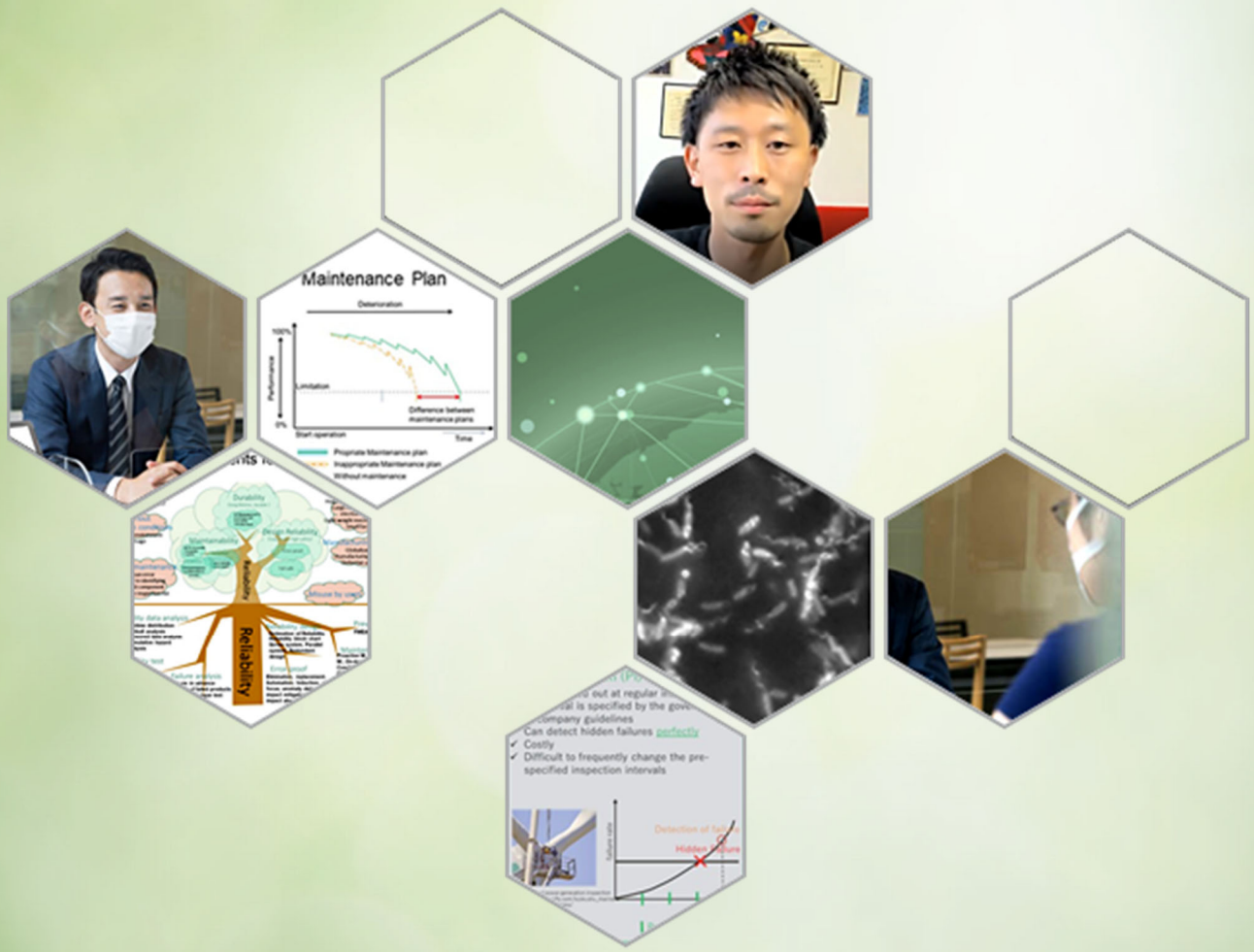
The University of Electro-Communications

