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New Year Messages

From the Minister for Internal Affairs and Communications, Secretary-General of ITU, President of ITU-AJ

Special Feature

Trends in the Application of Ultra-High-Definition Video in Industry, Medicine and the Arts

GT-8K: World's First Infrastructure Inspection Vehicle using 8K Video Technology

Medical Applications of 8K Technology

8K Cultural Heritage Project Initiatives

Latest Trends and Future Directions in Ultra-High-Definition Imaging Technology Accelerating Smart Industry

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C O N T E N T S

About ITU-AJ

The ITU Association of Japan (ITU-AJ) was founded on September 1, 1971, to coordinate Japanese activities in the telecommunication and broadcasting sectors with international activities. Today, the principle activities of the ITU-AJ are to cooperate in various activities of international organizations such as the ITU and to disseminate information about them. The Association also aims to help developing countries by supporting technical assistance, as well as by taking part in general international cooperation, mainly through the Asia-Pacific Telecommunity (APT), so as to contribute to the advance of the telecommunications and broadcasting throughout the world.

2023 MIC Minister's New Year's Greeting

Takeaki Matsumoto
Minister for Internal Affairs and Communications

Happy New Year's to you all. My name is Takeaki MATSUMOTO, and I was appointed Minister for Internal Affairs and Communications in November of last year.

Since assuming this post, I am reminded of the broad jurisdiction of the Ministry of Internal Affairs and Communications, administering many important fields that form the core of our nation and support our citizen's daily lives, including local economies, elections, fire fighting, information and communications, broadcasting, the postal system, public-sector evaluation, and statistics.

As the Minister of Internal Affairs and Communications, I am prepared to put all of my effort into fulfilling my duty, working to implement our policies for all citizens of Japan.

Supporting digital reform

The top priority policy of Prime Minister Kishida's cabinet is his "Vision for a Digital Garden City Nation," and the Ministry of Internal Affairs and Communications will put all of our effort into realizing it, as the administration for local administration and finance, and for information and communication.

To realize this "Vision for a Digital Garden City Nation" will require consolidation of regional digital infrastructure and DX of local governments. To this end, we are completing integration of 5G networks in urban and regional areas, completing and maintaining regional fiber-optic networks, distributing data centers in regional areas and completing fiber-optic submarine cable networks.

We are also promoting a comprehensive technology strategy for "Beyond 5G," the next-generation information and communications infrastructure, utilizing funding from the National Institute of Information and Communications Technology (NICT), which has been made permanent through legislative amendments. This involves accelerating R&D and implementation in society, promoting a comprehensive technology strategy including obtaining intellectual property and international standardization, and promoting R&D on important advanced technologies such as quantum communication, AI and space development.

Addressing internal and external environmental change

We are addressing internal and external changes in our business environment with rapid technical innovation.

We are working to promote economic security and stability amid rapidly changing international conditions in the field of information and communications, and also to strengthen our international competitiveness and have deeper international cooperation. In particular, we are promoting "Data Free-Flow with Trust" (DFFT) through the G7 and the Internet Governance Forum (IGF), which will be held in Japan this year, by building high-quality, robust network infrastructure to support it, and by holding discussions toward international cooperation promoting and maintaining a free and open internet.

We are also promoting cooperation with the ITU more than ever before, as Japan's Dr. Seizo ONOE assumes the position of Director of the Telecommunication Standardization Bureau of the ITU in January this year. We are also promoting international expansion of the excellent MIC technologies and services in areas including 5G, optical submarine cable, broadcast content, postal services, fire fighting, administrative consulting, and statistics.

The rapid changes in technical innovation and international circumstances are also bringing great changes in business and user environments, resulting in more new issues. In anticipation of this, we are asking the Information and Communications Council to deliberate on directions that information and communications policy must take in Japan looking ten years in the future.

Considering the series of communications faults that occurred last year, due to disasters and other causes, we are working to be able to introduce roaming between operators as quickly as possible during disasters, so that operators can utilize each other's networks. As part of our comprehensive measures in this area, we are also promoting means of communication other than roaming, such as using public Wi-Fi or devices with multiple SIMs.

We are also increasing support for cyber security measures, such as personnel training and data analysis, considering the increased risk of damage from cyber attacks last year. We are also promoting comprehensive measures to deal with abuse and defamation on the internet and to streamline provision of aid to victims through consistent application of the "Amended Act on the Limitation of Liability for Damages of Specified Telecommunications Service Providers," to promote efforts by platform operators to remove such content, and by strengthening systems for education and consultation.

Considering the changes taking place in the broadcasting environment, such as viewers moving away from television and increasingly watching video through the internet, we are also reexamining NHK and commercial television's broadcast systems as broadcasters in the digital age. It is important for NHK to continue to fulfill its mission as a public broadcaster, according to the demands of the age, and with that in mind, we are studying how the internet should be utilized in our work.

Regarding use of mobile telephone frequencies, we are also studying how the system for reallocating frequencies can operate smoothly, and how to secure new bandwidth for mobile communications.

To continue providing useful public statistics in response to changes in the economy and society, we have also bolstered our system for securing the required personnel. We continue comprehensive quality management and promotion of statistics reforms with measures such as personnel training and digitalization.

Conclusion

Please allow me to conclude my New Year's greeting by wishing you all health and much happiness in the coming year!

New Year Message: Tremendous Progress Together, but Much Left to Do

Ms Doreen Bogdan-Martin
Secretary-General
International Telecommunication Union

Let me begin by wishing all members of the ITU Association of Japan a very happy and prosperous New Year.

Recent times have certainly been challenging for many of us. Geopolitical tensions are at their highest in decades, economic and job concerns are rising, the impact of the global pandemic continues, and food security looks precarious for much of the world. Environmental and climate concerns can no longer be ignored.

The growing combination of threats and uncertainties has only increased the urgency of our work to connect the world.

The crucial need for connectivity has brought more people online more quickly. At the same time, it has focused the minds of leaders on the need to bridge digital divides, which today keep almost one-third of humanity totally offline and many hundreds of millions more without meaningful connectivity that could help them build a better future.

We still have a long way to go to reach our dream of a fully connected planet. But let's also start the year by recognizing what a long way we have come since 1994, when I first joined the ITU regulatory team. Back then, only some 20 million people – less than 0.1 per cent of the global population at that time – were Internet users. Today, an estimated 5.3 billion are online, and that number grows with every passing week.

The progress achieved to date reflects the tireless efforts of ITU staff, as well as the steadfast support, commitment, and hard work of ITU members.

All that terrestrial telecommunications infrastructure; all those software protocols, satellite systems, undersea cables; all those agreements on the shared use of resources like radio-frequency spectrum – in short, all those complex networks empowering billions of people and supporting millions of businesses around the world – are founded on the crucial technical, regulatory and development work that takes place under auspices of ITU as the United Nations specialized agency for information and communication technologies. I believe this is something in which we can all take enormous pride.

Throughout the course of this long journey, I cannot overstate the contributions of the Japanese government and the ITU Association of Japan in supporting our work.

Over many years, Japan has been a leading champion of innovation and digital development. It has put its considerable talents and resources to work to pioneer new technical standards though our ITU Standardization (ITU-T) and Radiocommunication (ITU-R) study groups; helped forge thought leadership on telecommunications policy issues through our many regional and global events; and worked alongside ITU on the ground to mitigate the impact of natural disasters, address human and environmental challenges, and expand meaningful connectivity to those most in need.

At the height of the global pandemic, Japan came forward as a founding member of the Connect2Recover initiative, working alongside ITU and partners to reinforce digital resilience in the world's least developed countries, landlocked developing countries, small island developing states, and countries undergoing transition or facing disruption.

I extend my most sincere commendation and gratitude to Japan for its commitment and support in helping us building a connected and trusted digital future.

We've made tremendous progress together, but there is still so much left to do, especially for those who are unconnected, vulnerable or otherwise digitally excluded.

The ITU Strategic Plan for 2024-2027, adopted during our 2022 Plenipotentiary Conference in Romania, encompasses two core strategic goals: Universal Connectivity and Sustainable Digital Transformation.

Achieving these goals entails significant challenges. But those will be far from insurmountable if we all work together towards a shared global vision. As we approach 2030, the target date for the UN Sustainable Development Goals, we must seize our chance to leverage the power and potential of digital technologies to ensure that no one is left behind.

