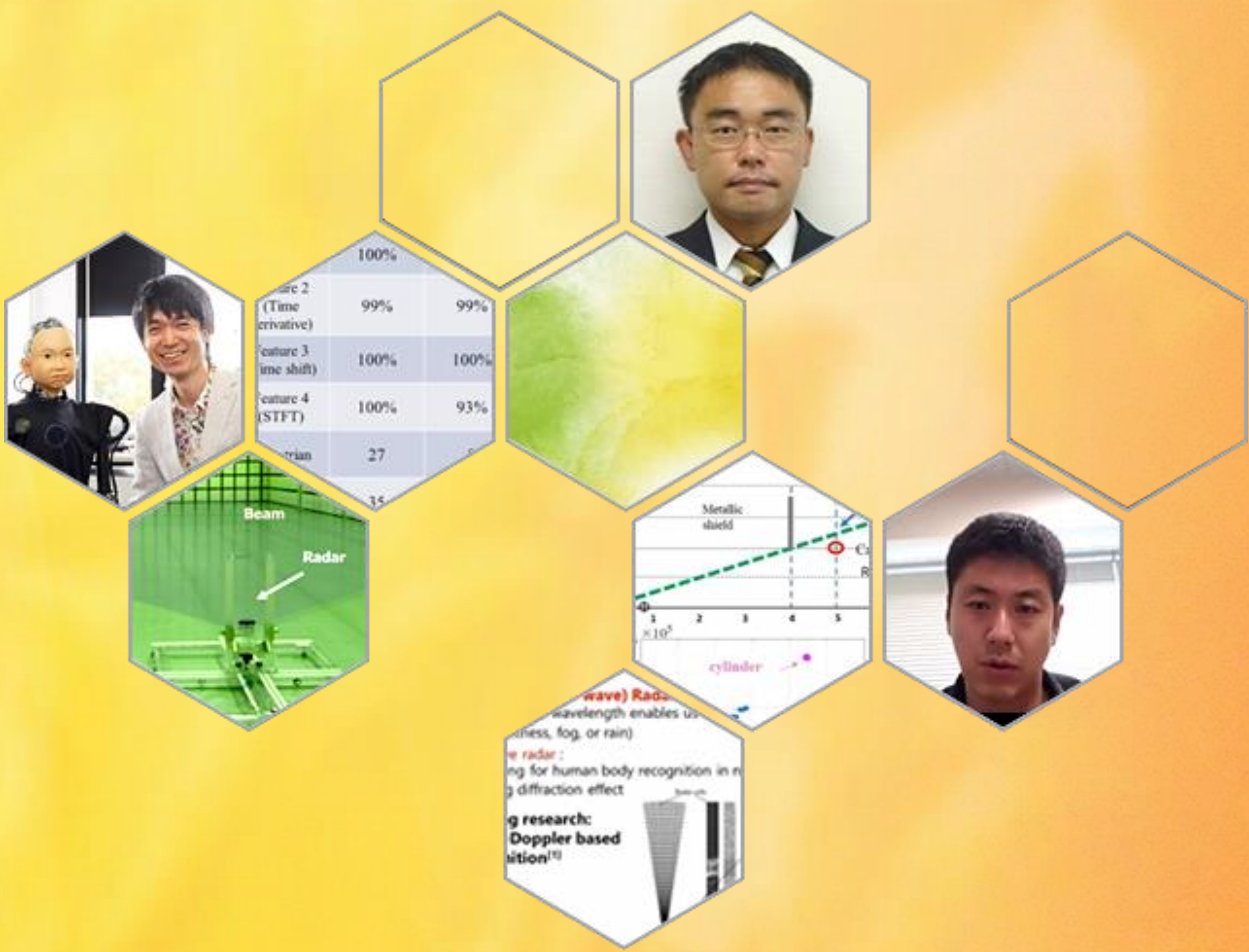
The University of Electro-Communications

# UEC e-Bulletin

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

## Vol.29, September 2021

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## Research Highlights

- Radar-based human recognition for self-driving cars
- Getting the most out of quantum systems

## Researcher Video Profiles

- Radar-based human recognition for self-driving cars

## Topics

- Creating robots to coexist in harmony with humans in the real world

## News and Events

- Relationship between the speed at which insects move and the environmental temperature

