10.1109/TASLP.2023.3278488

通話音声から声の状態を診断

遠隔医療における構音障害診断システムの開発に向けて

細田 侑也

豊橋技術科学大学IT活用教育センターの細田侑也助教は、人間の発声メカニズムにおける声帯振動のピッチを通話音声から推定する手法を開発しました。本手法では、音声の振幅及び位相スペクトルから抽出された特徴量を複素平面上で統合してピッチを推定します。実験では、通信規格で周波数帯域が制限されている通話音声に対しても有効であるだけでなく、背景雑音が付加された環境でも提案法が頑健に機能することを示しました。

パーキンソン病などの神経変性疾患の重症化を防止するためには、初期症状である構音障害を早期に診断することが望ましいです。構音障害の特徴として、声の震えや呼気の乱れが挙げられます。臨床検査では患者の声から症状を診断しますが、時間や労力がかかるだけでなく、山間部などの遠隔地での対面実施は困難です。そこで本研究では、通信機器を介して回診する遠隔医療により、自動的に構音障害を診断するシステムの開発を目指します。

構音障害の患者には、肺から放出された空気で生じる声帯振動が喉や口腔で共鳴して声が生成されるという発声メカニズムに異常が生じています。本研究では、声帯振動に関する状態を診断するために振動周期（ピッチ）を推定することを目的とします。これまでに、音声の周波数解析で得られる振幅スペクトルに関する特徴量に基づいて、背景雑音に対しても頑健なピッチ計測手法が考案されています。しかし、遠隔医療における通話音声では、通信規格により振幅スペクトルが一部欠如しています。そのため、情報量が削減されている振幅スペクトルから特徴量を抽出すると、ピッチを誤って推定する恐れがあります。

本研究では、振幅スペクトルに加えて、周波数解析の副産物である位相スペクトルから追加で特徴量を抽出する手法を提案しました。まず、時間方向及び周波数方向における位相のズレとピッチの関係式を導出して、観測された位相のズレを関係式に当てはめることで、ピッチを推定できることを検証しました。この知見に基づいて、関係式への当てはまり具合を定量的に評価する特徴量を新たに位相スペクトルから抽出しました。最終的に、振幅スペクトルから抽出される特徴量と複素平面上で統合することで、背景雑音に対する頑健性を維持しつつ、通話音声のピッチ推定で生じる特徴量不足を補いました。

図は、通話音声に対するピッチ推定結果を表します。振幅スペクトルのみを使用する先行研究では、帯域制限で情報量が削減されているため、本来よりも高くピッチを推定しました。一方で提案法では、振幅及び位相スペクトルに関する特徴量を用いて通話音声から正確にピッチを推定しました。また、誤差が生じた区間の割合を表す評価指標 Gross Pitch Error (GPE)では、先行研究の42.2%に対して、提案法は9.5%まで改善しました。加えて、背景雑音が付加された通話音声に対しても15.2%を達成して頑健性を示しました。

本研究では、声帯振動の異常を検出するためにピッチ推定に着目しましたが、呼吸器や口腔の異常も構音障害を引き起こす要因です。これらの症状を検出するために、振幅スペクトルから特徴量を抽出する手法が考案されていますが、位相スペクトルに関しては十分に検証されていません。将来的には、他の症例に関しても位相スペクトルから関連する特徴量を抽出することに取り組みます。また、それらの特徴量を総合的に解析することで、遠隔医療において有効に機能する構音障害診断システムを開発します。

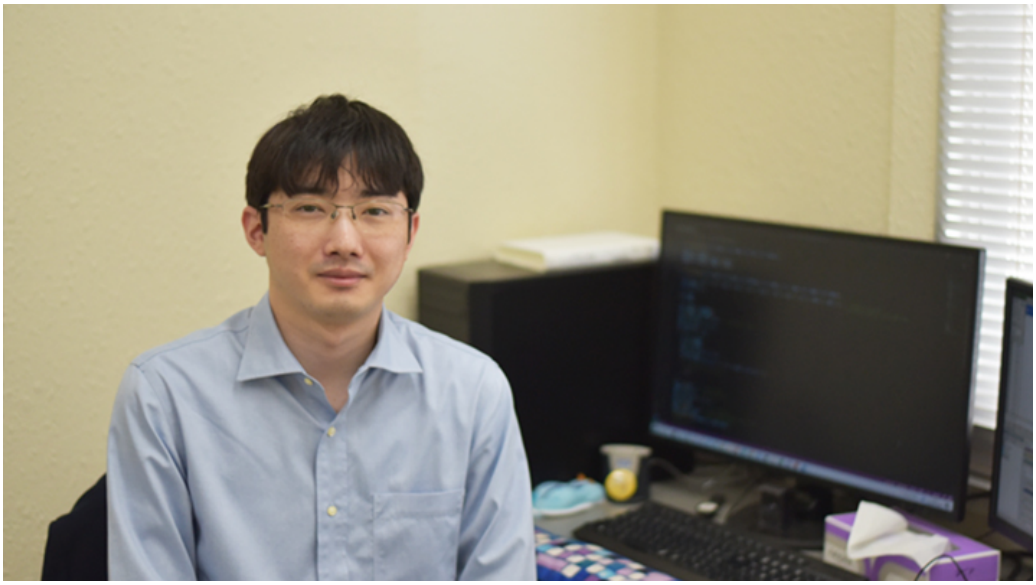
Researcher Profile

Name	Yuya Hosoda
Affiliation	Center for IT-Based Education (CITE)
Title	Assistant Professor
Fields of Research	Speech Signal Processing