The actions we take today will lay the foundation for the future – not just for us, but for generations to come. As UN Secretary-General António Guterres said: "We, the leaders, must deliver for we, the peoples."

I know that, as always, ITU can count on Japan to bring an exceptional level of energy and expertise to the challenges ahead. I look forward very much to working with ITU's new leadership team, including distinguished engineer Seizo Onoe, our new Director of Telecommunication Standardization, as we all seek new ways to advance the power of technologies and connectivity to change the world.

Once again, I thank the Government of Japan, the ITU Association, and Japan's many ITU sector members and partners for their invaluable role in promoting digital development and driving innovation.

May this year, and the many years to come, be prosperous, progressive, and peaceful for all.

New Year's Message

Tetsuo Yamakawa
President
The ITU Association of Japan

The very best wishes to all in this New Year!

2022 was a year of great change, beginning with Russia's invasion of Ukraine in early spring. In Ukraine the fighting continues and there is no resolution in sight, but the dispute must be stopped, the damaged towns and infrastructure must be restored, and people's lives must be returned to normal. There is also strong desire to employ our collective wisdom to find peaceful solutions to the energy problems, the disorder in logistics, the rising commodity prices and other difficulties that this invasion has caused around the world, and to restore safety and orderly daily life and economic activity for all.

The COVID-19 pandemic continues with varying conditions in each country so we will need to keep monitoring these trends, but we expect new developments in the coming year and have high hopes for a good and prosperous year.

Meetings and events in the past year with our related organizations, the ITU and APT, included the World Telecommunication Standardization Assembly (WTSA) held in Geneva in March, the World Telecommunication Development Conference (WTDC) held in Kigali, Rwanda in June, and the ITU Plenipotentiary Conference (PP-22) held in Bucharest, Romania in September and October.

One particularly notable event at PP-22 was that NTT's Dr. Seizo ONOE was elected as the Director of the ITU Telecommunication Standardization Bureau. We heartily celebrate this event and hope the best for his efforts in his various activities at the ITU. Japan was also elected as a Council Member State in the same conference. The ITU-AJ also supported work at the on-site offices for PP-22. At the WTSA in March, candidates from Japan were selected for two ITU-T TSAG/SG chairperson positions and seven vice-chairperson positions, and at WTDC in June, candidates from Japan were selected for two ITU-D SG vice-chairperson positions. We wish them every success in their efforts.

On May 17, the ITU-AJ also held our annual "Celebration of World Telecommunication and Information Society Day" (WTISD) at the Keio Plaza Hotel, also streaming it on line. At the ceremony, Dr. Kohei SATOH (NICT) received the MIC Minister's Award for his activities in international standardization at the ITU and APT over many years. Dr. Chieko ASAKAWA (IBM Fellow, IBM Corp.; Chief Executive Director of the National Museum of Emerging Science and Innovation (Miraikan); IBM Distinguished Service Professor, Carnegie Mellon University) also received an ITU-AJ Special Achievement award, and delivered the Anniversary Keynote Presentation. Eleven Accomplishment Awards and 18 Encouragement Awards were also conferred. We offer sincere congratulations to all recipients!

This year in the telecommunications field, we expect commercial 5G services to become widely established and to advance. Through 5G and other ICT technologies, we hope to find solutions to social issues and to make a leap toward Society 5.0.

In November, the ITU will hold a Radiocommunication Assembly (RA) and the World Radiocommunication Conference (WRC) in Dubai, UAE. We will prepare for these conferences, using our past experience and collaborating with those who are involved in ITU and APT meetings and events.

Within ITU-AJ, we plan to continue operation of our Japan Platform for Driving Digital Development (JPD3), which began in 2020. In February and March, we will also support the Japan booth exhibit at the Mobile World Congress (MWC) 2023 in Barcelona, which is a new initiative for us. Through these efforts we plan to help with expansion of Japanese ICT enterprises globally.

I would like to offer our gratitude to all who have supported the ITU-AJ, and we will continue and increase our efforts to be a bridge between the Japanese government, our supporting members, and the ITU into the future.

I also wish you all a heartfelt Happy New Year and wish all health and vitality in the year ahead.

■ Dr. Seizo ONOE elected as director of the TSB

■ Guests and Award-winners at the WTISD celebration

GT-8K: World's First Infrastructure Inspection Vehicle using 8K Video Technology

Narumi Kurihara
General Manager, Camera business promotion
Video Engineering Dept.
ASTRODESIGN, Inc.

Kazutomo Yamamoto
Engineer
Mobility Spatial Information Department
MMS Technology Group
Aero Asahi Corporation

1. Introduction

So far, 8K technology has developed mainly for broadcasting. NHK Science and Technology Research Laboratories has been developing 8K under the name of Super Hi-Vision since 2004 and began 8K broadcasting in 2018. During development, several large scale specialized devices were used for filming, but for roughly 15 years, 8K equipment has become more compact, 8K TVs have appeared on the market, 8K video compression technology has advanced, and products such as 8K processing workstations have entered the market.

Through this process, the characteristics of 8K have also been widely researched, and applications in industry are highly anticipated. One characteristic of 8K is that it can capture high-definition state over a wide area. If an unexpected outcome is perceived from the overall image, the overall features can be analyzed on a single image rather than attempting to join images from multiple cameras. It is hoped that this will show the benefits of 8K in industry. To apply a new technology such as 8K in industry requires the desired objective to be achieved, but also that the technology is both practical and economical.

ASTRODESIGN has put effort into developing devices for 8K broadcasting and has commercialized successive products including cameras, signal processing equipment, recorders and displays. Here we describe how we provided comprehensive leading-edge technology, when it was needed, during completion of the GT-8K, the world's first 8K infrastructure inspection car. We have conducted repeated trials since development began, and now understand the effects of using 8K technology for infrastructure inspection, so we are now ready to apply the technology. Here, we describe the development process, show operation and results from the inspection system, and results achieved in light of issues with current infrastructure inspection practices.

2. Evolution of 8K equipment

ASTRODESIGN has worked on developing products since the beginning of Super Hi-Vision development, and been broadly involved in 8K products. As FPGAs have advanced, they became a technology for processing 8K efficiently. They have been a high quality signal processing technology for broadcasting, contributing to advancement of devices such as cameras. They are the eye of the system, the entryway for images, and an essential component when considering industrial applications of 8K. Earlier 8K cameras were large systems requiring much power, but their size and power consumption has been reduced, without decrease in performance. These advances have greatly reduced the hurdles to using 8K cameras in industry applications.

Currently, ASTRODESIGN has a lineup of two cameras for industrial use, with model numbers AB-4815 and AB-4830/AC-4829.

Both models can output 8K video (12G-SDI×4 channels) in real time, to use the characteristics of 8K video. The AB-4815 is a compact camera with the main unit measuring 148 mm × 150 mm × 241 mm, which outputs image-processed video and consumes only 90 W of power. The other model, the AB-4830/AC-4829, is separated into a camera head and a video processing unit. The camera head is more compact, measuring only 65 mm ×65 mm × 85 mm and weighing only 340 g. Including the AC-4829 signal processing unit, it only consumes 80 W of power. These compact designs expand the range of possible non-broadcasting applications.

Use of 8K video for industrial applications requires capture as well as storage of the video and processing with CPU/GPU. ASTRODESIGN has developed a hardware-based 8K recorder, but we also developed a workstation able to receive the video data to create a more flexible capture system. The AW-8800 workstation is able to receive 8K video from up to four camera systems. For such a case, the system would be implemented with four capture boards capable of transmitting and receiving

■ **Figure 1: 8K camera (left: AB-4815, right: AB-4830/AC-4829)**

■ **Table 1: AB-4815 specifications**

Item	Specifications
Image sensor	Super 35 mm CMOS image sensor
Effective pixels	Approx. 33 million
Lens mount	PL mount
Frame frequencies	59.94 Hz, 60 Hz, 50 Hz, 30 Hz, 29 Hz, 25 Hz, 24 Hz
External dimensions	148 (W)×150 (H)×241 (D) mm
Weight	3.5 kg

■ Table 2: AB-4830/AC-4829 specifications

Item	Specifications
Image sensor	Super 35 mm CMOS image sensor
Effective pixels	Approx. 33 million
Lens mount	Micro Four Thirds mount
Frame frequencies	59.94 Hz, 60 Hz, 50 Hz
External dimensions	Camera head: 65 (W)×65 (H)×88.5 (D) mm CCU: 210 (W)×133 (H)×370 (D) mm
Weight	Camera head: 340 g CCU: 5 kg

four 12G-SDI channels installed in five-lane PCIe slots. The workstation is also equipped with 16 U.2 NVMe SSDs in a RAID configuration. The system can also be implemented with 8 GB DDR4 DIMM in 24 slots, so the system can record even uncompressed high-bit-rate video data. The CPU has 56 cores, so that workstation-based systems can be built for high-performance and specialized applications, able to process 8K in real-time.