Recognition technology

## Radar-based human recognition for self-driving cars

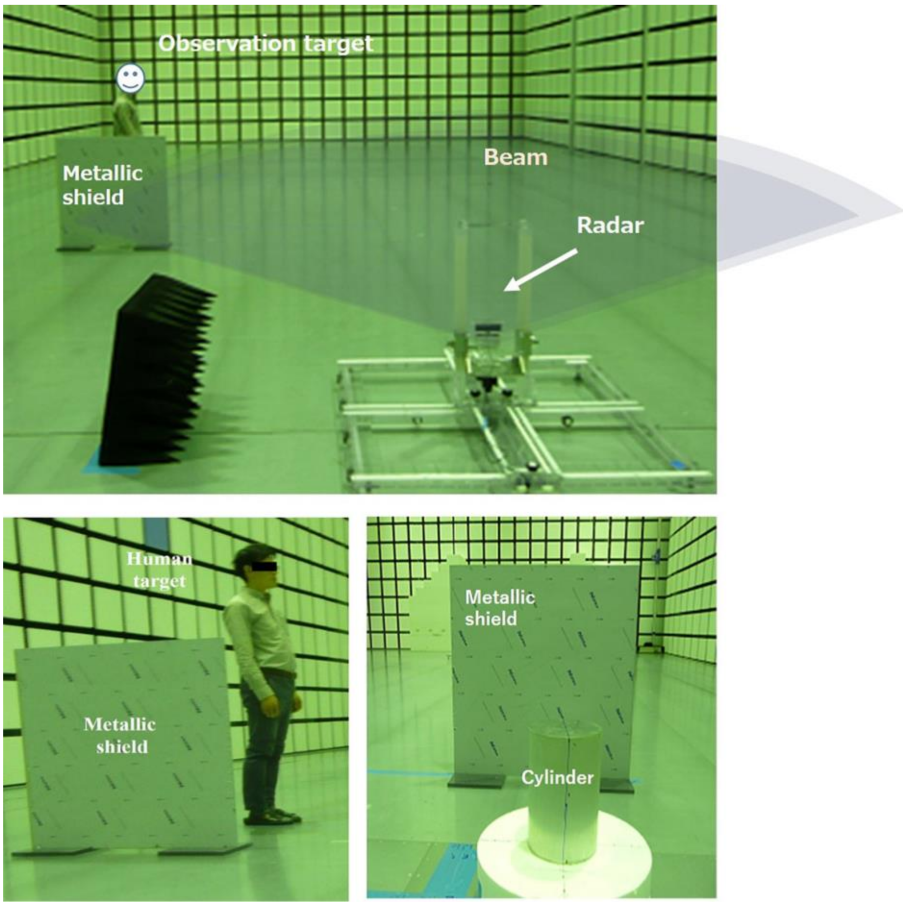
Self-driving car technology requires detectors capable of sensing a car's environment, also in situations of limited visibility like bad weather conditions. Radar-based sensors have emerged as an essential component of driver assistance systems and self-driving vehicles, as they can robustly distinguish nearby pedestrians and other traffic-relevant objects. Apart from being applicable in bad weather, artificial recognition systems also need to be capable of dealing with so-called non-line-of-sight (NLOS) situations, when the line of sight between detector and object is obstructed. In traffic, NLOS situations occur when pedestrians are blocked from sight; for example, a child behind a parked car, about to run suddenly into the street. Now, Shouhei Kidera from the University of Electro-Communications and colleagues have developed a radar-based detection method for recognizing humans in NLOS situations. The scheme is based on reflection and diffraction signal analysis and machine-learning techniques.

The researchers performed radar experiments in an anechoic chamber (a room completely absorbing reflections). The working principle of a radar is to send radio waves to a target object and then analyse the reflected waves (e.g. changes in frequency), which provides information about the object, such as its distance to the source.

Kidera and colleagues put a metallic plate in the chamber so that a NLOS situation arises when the target object is behind the plate from the radar's point of view. The radar's frequency was 24 GHz, and two target objects were used in the experiments: a 30 cm long metallic cylinder, and a human wearing light clothes. Three regimes were investigated: complete NLOS, partially NLOS (target object positioned at the border between the NLOS and the LOS zone) and complete LOS. The signals received by the detector were intrinsically different for the metallic cylinder and the human. Even if a human stands still, breathing and small movements related to posture control cause changes in the reflected wave signals. The scientists found that the differences are enhanced by diffraction effects: the 'bending' of waves around the edges of the metallic plate.