UEC *e*-Bulletin

Updates on research, innovation, and events at UEC:
Unique and Exciting Campus in Tokyo

Vol.28, June 2021



The University of Electro-Communications 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585

The University of Electro-Communications
UEC e-Bulletin
Vol.28, June 2021

Research Highlights

Researcher Video Profiles

Topics

News and Events

The University of Electro-Communications 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585

UEC The University of Electro-Communications
UEC e-Bulletin Vol.28, June 2021

Efficient & reliable data processing for scalable Internet of Things: Innovative amplify-and-forward-based AirComp

One of the critical issues for the proliferation of Internet of Things (IoT) is the collection and computational analysis of wireless data from huge networks of smart sensors being implemented in applications that include smart transportation and cities. Recently, the technique of over-the-air computation (AirComp) has been proposed as an integrated approach for collection and processing of data from sensor networks transmitting Big-data simultaneously. Notably, although this method is efficient, it requires that all signals from nodes arrive simultaneously at the sink, aligned in signal magnitude so as to enable an unbiased estimation. However, for nodes far away from the sink with low channel gains, it is not possible to avoid misalignment in signal magnitude.

Now, Suhua Tang and colleagues at University of Electro-Communications, Tokyo, University of Science and Technology, China, and Xi'an Jiaotong University, China, describe their solution to the misalignment problem using the amplify-and-forward (AF) based relay mechanism.

In their paper, Tang and colleagues first present the general relay model for AirComp, and investigated the possibility of using a simple relay (SimRelay) approach in which a node either directly transmits its signal to a sink or via a relay node, but not both. They emphasize that, "relay transmission power increases with the number of nodes that use the relay node."

The researchers also proposed a coherent relay (CohRelay) approach, in which a node can divide its power to transmit its signal to both the relay and the sink, and the replicas of its signal are coherently combined together at the sink. They also discuss the tradeoff between computation error and transmission power.

The CohRelay approach greatly reduced the computation error, as well as reducing the relay transmission power and the overall transmission power, which is a major step forward towards the practical applications of AirComp.

Reference:

- Authors**:** (4) Suhua Tang, Huarui Yin, Chao Zhang, and Sadao Obana.
- Title of original paper: Reliable over-the-air computation by amplify-and-forward based relay.
- Journal, volume, pages and year: *IEEE Access*, vol. 9, pp. 53333-53342, Apr. 2021.
- Digital Object Identifier (DOI): 10.1109/ACCESS.2021.3070901
- Affiliations: Department of Computer and Network Engineering, Graduate School of Informatics and Engineering, The University of Electro-Communications.
- Department website: http://www.tang.cs.uec.ac.jp/index-e.html

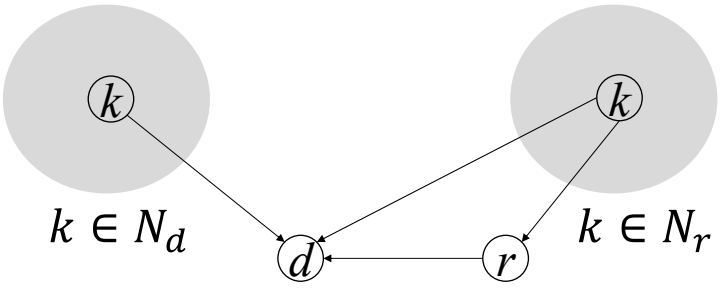


Figure caption: Relay for AirComp, an analogy to a conventional relay network.

The University of Electro-Communications
UEC e-Bulletin Vol.28, June 2021

Innovative building blocks for the quantum internet: All fiber platform for quantum photonic processing on tapered optical fibers

Research on quantum photonics is focused on the coherent control of individual quanta of light known as photons. Such control of light is an important step towards the realization of optical quantum networks and ultimately the so-called quantum internet.

Notably, single photons can be efficient carriers of quantum information, and they travel at the speed of light incurring the minimal of interaction with the medium through which they move. However, these same physical characteristics lead to difficulties in isolating (generation) and controlling (storage/retrieval/switching) single photons.