Creation of training data to estimate the physical state of care robot users

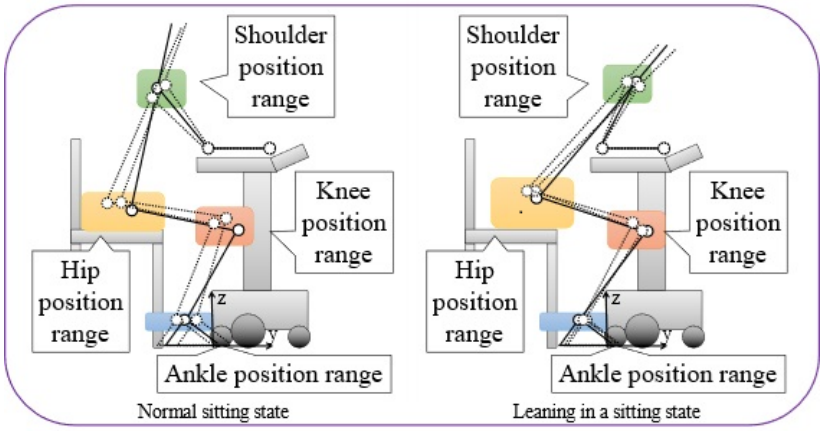
Creating training data from a human body link model without measurements

Mizuki Takeda



A research team led by Assistant Professor Mizuki Takeda from the Department of Mechanical Engineering, Toyohashi University of Technology, has developed a technique to generate training data for robots that operate based on estimations of the user's state using machine learning. Previously, research a method had been proposed to estimate the condition of robot users based on machine learning which used candidate points for the position of the center of gravity. However, for such learning, training data corresponding to when the robot is used to support movements are required. The above-mentioned research team developed a method of creating training data by using a human body link model without the need to analyze the movements.

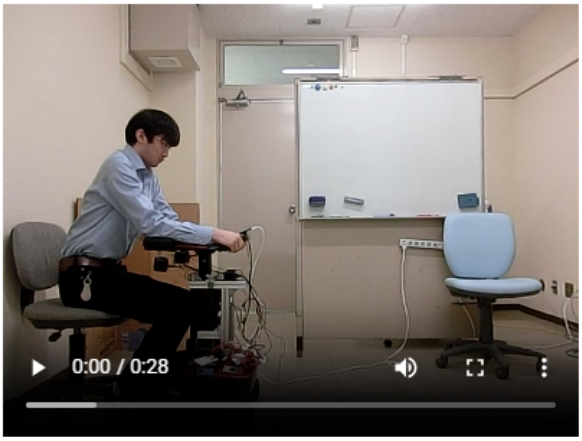
The development of robots supporting frequently performed tasks such as standing up and walking is progressing as elderly people with weakened muscles often require assistance in their daily lives. In order to reduce the burden on caregivers, robots must be able to automatically perform supportive actions. To achieve this, it is necessary to estimate the condition of the elderly person using the robot and provide assistance appropriate to that condition. Currently, the research team has proposed a method for calculating the candidate positions of the center of gravity of the robot user and estimating their physical state using machine learning. However, this method requires the acquisition of the user's movements during use of the robot as teacher data, and in particular, the measurement of data for abnormal conditions (such as when the user is about to fall over while walking) could be burdensome for the elderly.



Link model in each state.
The human posture in states such as sitting (left) and leaning forward in a sitting state (right) is represented by a link model, and candidate positions for center of gravity are calculated to create training data.

To solve this problem, the research team developed a method to generate candidate center-of-gravity teacher data without measuring movements by using a human body link model. The human body link model is a simple model representing the human body with rigid links and rotating joints. This model can be used to simulate human positions in various states such as sitting and standing, as well as abnormal states, and in this way generate training data. Experiments have confirmed that the care robots can learn based on the training data created by this method, estimate the user's state, and support standing up, walking, and sitting down actions.

The research team believes that the developed training data creation method based on the human body link model can be applied to care robots of various shapes and serving various purposes. Moreover, it can be applied to industrial and communication robots that rely on estimating the condition of humans and operating accordingly. In the future, we aim to realize a more secure and user-friendly system in which the robot not only operates based on the estimation, but also provides necessary information to the user so that the human and robot can communicate well with each other.