The 8K infrastructure inspection system described here is a simple configuration including four 8K cameras (AB-4815) and an AW-8800 workstation.

■ Figure 2: AW-8800 TAMAZONE workstation

■ Table 3: AW-8800 specifications

Item	Specifications
CPU	Intel® Xeon® processor×2 (56-core)
Memory	DDR4-2666 8 GB×24
Drive	2.5” U.2 NVMe SSDx×16
GPU	NVIDIA® Quadro® P4000
PCIe slots	PCIe Gen3×16 4-Lane PCIe Gen3×4 (DMI) 1-Lane
Chassis	5U Chassis, 28.7” (L) ×18.0” (H) ×8.54” (W)

3. GT-8K: World’s first infrastructure inspection car

During the years of rapid economic growth in Japan, large amounts of social infrastructure were built, including roads, tunnels, and railways. As this infrastructure deteriorates, managing maintenance is becoming more important, while at the same time, a shortage of inspection personnel and increasing inspection costs are becoming major issues. The Ministry of Land, Infrastructure and Transport has designated infrastructure facilities that were built 50 years or more in the past as deteriorated facilities, and is working on policy to replace inspection, which has basically involved close visual inspection, with technology.

On June 3, 2020, Aero Asahi Corporation and ASTRODESIGN announced completion of joint development of GT-8K, a new measurement vehicle equipped with 8K video technology to advance and increase performance in maintenance of various infrastructure such as roads, railways and airports. It is a vehicle-mounted Mobile Mapping System (MMS) and is able to record 8K video while travelling at highway speeds, linking it with positioning data to collect accurate data at high speed. The Aero Asahi Corp. mobile measurement vehicle technology combined with ASTRODESIGN’s high-quality video technology creates a highly accurate and practical measurement system.

Since 2019, we have conducted repeated trials inspecting tunnels, demonstrating that we achieved our goal of detecting cracks on the order of 0.1 mm to complete the photographic system. Till now, we have been operating the GT-8K and integrating the crack detection system with point cloud data. Using the results, we have implemented industry applications of 8K, delivering measurement services and the measurement data as a commercial product.

■ Figure 3: GT-8K (left) and GT-8K in operation (right)

4. Measurement system configuration

GT-8K consists of four 8K cameras, a video collection workstation, high-output illumination and a laser scanner, all mounted on a vehicle.

The image capture component has 8K cameras with fixed-focus lenses, which send video signals to the components in the vehicle. The cameras also have high-powered lighting on both sides to ensure that the tunnel walls are adequately illuminated. The laser scanner component is equipped with a Global Navigation Satellite System (GNSS) antenna, an Inertial Measurement Unit (IMU) and a laser scanner. The GNSS is not able to receive radio signals inside a tunnel, so the IMU positioning measurements enable the system to record accurate positioning data as the vehicle moves, even while in a tunnel. Based on this positioning data, point cloud data is generated using the laser scanner. Overall control of the system and data collection is done by a PC in the vehicle, and data collection can be monitored in real time on a terminal in the vehicle as it moves. All of this equipment is driven by a power supply installed under the cabinet. The simplified system configuration enables the entire system to be installed on a single vehicle.

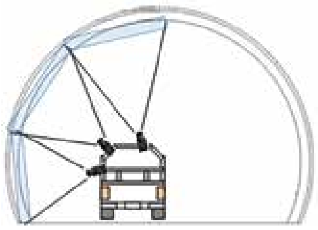
The laser scanner is able to acquire range data for one million points per second. By combining this point cloud data with the 8K video, an expanded image of the inside of the tunnel is created with both location and image information.

The video and point cloud data are synchronized during capture using a video synchronization signal (30 Hz TTL pulse). The cameras output 30 Hz 8K video and the workstation is equipped with up to four 12G-SDI capture cards. The PC receives uncompressed video, which is transferred to main memory, and then written sequentially to the SSDs. The input video data rate is 96 Gbps, and the application is optimized to ensure that no data is lost. To enable monitoring of the measurement status, the image data in the SSDs is also processed to display it on a terminal as it is recorded.

Three or four cameras are used for measurement of the surface of tunnel walls. The number of cameras and lenses are selected beforehand based on the tunnel shape, and the position and orientation of the cameras on the cabinet and the path of the vehicle are adjusted through prior simulation and at the site.

Figure 4: GT-8K configuration

Figure 6: Capturing tunnel wall surfaces

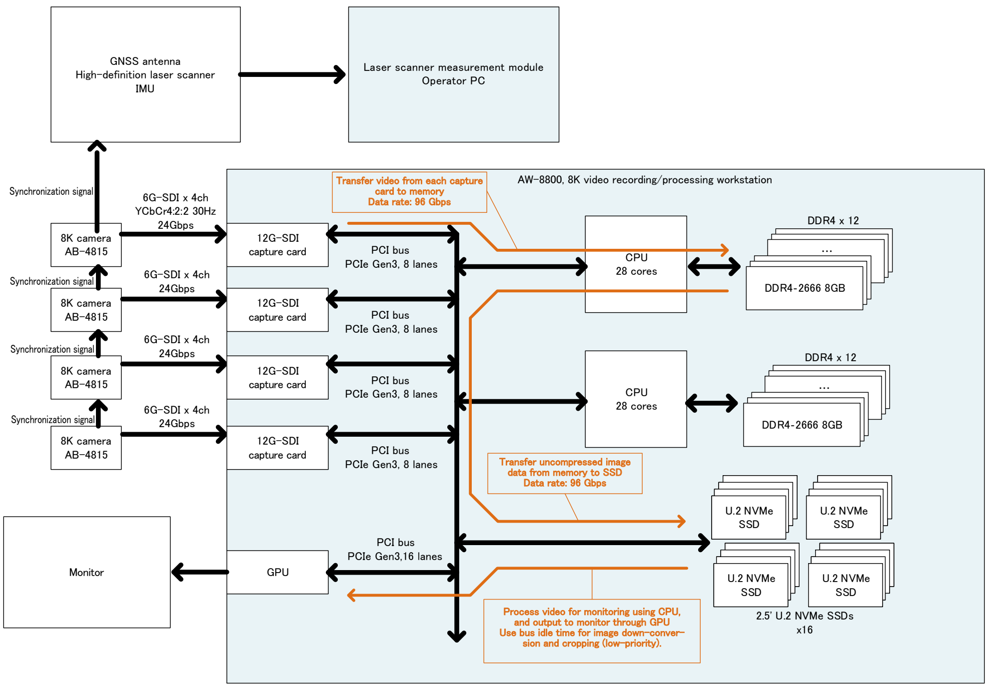


Data collection is then performed after tuning the lens focus and lighting conditions. To utilize the horizontal resolution of the 8K video, the cameras are tilted by 90° facing the wall surface. To capture an entire tunnel with inner circumference of 15 m, three cameras are used to capture the left-hand surface, and the vehicle drives down the opposite late to capture the other half.

In this case, a single camera captures an area of 2.5 m × 1.4 m, and each pixel represents an area of approximately 0.3 mm × 0.3 mm. We have targeted this 0.3 mm size when measuring cracks, but there is a high contrast ratio between cracked areas (which appear black) and the tunnel walls, so we are able to use this difference in contrast ratio to measure cracks that are smaller than the pixel size. In practical tests, we have been able to discriminate cracks down to approximately 0.15 mm.