A solution to this problem is the development of means to control photons using atomic media. In this approach, one key requirement is to be able to confine atoms and photons to subwavelength dimensions, that is, within a single atom absorption cross-section to realize efficient light-matter interaction at the single quanta level. Therefore, there has been increasing interest in the strong confinement of photonic modes in nanophotonic waveguides and resonators that exhibit quantum electrodynamics (QED) effects.

Now, Kali Prasanna Nayak and colleagues at the University of Electro-Communications, Tokyo, are developing a unique all-fiber platform for quantum photonics applications using tapered subwavelength diameter waist optical nanofibers.

The key feature of the UEC optical nanofiber technology is that the optical field is tightly confined in the transverse direction while propagating over long distances as a guided mode and enabling strong interaction with the surrounding medium in the evanescent region. This characteristic has led to unique possibilities for manipulating single atoms (solid-state quantum emitters) and fiber-guided photons. Furthermore, implementing even moderate longitudinal confinement in nanofiber cavities has enabled the strong coupling regime of cavity QED where coherent light-matter interaction can be realized at the single quanta level.

Based on their achievements to-date, Nayak and colleagues are developing both quantum interfaces between trapped (laser-cooled) single atoms and fiber-guided photons using photonic crystal nanofiber cavities, and fiber-coupled quantum light sources using hybrid systems of single quantum dots deposited on nanofibers. These fiber-coupled quantum photonics platforms show promise as building blocks for optical quantum processors and can be easily integrated into optical quantum networks.

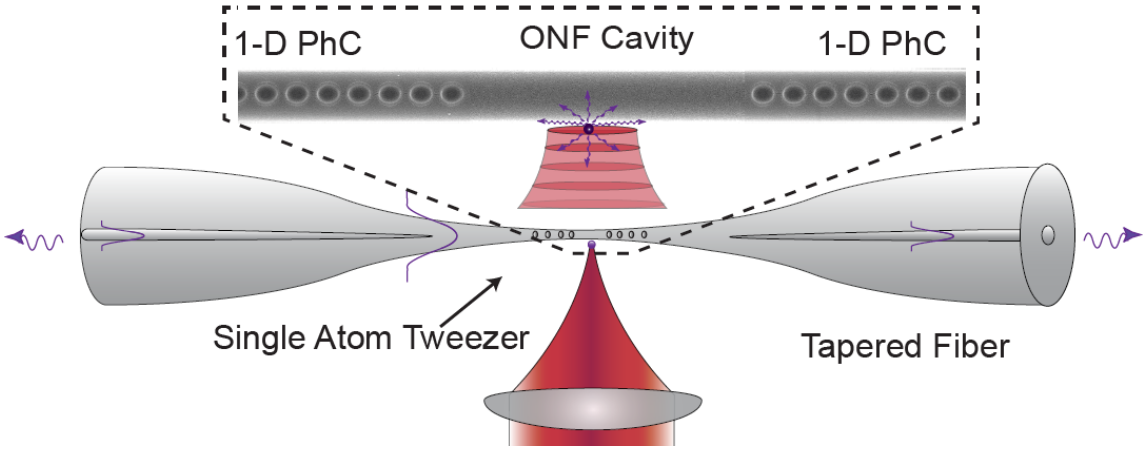


Figure caption: Schematic diagram of a nanofiber-based quantum interface. The nanofiber is located at the waist of a tapered single mode optical fiber. The nanofiber cavity (ONF Cavity) is formed by fabricating two photonic crystal (1-D PhC) Bragg mirrors on the nanofiber using femtosecond laser ablation. Single atoms are trapped and interfaced to the nanofiber cavity using a tightly focused optical dipole trap (single atom tweezer).