The researchers applied a machine-learning algorithm to the reflection and diffraction signals in order to let their sensing device learn the difference between a human and a non-human object. A recognition rate up to 80% was achieved. They also performed experiments with an actual car as the shielding object, which led to similar results and additional understanding of the dependence of the recognition success rate on the radar's position relative to the target. Also, by carrying out additional experiments with a human performing a stepping motion, the scientists were able to recognize whether a human is standing still or walking, even in complete NLOS situations.

The results of Kidera and colleagues signify an important step forward to feasible self-driving car technology. Of course, in order to fully control realistic situations, more research is needed. Quoting the researchers: "… there should be further investigation using other classifiers or features, which is our important future work".




[Fig. 1b from the paper]

Experimental setup used by Shouhei Kidera and colleagues.

Jianghaomiao He, Shota Terashima, Hideyuki Yamada, and Shouhei Kidera, Diffraction Signal-Based Human Recognition in Non-Line-of-Sight (NLOS) Situation for Millimeter Wave Radar, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* **14**, 4370–4380 (2021).

URL: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9405398

DOI: 10.1109/JSTARS.2021.3073678

Quantum state estimation

## Getting the most out of quantum systems

Quantitative information about a physical system comes in the form of numbers following from the system's mathematical description — equations capturing the physical processes involved. In classical physics, it is in principle possible to retrieve, by means of measurements, the complete information of a system. According to quantum mechanics, however, one can never obtain all information of a system with infinite precision because of the quantum-mechanical uncertainty principle stating that certain pairs of quantities (e.g. momentum and position) cannot be measured simultaneously with absolute certainty.

Also, in quantum mechanics, measurements affect the state of a system, so it is actually impossible to determine a system's state without prior knowledge about it. Quantum state estimation is the statistical framework addressing the question how to obtain the most — but, unavoidably, still incomplete — information about a quantum system from measurements.

Now, Jun Suzuki from the University of Electro-Communications and colleagues have extended the framework to include the situation of so-called 'nuisance parameters': parameters that are not really of interest but do affect the precision of estimations of other parameters that are of interest.

Nuisance parameters have been extensively studied in the context of classical physics and statistics. A key theoretical result is the Cramér-Rao inequality, providing a lower bound on the variance of the estimated value of a parameter. (The variance of a parameter is the expectation value of the square of the deviation from its mean value.) Suzuki and colleagues derived a scheme to obtain quantum Cramér-Rao bounds in the framework of quantum state estimation taking the presence of nuisance parameters into account.

After developing the general formalism, the researchers focused on the one-parameter case: the situation where only one parameter is of interest, but one or more nuisance parameters exist alongside. They succeeded in obtaining a straightforward 'recipe' for calculating the ultimate precision limit for the one parameter of interest. They applied their scheme for the description of a noisy quantum clock, as well as that of a so-called 'qudit', a multi-state generalization of a qubit. (The latter refers to a quantum-mechanical two-state system, like the spin of an electron, and is the fundamental concept underlying quantum computing.)

Suzuki and colleagues point out that their findings are relevant for quantum metrology. Quantum metrology essentially deals with estimating, with high sensitivity and high precision, parameters in quantum-mechanical physical processes by utilizing quantum resources. One of the main issues in this field is to perform quantum metrological tasks in a noisy environment; the noise thus depends on unknown nuisance parameters. Quoting the researchers: "Suitable extensions of the tools presented … will, therefore, be able to quantify the effects of nuisance parameters in quantum metrology."

Jun Suzuki, Yuxiang Yang, and Masahito Hayashi, Quantum state estimation with nuisance parameters, *J. Phys. A: Math. Theor.* **53**, 453001 (2020).

URL: https://iopscience.iop.org/article/10.1088/1751-8121/ab8b78

DOI: 10.1088/1751-8121/ab8b78

Further information

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## Radar-based human recognition for self-driving cars

Shouhei Kidera, Associate Professor
Department of Informatics
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Shouhei Kidera and his group is focusing on recognizing pedestrians using millimeter wave radar—that enables sensing in darkness, fog, or rain—for self-driving cars. "We use millimeter wave radar because it is effective for recognizing pedestrians even in non-line-of-sight sensing scenarios by exploiting diffraction signals," explains Kidera. "Most other radar based human recognition methods use micro-Doppler analysis. However, this approach needs higher Doppler velocity, temporal, and range resolution. Our approach is based on raw data machine learning, assuming Non-Line-of-Sight (NLOS) scenarios."