To capture from the vehicle while it is moving requires suppression of motion blur. When capturing at 30 Hz and travelling at 60 km/h, the vehicle travels roughly 550 mm during a single frame. To suppress motion blur due to this motion, the camera shutter speed must be increased. Using a shutter speed of

Figure 5: GT-8K system schematic diagram



1/10000 s, image blur can be reduced to approximately 1.5 mm. When conducting data measurements, target capture conditions must be verified beforehand, and also adjusted at the site. The 8K cameras and workstation provide advantages for achieving this in that the system is simplified and has functions for real-time tuning at the site.

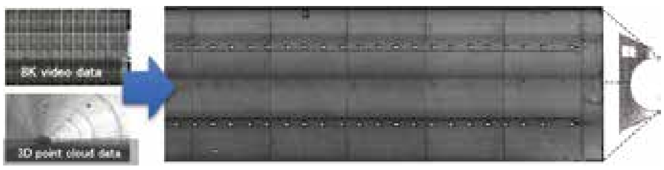
An expanded image of the tunnel is generated by combining the 8K video with the point cloud data obtained when collecting the data. The images are combined by projecting a mosaic of the images onto a 3D projection surface generated from the laser data using the position and orientation of the camera. The complete expanded image is further processed to provide a record of the position and shape of any cracks. Besides cracks, areas with water stains, and where markings have been added manually in the past are also isolated comparatively.

The expanded view image can be analyzed automatically using image processing and can also be inspected visually by an inspector at a later date. The data is also archived, so any changes detected in periodic inspections can also be used for forecasting future changes.

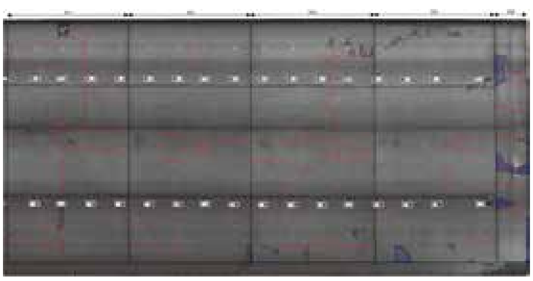
5. Benefits of the 8K infrastructure inspection vehicle

Creating this expanded view from the video captured using the 8K infrastructure inspection vehicle enables automation of inspections, reduction in required personnel, increased accuracy, and greater stability of inspection quality. Compared with conventional periodic inspections, the labor and costs of the close visual inspections, hammer testing and other tests required in the past are reduced and on-site work is more efficient. The system also supports diagnosis of tunnel shape and soundness, improving the quality of the diagnostics that can be done.

■ Figure 7: Tunnel expanded view

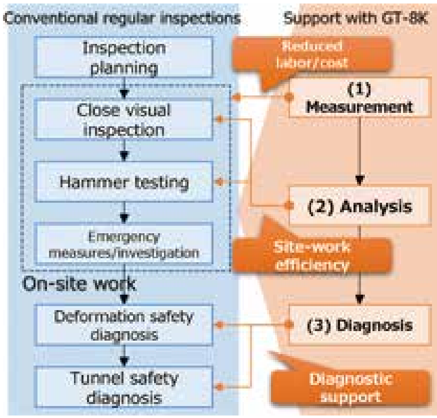


■ Figure 8: Image processing results



■ Figure 9: Image analysis

■ Figure 10: GT-8K inspection support



Use of 8K cameras in the inspection system reduces the number of cameras needed and reduces the preparation and tuning time required. It can also be expected to help reduce difficulties and errors, and to simplify monitoring during image capture. Image captured with the video cameras are consecutive in time and with images taken from other viewpoints, they can complement each other to enhance the inspection. Even for images that are difficult to discern due to the light and shadows of a structure, other images can be used for the inspection, increasing reliability and utility of the inspection. In particular, the system is designed to maximize performance of the 8K cameras, so the expanded view of the tunnel retains the color and texture of the images. This makes the inspection similar to a visual inspection, so that inspectors can use their experience gained in the past.

6. Conclusion

The increasing amount of deteriorating infrastructure is becoming an urgent issue, and we have tested effective use of 8K video technology for work inspecting such infrastructure. Digitalization of inspections promotes efficiency, and can also increase reliability, so we can expect it to be used in an increasing range of scenarios in the future. The characteristics and potential of 8K are extremely well suited to the field of infrastructure inspection, and we expect that even more successes and research results will appear in the future.

In this case, we examined roadways and tunnels, but there are also other infrastructure areas such as bridges, railways, water supply and drains, gas and electricity. We will continue to refine our technologies so that 8K can be used to increase safety and efficiency with respect to the huge amounts of infrastructure in these areas as well.

Medical Applications of 8K Technology

Takayuki Ito
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Video technology is an aspect of broadcasting that has been applied to various industries as a means of visualization. In particular, various life-saving advances have been made in the medical field through the prompt application of the latest video technology. Here, we introduce the efforts made by NHK Engineering System Inc. (NES)[1][2] to apply 8K technology developed by NHK to the medical field.

1. Development of an 8K camera and filming of surgery

Medical applications of 8K began with the filming of various surgical procedures in 8K. During each year from 2010 to 2014, we filmed heart surgery operations using 4K/8K cameras so that live video can be transmitted to other venues and presented at large-scale conferences attended by many medical professionals (organized by Tokyo Heart Lab).

In 2014, as part of an 8K technology demonstration experiment by the Ministry of Internal Affairs and Communications, we obtained 8K video of operations being performed in the fields of cardiac surgery, esophageal surgery, and liver/gall bladder/pancreas surgery at the University of Tokyo Hospital. These were presented at conferences related to each field within the hospital in order to elicit the opinions of medical professionals on the usefulness and issues of 8K images.

In 2014, we also obtained 8K video of an off-pump coronary artery bypass procedure performed by Dr. Atsushi Amano of Juntendo University Hospital. Dr. Amano is a cardiac surgeon who performs highly difficult coronary artery bypass surgery while the heart is beating and without the use of an artificial heart (i.e., off-pump). In the 8K video, it is even possible to see subtle deformations of the vessel walls while the blood vessels are being sewn together with fine thread. This highlighted the usefulness of 8K video in medical applications, with viewers remarking that it was possible to grasp the amount of force applied to the thread, and that this sort of video is extremely useful for passing on the skills of skilled physicians [2].

In February 2015, an 8K camera was attached to a surgical microscope to film a neurosurgical operation performed by Dr. Arakawa of Kyoto University School of Medicine (Fig. 1). Here, the lead surgeon and his assistant performed the surgery while looking through a microscope, and the same operative site was filmed from different optical paths. It may eventually capture microscope images with an 8K camera so that surgery can be performed while viewing a large 8K monitor.

Figure 1: A neurosurgical procedure performed under a microscope (2015)

These demonstrations not only confirmed the usefulness of 8K in the medical field, but also helped us to accumulate know-how and clarify the requirements for cameras and other equipment for such purposes. It was also suggested that 8K could be used for education by filming and storing video footage of surgeries performed by prominent surgeons.

2. Experimental demonstration of 8K telemedicine

For some time, hopes have been pinned on the use of telemedicine as a way of addressing the uneven regional distribution of medical experts and regional disparities in advanced medical care. If the use of 8K technology makes it possible to perform diagnoses that have been difficult to make with conventional technology, then it could bring about rapid progress in telemedicine. In 2016, a telemedicine demonstration experiment in which video was captured, transmitted and displayed using 8K technology was conducted by the Ministry of Internal Affairs and Communications to verify the applicability of 8K to telemedicine and the medical efficacy of this technology.