Reference:

- **Authors:** Kali P. Nayak, Mark Sadgrove, Ramachandrarao Yalla, Fam Le Kien and Kohzo Hakuta
- **Title of original paper:** Nanofiber quantum photonics
- **Journal, volume, pages and year:** *J. Opt.* **20,** 073001 (2018).
- **Digital Object Identifier (DOI):** 10.1088/2040-8986/aac35e
- **Affiliations:** Department of Engineering Science, University of Electro-Communications.

Department website: http://kjk.office.uec.ac.jp/Profiles/56/0005533/prof_e.html

UEC The University of Electro-Communications
UEC e-Bulletin Vol.28, June 2021

Bacteria in the spotlight: Bacterial community exhibits only counterclockwise movement

The collective motion of self-driven particles is a fascinating area of research in physics and biology. In the case of bacteria, macroscopic behavior emerges through the movement of millions of bacterial cells self-propelled by flagellar rotation.

Here, Daisuke Nakane and colleagues report on the observation of a new mode of collective motion in non-flagellated soil bacterium known as *Flavobacterium Johnsonian*.

The researchers discovered that when bacterial cells were spotted on an agar plate with a low level of nutrients, the bacterial community exhibited vortex patterns that spontaneously appeared as lattices and integrated into a large-scale circular plate.

Notably, the large-scale circular plate exhibited unidirectional rotation in a counterclockwise manner without exception.

Nakane and his colleagues postulate that “this behavior might be an efficient strategy for cells of this species to find nutrients.”

Reference:

- Authors**:** Daisuke Nakane[1], Shoko Odaka[2], Kana Suzuki[2], and Takayuki Nishizaka[2].
- Title of original paper: Large-scale vortices with dynamic rotation emerged from monolayer collective motion of gliding *Flavobacteria*
- Journal, volume, pages and year: *Journal of Bacteriology* **203**, e00073-21. (2021).
- Digital Object Identifier (DOI): 10.1128/JB.00073-21
- Affiliations: [1]Department of Engineering Science, The University of Electro-Communications, [2]Department of Physics, Gakushuin University
- Department website: https://nakane-lab.amebaownd.com/

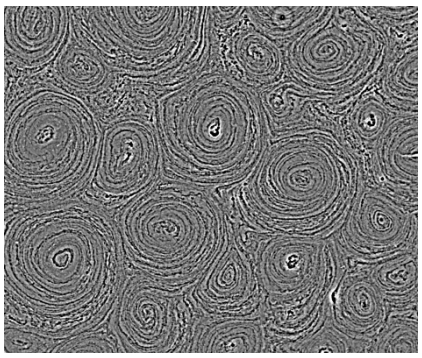
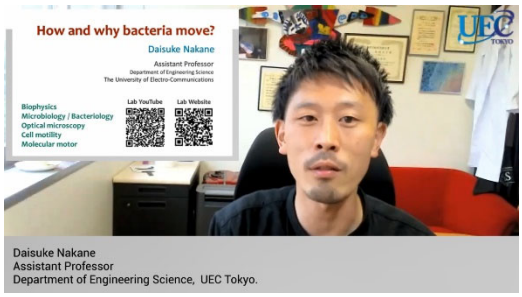


Figure caption: Vortex patterns of bacteria
https://www.youtube.com/watch?v=auhm-uGOPDA

The University of Electro-Communications
UEC e-Bulletin
Vol.28, June 2021

How and why do bacteria move?

Daisuke Nakane, Assistant Professor, Department of Engineering Science, UEC Tokyo.



Here, Daisuke Nakane describes his research interests and recent results on how and why bacteria move.

It is well known that bacteria are one of the simplest forms of life on Earth. They live everywhere, and have a great impact on our lives, including health, agriculture, and environment.

“Bacteria are too small to be seen directly,” says Nakane. “My research is focused on visualizing bacterial cells and their biological motion using optical microscopy to understand their behavior on a molecular level.”

The molecular systems of bacterial cell motility are completely different from that of humans because they are based on eukaryotic motor proteins such as myosin, kinesin, and dynein.