Kitera and his colleagues use Frequency Modulated Continuous Wave Millimeter Wave (FMCW MMW) radar with 24 GHz center frequency, 700 MHz bandwidth, and horizontal and vertical beam widths of the radar of ± 45 degrees and ± 6.5 degrees, respectively.

In recent research they studied two different types of targets: a metallic cylinder, and a human with static motion and breathing [1].

In a Line of Sight scenario the team compared reflection responses from a human and metallic cylinder. "We obtained Gaussian distribution reflection spectra for a specific range," says Kidera. "We confirmed the temporal variation of the response of a stationary human body in both amplitude and phase, which did not appear in cylinder target. These differences are promising for discriminating between human and metallic cylinders."

Finally, the team investigated support vector machines (SVM) based machine learning using a variety of features with corresponding raw data (Details in the video).

Notably, the results on the recognition rate between human and metallic cylinder and SNR, and showed perfect recognition in LOS or partially NLOS situations. Also, in completely NLOS case, the recognition rate increased to 80 % by exploiting multiple temporal features, even in very lower SNR situations.

References and further information

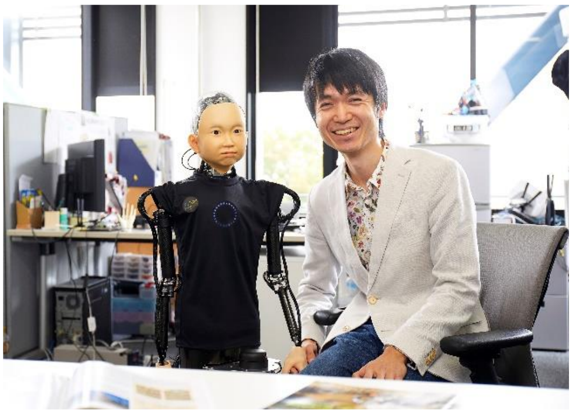
Jianghaomiao He, Shota Terashima, Hideyuki Yamada, and Shouhei Kidera, Diffraction Signal-Based Human Recognition in Non-Line-of-Sight (NLOS) Situation for Millimeter Wave Radar, *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* **14**, 4370–4380 (2021).

URL: https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9405398
DOI: 10.1109/JSTARS.2021.3073678

Website
http://www.ems.cei.uec.ac.jp/index_e.html

## Creating robots to coexist in harmony with humans in the real world

Yoshihiro Nakata
Associate Professor, School of Informatics and Engineering, Department of Mechanical and Intelligent Systems Engineering, UEC Tokyo.



“The is extensive research on autonomous robots and androids that look and behave like humans”, says Yoshihiro Nakata, an associate professor at the School of Informatics and Engineering, UEC Tokyo. “Ultimately, in order for robots to become an integral and functional part of modern society, they must be able to move freely within everyday social settings alongside humans, without danger or concern. The key to realizing such a society is for robots to be able to “gently interact” with humans without the unnatural rigid movements associated with conventional robots. To achieve a society of “gentle robots” it is necessary to develop new generations of actuator technology. This is the goal of my research. Namely, to develop actuators for powering “gentle and socially acceptable robots.”

Nakata’s research can be divided into three types: actuators, mechanisms, and humanoid robot research. In actuator research, Nakata and his colleagues have focused on making actuators that mimic the flexibility, power, and agility of human muscles, with the goal creating machines with a gentle touch.

Research on mechanisms he has been trying make a “body that can tolerate various forms of contact from the environment and “feel” the force not via joints but by the whole body—the goal is to create machines that gently feel such forces.

The third is research theme is on humanoid robots, with the goal of creating robots that can be part of the natural world without feeling the burden on people in society.

"I started research on actuators when I was an undergraduate student," says Nakata. "For flexibility and agility, I developed linear motors as actuators for robots. And since linear motors do not have an intrinsic deceleration mechanism and is direct drive, it is possible to devise actuators with flexibility against external forces, with high response and high accuracy by driving with electromagnetic forces."

Now, since moving to UEC Tokyo in March 2021 Nakata has defined three goals for this research for the development of robots that behave in a human-friendly manner in the real world.

- Fine adjustment of force and alternatives to advanced work: Study how robots equipped with pneumatic-electromagnetic hybrid actuators behave in unknown environments. Applications for precision processes and rehabilitation, where it is important to fine tune forces.

- Robot body that adapts to the environment and evolves: Actuator network system applications of multi-degree-of-freedom robots. Appropriate information sensing and network optimization.

- Robots that learn behavior from humans: Research on how robots can learn from being part of human society.