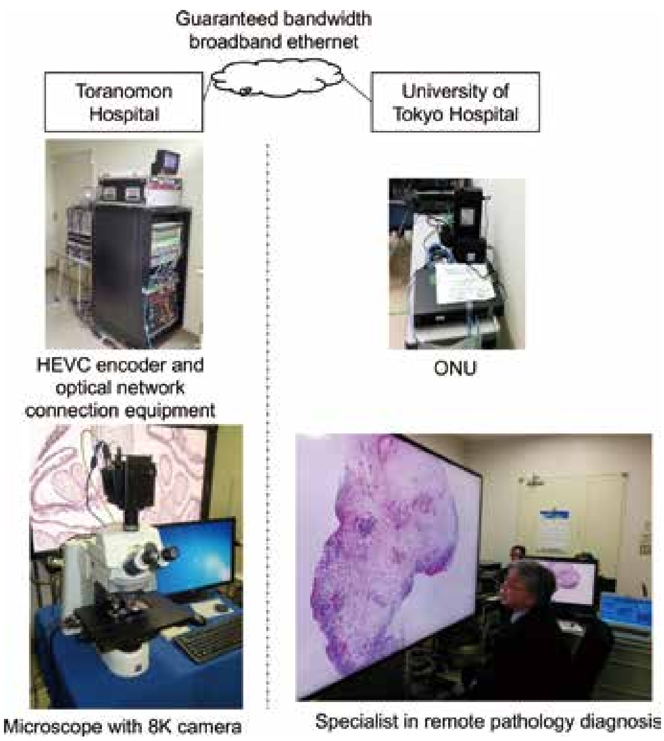
(1) Remote pathological diagnosis

Pathological diagnosis involves examining thin sections of organ parts, etc. under a microscope to check for the presence of cancer cells, bacteria, or lesions. In the case of cancer surgery, rapid pathological diagnosis is performed while surgery is in progress to confirm whether a tumor has been completely removed, and that the surfaces left after excision do not contain any cancer cells. However, since pathologists are not available at every hospital that performs cancer surgery, there is a need for the implementation of high-precision remote pathological diagnosis.

In this experiment, a microscope equipped with an 8K camera was installed in a hypothetical hospital with no pathologist, and the 8K images were transmitted over broadband Ethernet to a specialist hospital where they could be observed by a pathologist for diagnosis. The video signals were encoded using the HEVC (H.265) compression standard. Figure 2 shows an overview of the experiment.

The results of this experiment showed that 8K remote diagnosis is not inferior to direct diagnosis (103 out of 104 correct answers). The 8K remote diagnosis system is also ideal for displaying large areas of prepared specimens at once on a single high-definition screen so that the pathologist can approach the screen to get a close-up view of areas of interest in much the same way as would be achieved by switching the objective lens of a microscope. This new system is expected to be effective at improving diagnostic accuracy and reducing the burden on the medical examiner.

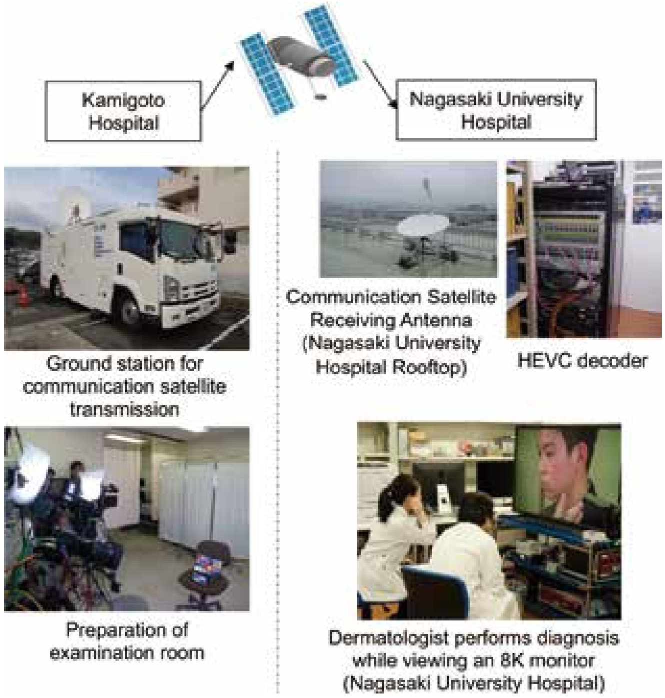
Figure 2: 8K remote pathological diagnosis demonstration experiment (2016)



(2) Telemedicine Support

To demonstrate the use of 8K technology in supporting telemedicine, we chose the field of dermatology, where visual information is considered to be of particular importance. Using a satellite link, we connected a remote island hospital in Nagasaki Prefecture, which has no full-time dermatologist, to a university hospital where a dermatologist was able to provide experimental telemedicine support. 8K images of the affected areas of patients were transmitted to the dermatologist, who was able to view them while interviewing the patients and giving instructions to the doctor on the remote island to enable to acquisition of information necessary for diagnosis. An outline of the experiment is shown in Fig. 3. By comparing the results of diagnoses made by dermatologists in person with those made by remote diagnosis, we found that the rate of agreement between these results was much higher than achieved using conventional video systems such as HD. The dermatologists who participated in the experiment commented that the ability to observe minute lesions made it possible to recognize signs of malignancy and refer patients for more thorough examinations at an earlier stage. On the other hand, it became clear that there is a need for imaging equipment that is smaller, more sensitive, and as easy to use as consumer-oriented cameras.

Figure 3: 8K telemedicine support demonstration (2016)



3. Research and development of an 8K rigid endoscopic (laparoscopic) surgical system

A rigid endoscope is a non-flexible endoscope that basically consists of lenses built into a metal pipe, unlike a soft endoscope (which is called a gastric camera). A camera is usually attached to the eyepiece so that surgery can be performed while viewing the images displayed on a monitor. A laparoscope is a rigid endoscope that is used to observe the interior of the abdominal cavity. Most rigid endoscopes use 2K cameras, but 4K endoscopes are also commercially available. To develop an 8K rigid endoscope system, it is necessary to develop a compact and high-performance 8K camera and high-performance rigid endoscope lenses that match the high-resolution performance of 8K.

In December 2015, in collaboration with the National Cancer Center Hospital and Olympus Corporation, NHK Engineering System Inc. (NES) successfully filmed the intra-abdominal cavities of animals by using an 8K camera in combination with a 4K rigid endoscope. Despite only using 4K apparatus, on seeing the 8K images for the first time, the medical professionals were surprised to find that the images were clear enough to demonstrate the benefits that can be expected from 8K technology.

In addition to clearer images, the medical professionals also expressed their hopes for the following benefits:

(1) With existing laparoscopes, it is often necessary to bring the tip of the laparoscope very close to internal organs for a closer look at the affected area, and as a result, the laparoscope is liable to get in the way of the surgical implements. With 8K resolution, it would be possible to obtain a detailed view of the affected area by observing the operation area from an overhead position and using electronic zoom when a close-up view is needed, thereby resulting in fewer blind spots and less interference between the surgical instruments and the laparoscope.

(2) With an 8K system, it is relatively easy to identify nerves that are difficult to see with conventional laparoscopy. This is expected to be effective for preserving autonomic nervous system functions in operations such as colorectal cancer surgery.

A research group that includes the National Cancer Center, Olympus and NES was entrusted by the Japan Agency for Medical Research and Development (AMED) to conduct research and development related to 8K laparoscopic surgery systems over the two periods of FY2016–8 and FY2019–21.

In the first period, we worked on the development of a compact, high sensitivity 8K camera and an electronic zoom device, and we performed animal experiments to verify the performance of the 8K system combined with a prototype 8K laparoscope made by Olympus. This 8K laparoscopic camera is shown in the upper part of Fig. 4. The camera is a modified broadcast camera using a 1.7-inch imaging device[4], and the camera head connected to the laparoscope weighs 720 g. In addition to this camera, we also implemented functions including an electronic zoom function (magnification 1.0–4.0×) that scales up a section of the 8K image. From March 2018 to March 2019, we conducted clinical trials of this system in 25 cases to verify the effectiveness of the 8K endoscopy system (see Fig. 5). The results showed that the amount of blood loss during operations was reduced to about half that of conventional laparoscopic surgery, while the camera, although smaller, was still large and made it difficult to change the operation area during surgery [5].