Some examples in the video show swimming motility driven by rotating flagellar filaments as propellers. This is one of the most famous and well-studied forms of molecular machinery. The flagellar filament is only 20 nm in diameter and rotates at 50 Hz in this species.

Nakane has visualized its rotation with high spatiotemporal resolution with optical microscopes. This had led to new scientific discoveries, such as the observation that some bacteria exhibit a new swimming style of flagella wrapping. When the flagellar filaments switch their rotation towards the other side, the cell wraps the filaments around their bodies and moves like a drilling tank.

More examples include a bacterial Spider-Man, caterpillars, helices and kinks, and walking bacteria with legs.

“Research on bacteria motility over the last 20 years has shown that they exhibit a surprisingly diverse range of movements,” explains Nakane. “This dynamic behavior was observed mainly under laboratory conditions. We do not actually know to what degree these movements contribute to their survival in real environments. I think that the next challenge is to answer the question as to why bacteria move.”

Nakane's recent work includes observations of the collective motion of bacteria. Experiments of bacterial surface movement in Petri dishes showed bacteria to move in striking patterns of vortices that rotate only in the counterclockwise direction. Given that this is triggered by starvation, the vortex pattern might be a new strategy by bacteria to find nutrients for their survival. Details about this research are given in the *Journal of Bacteriology [1].*

"You can even see microbes even in a Zoom meeting by using with a smart phone," demonstrates Nakane in the video using a small chamber containing thousands of microbes. "When I put a drop of water on the camera, it turns into a microscope, and enables us to visualize the individual cell behavior directly. My lab has is new being established in October 2020. I look forward to collaborating with researchers in many other fields. Let's enjoy science together."

Keywords of Daisuke Nakane's research are biophysics, microbiology, and optical microscopy.

Reference

[1] Daisuke Nakane, Shoko Odaka, Kana Suzuki, and Takayuki Nishizaka
Large-scale vortices with dynamic rotation emerged from monolayer collective motion of gliding *Flavobacteria*, *J. Bacteriol.* 203: e00073-21. (2021)

DOI: 10.1128/JB.00073-21
URL: https://journals.asm.org/doi/abs/10.1128/JB.00073-21

The University of Electro-Communications
UEC e-Bulletin Vol.28, June 2021

Insights into modern reliability engineering

Lu Jin, Associate Professor at the Department of Informatics, UEC Tokyo

“My research is based on reliability engineering,” says Lu Jin, an associate professor at the Department of Informatics, UEC Tokyo. “I am working on maintenance planning to study a wide range of systems for ensuring the safety and security of our society. The interest of my research is developing decision-making models for realizing more flexible and efficient maintenance plan while maintaining high reliability and safety.”

Jin is developing decision-making models for systems focused on optimizing problems for maintenance plans such as periodic maintenance and condition monitoring maintenance.

Specifically, Jin wants to reduce maintenance costs while maintaining reliability levels by dynamically adjusting and controlling maintenance plans based on monitoring information on operating systems. A maintenance plan that uses the Markov decision process as the core model, takes into consideration the effects of direct and indirect measurement of system deterioration, measurement accuracy, changes in the operating environment, and so on, and yields a trade-off between maintenance costs and failure losses.

Recent research results on maintenance decisions that take into account the uncertainty and changes in information being monitored.

- Effective utilization of maintenance opportunities with incomplete information

(Awarded prizes at the Japan Quality Control Society and ANQ2019 international conference. Scheduled to be published in TQS Journal)

- Economically optimal maintenance plan based on continuous deterioration process (maintenance planning)
  - Periodic inspection plan with variable cycles