"My research in really challenging because it's necessary to carefully study the behavior of both robots and humans," says Nakata. "Ultimately, I want to realize an advanced intellectual system by understanding human behavior and applying it to robots, and aim for a deeper and more essential understanding of humans."

**Further information**
Nakata Laboratory website (In Japanese)
http://www.nakata-lab.mi.uec.ac.jp/members/
Yoshihiro Nakata website
https://yoshihiro-nakata.net/

Publications
Hybrid actuators
Development of a pneumatic-electromagnetic hybrid linear actuator with an integrated structure
https://ieeexplore.ieee.org/document/7354267
Design of an Integrated Pneumatic-Electromagnetic Hybrid Linear Actuator
http://mech.vub.ac.be/IROSWSActuators/3%20IROS2014Workshop_YNakata_TNoda_JMorimoto_HIshiguro.pdf

Actuator netwrok system

Adaptive Whole-Body Dynamics: An Actuator Network System for Orchestrating Multijoint Movements

https://ieeexplore.ieee.org/document/7547311

Preprint

https://yoshihiro-nakata.net/wp/wp-content/uploads/2019/09/RAM2016_aa.pdf

Open information about android robots

Development of ‘ibuki’ an electrically actuated childlike android with mobility and its potential in the future society

https://www.cambridge.org/core/journals/robotica/article/development-of-ibuki-an-electrically-actuated-childlike-android-with-mobility-and-its-potential-in-the-future-society/95D6E2AF4D09ECEDC4D710E85758BDD3

Video Friday: Professor Ishiguro’s New Robot Child, and More

https://spectrum.ieee.org/video-friday-professor-ishiguro-new-robot-child-and-more

Video Friday: Child Robot Learning to Express Emotions Using Body Language

https://spectrum.ieee.org/video-friday-ibuki-robot-child-emotional-gait

Video Friday: Android Printing

https://spectrum.ieee.org/video-friday-android-printing

https://www.techrxiv.org/articles/preprint/Android_Printing_Towards_On-Demand_Android_Development_Employing_Multi-Material_3-D_Printer/15034623

ibuki channel on YouTube

https://www.youtube.com/c/ibuki-android

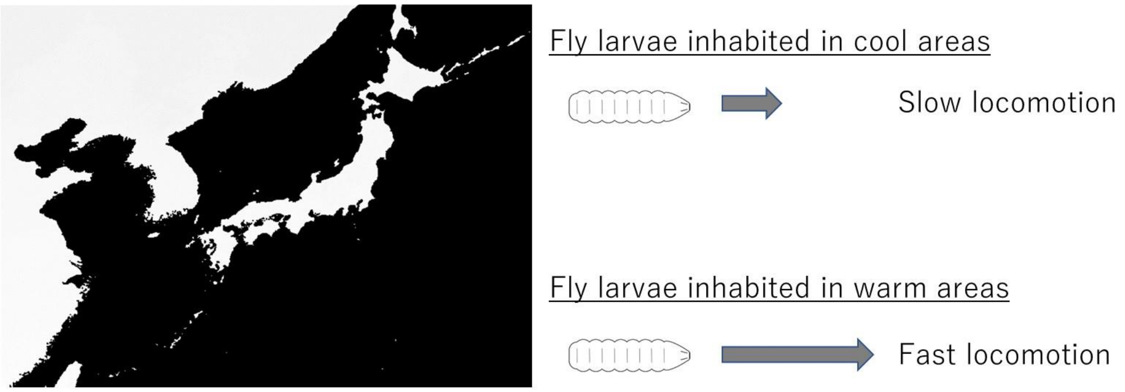
## Relationship between the speed at which insects move and the environmental temperature

Hiroshi Kohsaka an associate professor at UEC Tokyo, and colleagues report that the speed of movement of fly larvae varies from species to species. Furthermore, they found that larvae in cold regions tend to move slowly, and those in warm regions move faster. These results suggest that environmental diversity has contributed to the evolution of the diverse movement patterns exhibited by animals.

Details and Reference

Yuji Matsuo, Akinao Nose, Hiroshi Kohsaka, Interspecies variation of larval locomotion kinematics in the genus Drosophila and its relation to habitat temperature , *BMC Biology* 19, 176 (2021).

DOI: 10.1186/s12915-021-01110-4
https://bmcbiol.biomedcentral.com/articles/10.1186/s12915-021-01110-4




Summary of the research results

Hiroshi Kohsaka, Associate Professor, UEC Tokyo.

## 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.

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