Abnormality detection and standing support.

Reference

Mizuki Takeda and Kaiji Sato (2023). Training Data Generation Using Human Link Model for State Estimation of Care Robot User. IEEE Access, vol. 11, pp.69310-69325.
https://doi.org/10.1109/ACCESS.2023.3292344

福祉ロボット使用者の状態推定のための教師データ作成

計測せずに人体リンクモデルから教師データを作成する

武田 洸晶

豊橋技術科学大学機械工学系の研究チーム（武田洸晶助教ら）は、機械学習により、使用者の状態を推定して動作するロボットのための教師データの作成手法を開発しました。これまでに、重心位置の候補点を用いて機械学習によりロボット使用者の状態を推定する手法を提案してきましたが、その学習には、ロボットを用いて動作を行った際のデータが教師データとして必要でした。今回の研究では、人体リンクモデルを利用することで、動作の計測を行わずに教師データを作成する手法を実現しました。

筋力の衰えた高齢者に向けた日常生活の支援が望まれており、特に頻繁に行う起立や歩行などを支援するロボットの開発が進んでいます。介護士の負担を減らすためにも、ロボットは自動で支援動作を行うことが求められ、そのためには、ロボットを使用する高齢者の状態を推定して、その状態に適した支援を行う必要があります。研究チームはこれまでに、ロボット使用者の重心位置の候補を計算し、機械学習により状態を推定する手法を提案してきました。しかし、この手法では、ロボットを使用している際の使用者の動作を教師データとして取得する必要があり、特に異常状態（歩行中に使用者が転倒しそうな状態など）のデータの計測は高齢者の負担になる可能性がありました。

そこで研究チームは、人体リンクモデルを用いることで、動作を計測せずに重心候補の教師データを作成する手法を開発しました。人体リンクモデルは、剛体リンクと回転関節により人体を簡易的に表したモデルです。そのモデルを利用して座位や立位、異常状態などの各状態における人間の姿勢をシミュレートし、教師データを作成することができます。この手法で作成した教師データを学習し、実際に福祉ロボットで使用者の状態を推定して起立・歩行・着座を支援できることを実験で確認しました。

研究チームは、人体リンクモデルを用いた教師データ作成手法は様々な形状・用途の福祉ロボットに適用可能であると考えています。また、福祉ロボットだけでなく、人間の状態を推定して動作する必要がある産業用ロボットや、コミュニケーション・ロボットへの応用も期待されます。今後は、推定に基づいてロボットが動作するというだけでなく、ロボットから使用者に必要な情報を提示して、人間とロボットがうまくコミュニケーションを取ることで、より安心できて使いやすいシステムを実現することを目指しています。

Researcher Profile

Name	Mizuki Takeda
Affiliation	Department of Mechanical Engineering
Title	Assistant Professor
Fields of Research	Robotics / Human-Robot Interaction / Care Robot / Robot Ethics

Pick Up

The Robot Contest Club "TOYOHASHI☆ROBOCONS" wins ABU Robocon 2023 Championship!

Members of TOYOHASHI☆ROBOCONS in Phnom Penh, Cambodia.

On Sunday August 27th, the ABU Asia-Pacific Robot Contest (ABU Robocon) 2023 was held in Phnom Penh, Cambodia. Toyohashi University of Technology's Robot Contest Club, TOYOHASHI☆ROBOCONS, represented Japan in the contest, and came home with the championship title.

The 2023 competition featured a "ring toss game" with the theme of offering flowers to Angkor Wat, which is a UNESCO World Heritage Site in Cambodia. For their entry, TOYOHASHI☆ROBOCONS created two robots (a rabbit and an elephant), which worked together to toss rings onto a set of poles.

Our university emerged the winner across all the games conducted, and achieved "Chey-Yo" (Victory), which signifies the state of winning points on all of the eight poles that were set up. This makes it the third time that a Japanese representative has won this world championship, while being the first victory for our university. The team also received the ABU Robocon Award, given to the most outstanding robot in the contest.

We would like to thank all those who have supported our team.

ロボコン同好会「とよはし☆ロボコンズ」がABUロボコン2023で優勝しました！

本学ロボコン同好会「とよはし☆ロボコンズ」が、8月27日（日）カンボジア・プノンペンで開催された「ABUアジア・太平洋ロボットコンテスト（ABUロボコン）2023」に日本代表として出場し、優勝を果たしました。

2023年大会の競技はカンボジアの世界遺産、アンコールワットに花を手向けることをテーマとした「輪投げゲーム」で、うさぎロボットとぞうロボットの2台が協力してリングをポールに投げ入れます。

本学は全ての試合で、決められた8つのポールの得点を全て獲得した状態「チェイヨー」を達成して勝利し、日本代表としては通算3度目、本学としては初の世界大会優勝を果たしました。また、大会を通じて最も優れたロボットに贈られる「ABU Robocon Award」も受賞しました。

応援してくださった皆さまに感謝いたします。