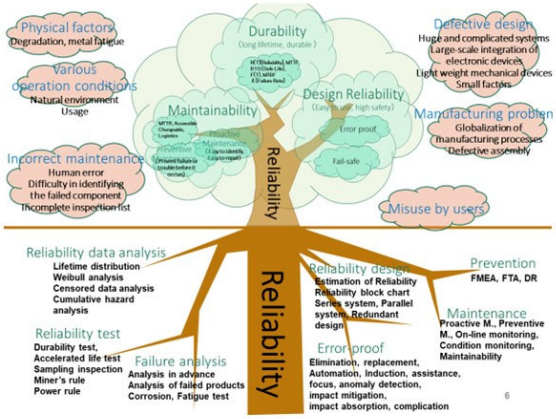
“I'm also working on joint research with colleagues at Mälardalens University in Sweden, on using existing maintenance optimization methods in other fields such as pricing options and examining investment strategies. This is an exciting area of research.”

References

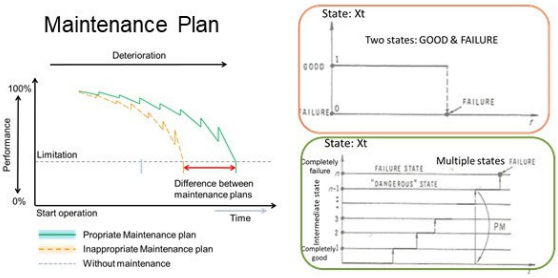
- Optimizing Opportunistic Maintenance by Using a Semi-Markov Decision Process, Odajima, Y. and Jin, L. Total Quality Science 2021 (In press)
- Optimal Policy for Periodic Inspections with Flexible Imperfect Inspection Frequencies, Jin, L., Koyama, N. and Yamamoto, W. Total Quality Science 4/ 3, 128-137, 2018.
- Approximate Log-Linear Cumulative Exposure Time Scale Model by Joint Moment Generating Function of Covariates, Yamamoto, W. and Jin, L. Frontiers in Statistical Quality Control 12, 327-339, 2018.

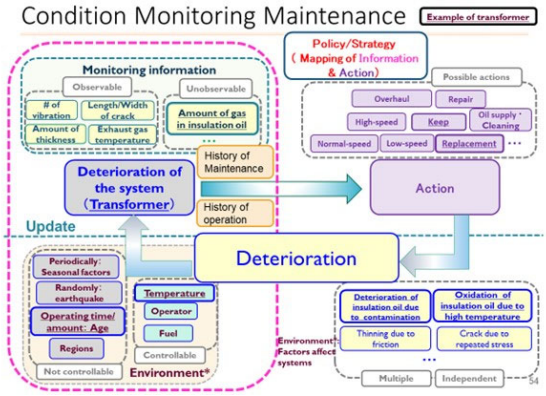
- Optimal Inspection Policy for Scheduled Maintenance of Aging Systems, Jin, L. and Yamamoto, W. International Journal of Industrial Engineering: Theory, Applications and Practice 24/ 4, 99-111, 2017.
- Optimal Control Limit Policy for Age-Dependent Deteriorating Systems, Jin, L., Bayarsaikhan, U. and Suzuki, K. Journal of Risk and Reliability 230/ 1, 34-43, 2016. DOI:10.1177/1748006X15589208
- Optimal Maintenance Policy for Aging Systems Under Non-stationary Markov Deterioration, Jin, L. Journal of the Japanese Society for Quality Control 45/ 4, 65-73, 2015.

System Reliability Maintenance Planning



Our research interest is maintenance decision-making for realizing more flexible and efficient maintenance plan while maintaining high reliability and safety.





The University of Electro-Communications
UEC e-Bulletin
Vol.28, June 2021

Research Topics

Decision making for maintenance based on partially information

- Maintenance plan for opportunistic maintenance under partially observation (Best paper award of ANQ2019)
- Optimal maintenance policy under varying environment
- Maintenance for system with non-stationary deterioration

Opportunistic maintenance(OM)

PM ; Preventive maintenance
CM ; Corrective maintenance

OM is one of the maintenance plans that take advantages of the maintenance opportunities from other components within the same system.