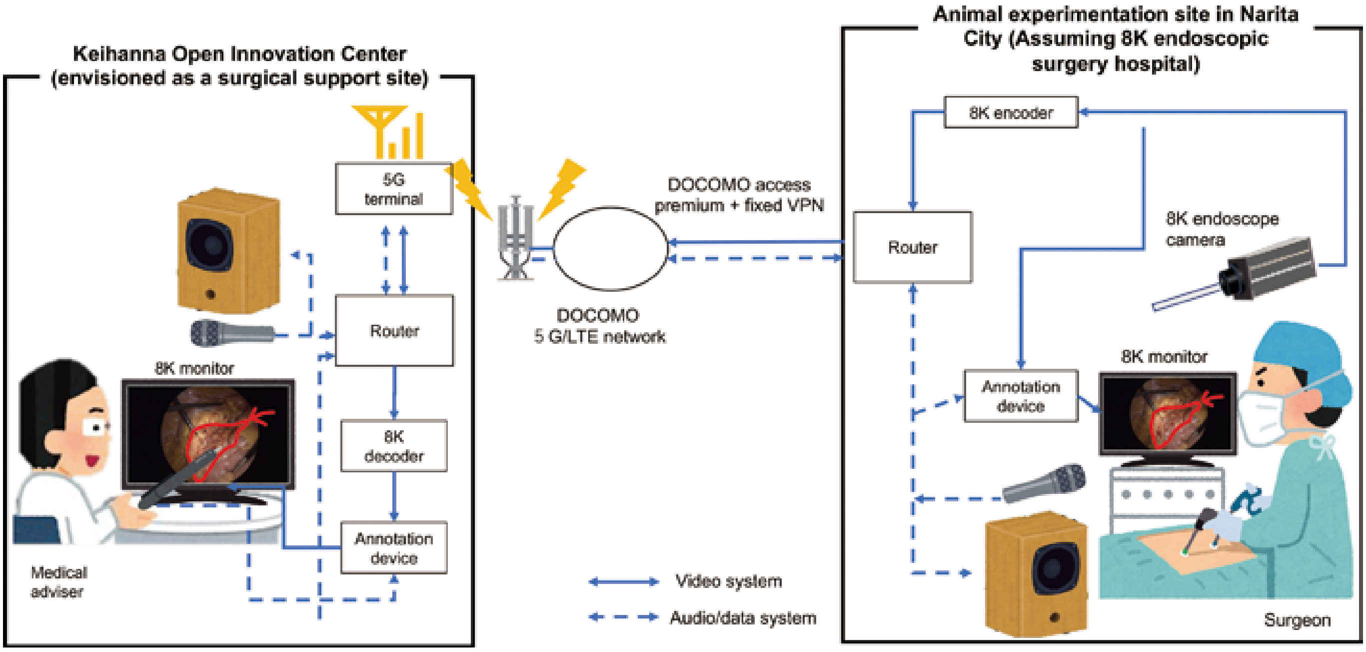
■ **Figure 4: 8K endoscopic camera system**
Top: Model #1 (2017), Bottom: Model #2 (2020)

■ **Figure 5: Clinical trial of the 8K endoscopy system**

4. Development and validation of an 8K rigid endoscopic surgery system for remote surgery assistance [6]

These clinical trials showed that although the 8K endoscopic surgery system is effective, further downsizing of the camera is also required. Based on these findings, we were commissioned by AMED to research and develop a remote surgery-assisted endoscopic surgery system for three years from FY2019 to FY2021. Recently, endoscopic surgery has become increasingly commonplace due to its low patient burden, but because it requires advanced skills, there are sometimes insufficient specialist surgeons in certain areas. We have developed an endoscopic surgery system for remote surgery assistance as a candidate technology for alleviating regional disparities in the availability of endoscopic surgeons. This system transmits endoscopic video images obtained during surgery to a remote specialist, who is able to monitor the progress of the surgery and offer advice to the surgeon in the operating theater while observing the endoscopic surgery in progress. This makes it possible to provide support to inexperienced surgeons and assistants. The purpose of the 8K endoscope is to make it possible for specialists to provide accurate

■ **Figure 6: System configuration of the remote surgery support experiment using live 8K live video transmission**



■ **Figure 7: Experimental animal surgery performed with remote surgical support**
Left: A specialist doctor provides verbal and written instructions via an 8K monitor (Kyoto Prefecture); Right: The surgeon proceeds with the surgery in accordance with the specialist doctor's instructions (Chiba Prefecture)

surgical support based on high-definition, highly realistic intra-abdominal images sent from remote locations.

NES developed this system after clarifying the above system requirements, and confirmed its medical effectiveness in animal experiments.

Prior to the development of the system, evaluation experiments were conducted with medical professionals to determine the bandwidth required for compression coding of 8K endoscope images and the acceptable lag time of transmitted images. As a result, it was found that a transmission bandwidth of at least 70 Mbps or thereabouts is required, with a video transmission lag time of no more than 1.3 seconds. The video coding method is H.265.

For the 8K camera that forms the core of the system, we developed an endoscope camera using a compact 8K medical camera that was jointly developed by NES and Ikegami Tsushinki (Figure 4, bottom). The camera weighs 210 g, which is less than a third of the weight of the #1 model. We also developed a camera control unit (CCU) with electronic zoom and autofocus functions. This camera is light enough to be used with a commercially available scope holder, making it easily adaptable to surgical applications. We also developed a system including an 8K video encoding and transmission device and a drawing and display device (annotation device) that can be used to write support information on the 8K screen and send it back to the operating theater, which is a necessary feature for supporting remote surgical operations.

5. Experiment verification of the remote operation support system[6]

To verify the effectiveness of this system, we conducted an animal experiment in which an inexperienced endoscopic surgeon and a surgical assistant were provided with guidance by a specialist physician who was able to view the 8K endoscopic images at a remote location. We compared the time taken to complete the surgery and the quality of operations performed with and without remote guidance. Figure 6 shows the system configuration used in this experiment. The experiment was conducted by connecting an animal experimentation site in Narita City, Chiba Prefecture, with the Keihanna Open Innovation Center, Kyoto Prefecture, via a wired network and 5G network so that 8K endoscopic images, bidirectional audio and on-screen instructions could be conveyed between the two sites. Figure 7 shows the setup at each end of this connection. The 8K video was transmitted at a bit rate of 80 Mbps, and the transmission lag from the endoscopic camera to the 8K display device at the remote site was approximately 600 ms.

Our experimental results show that two inexperienced surgeons were able to perform the same procedure in less time with remote guidance than without. We also evaluated the quality of surgery with and without support, based on the endoscopic images, and found that operations achieved better quality with remote guidance than without.

6. Future prospects

We have introduced activities on medical applications of 8K technology conducted by NES. High-definition imaging technology has always attracted attention in the medical field, and applications in this field have always been promoted. However, this trend is becoming particularly strong in the 8K era. In addition, “contactless” and “remote” technologies have become particularly important in the wake of the coronavirus pandemic over the last couple of years, and 5G is also expected to become an important part of the communications infrastructure. The combination of two cutting-edge technologies, 8K and 5G, is likely to become increasingly important in the medical field.

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Cover Art

View of Mount Haruna in the Snow, from Famous Views of 60 Provinces

Utagawa Hiroshige (1797-1858)

Source: National Diet Library, NDL Image Bank (https://rnavi.ndl.go.jp/imagebank/)

8K Cultural Heritage Project Initiatives

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1. NHK and Tokyo National Museum joint project: “Our 8K Cultural Heritage”

In September, 2020, the Tokyo National Museum and NHK began a joint research project using 8K technology titled, “Our 8K Cultural Heritage.” The joint research uses 8K and the latest scanner and photogrammetry technologies to focus on some of the national treasures and cultural properties held by the Tokyo National Museum, creating 8K cultural properties using ultra-high-definition 3D computer graphics, far exceeding video experiences created in the past.

Under restrictions on gatherings due to the COVID-19 pandemic, art galleries and museums around the world are searching for new ways to appreciate art. By combining these 8K cultural properties with various digital tools, we are pursuing ways to appreciate art in this new era, so that everyone can enjoy the cultural assets and experience a “wealth of heart and mind”. We are also presenting the results of this work at events and through broadcast programs.

NHK has produced and broadcast a television series related to this project titled “Fresh Encounters with our Cultural Heritage,” and the Tokyo National Museum plans to hold an exhibition featuring a compilation of results from this joint research in 2022, the 150th anniversary of the museum.

2. Created 8K cultural properties and content

8K cultural properties are extremely detailed 3D computer graphics (CG) models created using software to combine data from photogrammetry and various other sensors. So far, we have created 8K cultural properties including the seven listed below (in no particular order). For each of them, we prepared high-quality pre-rendered movies and/or interactive CG content rendered in real time, based on the original 8K cultural property CG models.