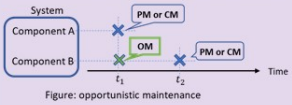
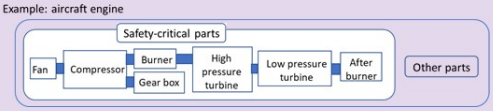


Figure: opportunistic maintenance

advantages
- Reduce set-up cost
- Reduce down-time cost

Example: aircraft engine



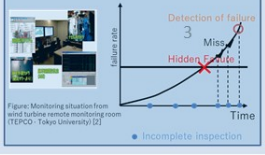
Dynamic maintenance plan

- Improving Scheduled Maintenance with Imperfect Inspections (Best paper award of ANQ2017)
- Operation and Maintenance Policy with Flexible Load Sharing
- Adaptive Age Replacement Using On-line Monitoring

Maintenance schedule for period inspection

Perfect inspection (PI)
- ✓ Being carried out at regular intervals
- ✓ PI interval is specified by the government or company guidelines
- ✓ Can detect hidden failures perfectly
- ✓ Costly
- ✓ Difficult to frequently change the pre-specified inspection intervals

Imperfect inspection (IPI)
- ✓ Being carried out during specified intervals
- ✓ IPI frequency is determined by maintenance crew
- ✓ Can detect hidden failures probabilistically
- ✓ Less expensive than PI
- ✓ The inspection interval can be adjusted easily (Frequency of data collection, analysis procedure etc.)



The University of Electro-Communications 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585

The University of Electro-Communications
UEC e-Bulletin Vol.28, June 2021

Joint demonstration experiment on visualizing carbon dioxide concentration inside Chofu City Hall with eight IoT sensors

1 June 2021

From 1 June 2021, the University of Electro-Communications (UEC Tokyo) and Chofu City plan to jointly carry out a demonstration experiment to visualize the carbon dioxide concentration in Chofu City Hall and maintain good ventilation as part of an industry-academia-government collaboration.

The demonstration will utilize high-precision compact carbon dioxide sensor developed by the Tanaka-Ishigaki Laboratory (Department of Informatics) and Yokogawa Laboratory (Info-Powered Energy System Research Center) at UEC Tokyo.

The sensors will be installed on the 1st to 3rd floors of Chofu City Hall, where many residents visit. The sensors will measure the surrounding carbon dioxide concentration and "visualize" the recorded values by displaying the color and numerical value of the sensors. If the measured value exceeds the standard value of 1,000 ppm, Chofu City staff will carry out ventilation in each of the surrounding places.

Furthermore, if the measured value exceeds the standard value, an e-mail alert will be automatically sent from UEC that is collecting data via the wireless networks to the section in charge of Chofu City, and the person in charge will implement procedures for proper ventilation.

Visualized image of carbon dioxide concentration (composite photo)

The University of Electro-Communications (UEC) in Tokyo

is a small, luminous university at the forefront of pure and applied sciences, engineering, and technology research. Its roots go back to the Technical Institute for Wireless Commutations, which was established in 1918 by the Wireless Association to train so-called wireless engineers in maritime communications in response to the Titanic disaster in 1912. In 1949, the UEC was established as a national university by the Japanese Ministry of Education, and moved in 1957 from Meguro to its current Chofu campus Tokyo.

With approximately 4,000 students and 350 faculty, UEC is regarded as a small university, but with particular expertise in wireless communications, laser science, robotics, informatics, and material science, to name just a few areas of research.

The UEC was selected for the Ministry of Education, Culture, Sports, Science and Technology (MEXT) Program for Promoting the Enhancement of Research Universities as a result of its strengths in three main areas: optics and photonics research, where we are number one for the number of joint publications with foreign researchers; wireless communications, which reflects our roots; and materials-based research, particularly on fuel cells.

International Public Relations
The University of Electro-Communications
1-5-1 Chofugaoka, Chofu, Tokyo 182-8585
E- mail : kokusai-k@office.uec.ac.jp
Website: http://www.uec.ac.jp/eng/