- The Kudara Kannon (held at Horyu-ji temple)
- The Goggle-eyed dogu (clay figurine)
- The Funakibon byobu screen with scenes in and around Kyoto
- The Kuze Kannon (held at Horyu-ji temple)
- A Kin-in (golden stamp, held at the Fukuoka City Museum)
- A Ko’omote-type Noh mask (Kawauchi)
- A Denyamanba-type Noh mask

▼ Scanning tools

The main tools used for scanning the cultural properties were the following.

Figure 1: Pre-rendered image of the Kuze Kannon 8K cultural property

Figure 2: Golden stamp 8K cultural property

- 3D laser scanner: FARO Focus350, ScanArm 2.5C
- Optical 3D scanner: AICON SmartScan
- Digital single-lens camera: SONY α7R Mark IV

▼Pre-rendered movies

To create the 3D CG models, Autodesk Maya and Foundry Modo software was used, and rendering was done using Arnold. We aimed to achieve high quality, assuming the results would be appreciated on an 8K-HDR display, striving to achieve near-real reproduction of both detail and color. Rendering high-quality, high-resolution CG is time consuming, and in some cases, production of these 8K cultural properties required more than an hour of processing per frame. For the four programs discussed below, NHK performed in-house rendering of 179,020 frames in a total of 160 cuts.

■ **Figure 3: Taking photos for photogrammetry**

■ **Figure 4: Pre-rendered image of the Kudara Kannon 8K Cultural property**

We received support from Mr. Shuichi Narita of AfterImage Inc. in producing these 3D CG models.

▼ Interactive content

With CG images rendered in real-time (real-time CG), it is difficult to achieve image quality better than pre-rendered CG images, but real-time CG has the advantage of interactivity, which cannot be achieved with pre-rendered CG. Observers can manipulate the item themselves, viewing it at whatever angle or size they desire. It is also useful in terms of efficiency, with lower production cost in many cases, depending on the length and number of cuts required.

The interactive content was produced using UnrealEngine, with collaboration from historia Inc. To avoid degrading the immersive quality of the content for viewers, we focused on maintaining resolution and a frame rate of 60 fps. When importing the original 8K cultural property data into the UnrealEngine environment, we optimized to minimize any visual effect. We used a workstation equipped with an NVIDIA Quadro RTX 8000 GPU to create the real-time CG images.

We output the interactive content to 8K displays and projectors, manipulating it with a game controller, and we also developed VR/AR content using a head-mounted display (HMD). To utilize the quality of the 8K cultural properties and facilitate immersive virtual-space content, we used a Varjo XR-1 capable of displaying high-resolution CG for the HMD.

The interactive content was all produced using the SDR color space. The photogrammetry photos are recorded as RAW data, so it would be possible to produce it with a richer color space, but considering issues such as production time and the processing load on the PC used for real-time CG rendering, we decided to use SDR. Support for HDR will be an issue for consideration in the future.

■ **Figure 5: Performer manipulating the Goggle-eyed clay figurine projected on a 450-inch screen**

3. BS8K program, “Fresh Encounters with our Cultural Heritage”

NHK is also producing a TV series for the BS8K channel titled “Fresh Encounters with our Cultural Heritage” (https://www4.nhk.or.jp/P6741/). The program features various cultural properties, with the host and guests examining them from angles and close-ups that would never be possible normally, gaining a thorough appreciation of the items, speculating on the intentions and values of the creators as they do so, and enabling viewers to also share in this appreciation.

As of January, 2022, the following four programs have been produced. We created pre-rendered movies and interactive content for each of the programs, to clearly present features of each item, as required for production. Each of the 8K cultural properties is discussed more specifically below.

▼ Goggle-eyed clay figurine

The 3D CG model of the clay figurine is composed of approximately 7.85 million polygons, using 13 8K-resolution textures. The interactive content can be manipulated using a game controller, with zoom, pan and tilt operations to rotate the figure and change the viewpoint. A user-friendly interface is provided, which can be used easily even by users not accustomed to 3D CG operations. It has a simple viewpoint-reset operation to reset the position to facing the figure, and a “B-dash” function to move the figure quickly, by holding the “B” button and operating the joystick. Another function enables the user to go inside the figure with the push of a button.

We also developed VR content that enlarges the figurine by

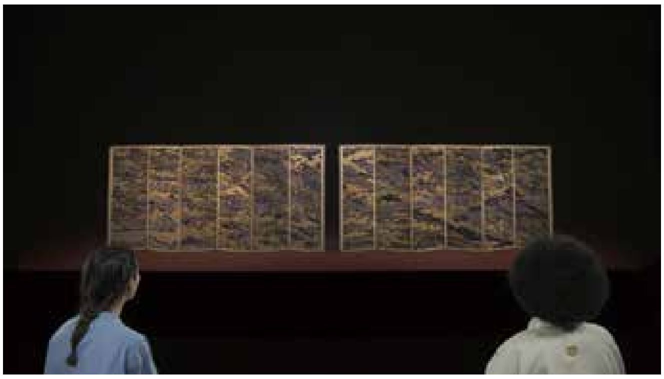
500-times and lets the user move around inside the figurine.

■ **Figure 6: Performer wearing an HMD and the clay figurine VR content**

▼ Funakibon byobu screen with scenes in and around Kyoto

The Funakibon byobu screen portrays more than 2,700 people of influence, such as samurai, as well as shopkeepers and other commoners. To be able to show each of the people on the screen magnified on an 8K display, the CG model required textures with extremely high resolution. The 8K cultural property of the Funakibon byobu screen with scenes in and around Kyoto uses 210 8K-resolution textures (which are actually divided into 840 4K-resolution images). This comprises over 100 GB of data, so it was impossible to load the entire set of textures into the GPU for display. By implementing careful high-speed processing to swap textures according to the camera distance and the area being displayed, we were able to implement seamless operation without losing detail, regardless of the magnification of the byobu screen (so-called level of detail (LOD) processing). With simple LOD processing alone, it is difficult to avoid noticeable texture switching, so before recording the TV program, we adjusted various parameters such as display timing on a trial and error basis to find the best settings.

■ **Figure 7: Pre-rendered image of the 8K cultural property, "Funakibon byobu screen with scenes in and around Kyoto"**



■ **Figure 8: Interactive content: Zooming to see people's facial expressions**

▼ Kudara Kannon

The first program in the series dealt with the Kudara Kannon, and preparation involved was really a learning process. The 3D CG model consisted of approximately 4.8 million polygons and 21 8K-resolution textures. In the studio we displayed the pre-rendered CG on a 1.6 m by 3.6 m LED display built on the set, to create a photo-real, actual-size display. We also developed interactive VR content that gives a sense of scale while wearing the HMD by showing the Kudara Kannon image over the Japanese archipelago, and AR content that allows very close observation by integrating the Kudara Kannon image with live images inside the HMD. In the program a Buddha sculptor attempts to carve a replica using this AR content.

Normally with VR and AR, some method is used to detect the location of the HMD and its motion is linked to a camera in the CG space to display the CG at the corresponding position in the HMD. In this case, we developed a function using a similar mechanism, using a controller attached to the HMD to move the camera in CG space, so the controller can be used instead of the HMD to set the camera position for the CG shown on an 8K display connected to a workstation. Using this function, after recording the program, the presenter's movements were reproduced using the controller, and the video seen by the presenter in the HMD was simulated as 8K video. This was output and recorded on P2. This arrangement was also used later

■ **Figure 9: Kudara Kannon 8K cultural property built into the studio set**

for the Goggle-eyed clay figurine content, and was effective for events during the COVID-19 pandemic.

▼ Kuze Kannon

The 3D CG model of the Kuze Kannon consists of approximately 6.65 million polygons and 17 8K-resolution textures. For interactive content, we developed two features: 1) Content that enables the Kuze Kannon to be appreciated on an 8K display or 8K screen from any viewpoint, using a game controller, and 2) AR content that enables the operator to pick up the CG Kuze Kannon and move it around using the HMD controller. In the TV program, a researcher in the studio uses this AR content, attempting to place the Kuze Kannon image appearing in the HMD onto a virtual pedestal. We also developed a system described below, to share the Kuze Kannon CG with remote locations (Tokyo, Nara), and conducted a "Digital research conference".

■ Figure 10: Interactive content video of the Kuze Kannon 8K cultural property

4. Non-broadcast exhibitions

▼ Tokyo National Museum exhibit event

In March, 2021, an event exhibiting our 8K cultural properties, together with a press conference, was held at the Tokyo National Museum. The interactive content for the Funakibon byobu screen with scenes in and around Kyoto was projected in 8K onto a large screen. Also in the exhibit were real byobu screens and PV of the 8K cultural property pre-rendered movie, on an 8K display playing on a loop. The Goggle-eyed clay figurine interactive content was also shown and demonstrated on an 8K display.

▼ Inter BEE 2020/ 2021 exhibits

For Inter BEE 2020, which was held online, a 3D scan was taken of the artistic set in the "Fresh Encounters with our Cultural Heritage" studio and presented as VR content under the topic, "8K production tour of studio and relay vehicle".

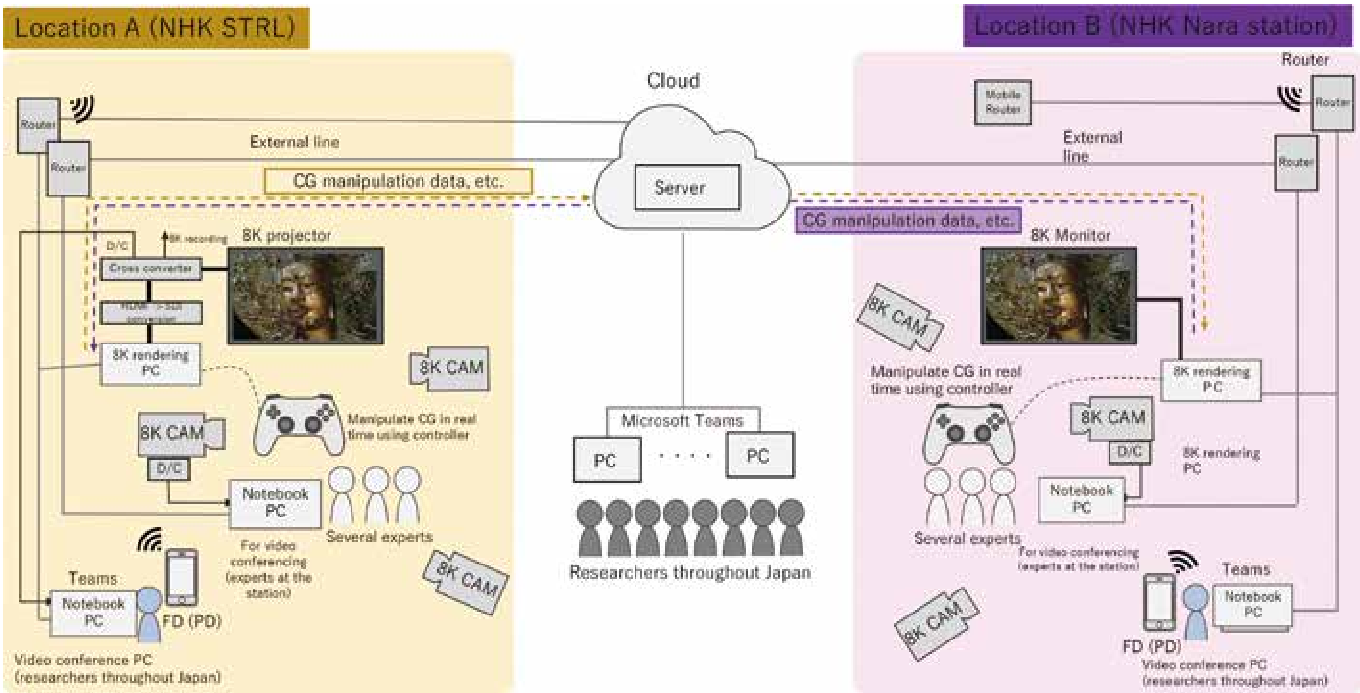
For Inter BEE 2021, the interactive content for the Goggle-eyed clay figurine was exhibited, and many visitors were able to experience this 8K cultural property.

▼ Kuze Kannon image digital research conference

In June, 2021, we held a "Digital research conference" as a special part of the 8K Cultural Heritage Project. For the research conference, researchers from the NHK Science and Technology Research Labs (NHK STRL) and from the NHK Nara broadcasting station gathered to study the Kuze Kannon, a national treasure. The Kuze Kannon interactive content was installed on workstations at the two locations and projected onto 8K screens. At each location, a game controller was used to zoom in and out, and to move the 3D CG model around, and the

■ Figure 11: Projecting the Funakibon byobu screen with scenes in and around Kyoto on a large screen

■ **Figure 12: Digital research conference overview**



■ **Figure 13: Digital research conference (NHK Nara broadcasting station)**

control signals were synchronized between the two locations to share the same 8K images.

At the meeting, specialists were able to zoom-in on particular areas of interest, sharing the image among all participants, while engaging in discussion and making new discoveries. Excerpts from the research conference were shared during the "Fresh Encounters with our Cultural Heritage: Kuze Kannon" program.

5. Future initiatives

In January, 2022, we completed a new 8K cultural property called "Noh Masks." For details, please watch for the up-coming program, "Fresh Encounters with our Cultural Heritage: Mysterious Noh Masks" (provisional title). We are currently working on production of another property called "Armor".

Since June, 2021, we have also collaborated with local broadcasting stations in Nara, Akita, Gifu and Sapporo to exhibit our 8K cultural properties. We hope to provide opportunities to appreciate and experience these properties at many more events in the future, although this will be depend on conditions with the COVID-19 pandemic. We also plan to hold an event to announce joint-research results from the 8K Cultural Properties Project as part of the Tokyo National Museum 150th anniversary celebrations. Please look forward to that as well.

■ **Figure 14: An event held in collaboration with the Gifu broadcast station in Hida City (at the Hida Miyagawa Archeology and Folklore Hall)**

Latest Trends and Future Directions in Ultra-High-Definition Imaging Technology Accelerating Smart Industry

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1. Introduction

4K and 8K ultra-high definition imaging technology is being used to improve image quality in broadcasting, but it is also being used in various other fields, such as to display advertising on outdoor displays, to implement ultra-high-definition systems for security and crime prevention, and for medical applications. In industry, where smart technologies are being used to increase productivity dramatically as we enter the IoT age, high-definition and high-quality images can be taken, and there is increasing use of sensing technologies utilizing infrared and other images not visible to the human eye. Image sensors are a key type of device necessary for these advanced types of machine-vision camera. Industrial image sensors require high quality and continuous availability. Industrial applications vary widely, so a significant feature of this market is the need for a broad product lineup. We are a leading company in image sensors, with a broad portfolio of products covering small to large, low to high-speed, low to high pixel counts, and from ultra-violet through infrared frequencies, to meet all kinds of requirements. Each series is also packaged with uniform pin-outs, so it is easy to develop product lineups when developing machine vision cameras.

This article describes our vision for advancement of image sensors for industrial applications and introduces some examples of practical applications. Figure.1 shows our vision for the evolution of image sensors in the future. We have defined three directions for advancement. The first is to improve the performance of our base image sensors, the second is to extend performance from imaging to sensing, and the third is to optimize functionality for edge systems. We describe each of these perspectives in detail below, and also give examples of related machine vision cameras systems.

2. Advances in imaging performance

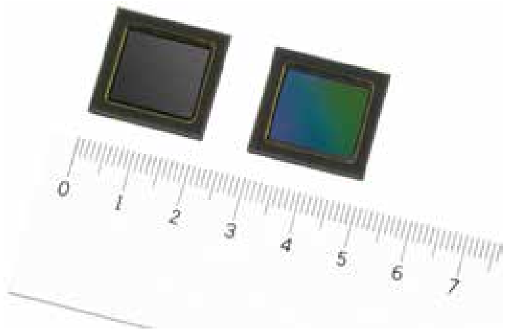
To implement advanced automation in areas such as factories or logistics requires improved efficiency by increasing the accuracy and decreasing the time required for inspections. For machine vision cameras, which handle most of these functions, this requires image sensors with higher imaging performance in terms of resolution (higher definition), higher speed, and other factors. This section examines typical image sensor performance improvements in the areas of increasing resolution while reducing size, and technologies to improve productivity by increasing image-sensor size while accelerating data read-out.

2.1 Achieving both higher resolution and smaller size

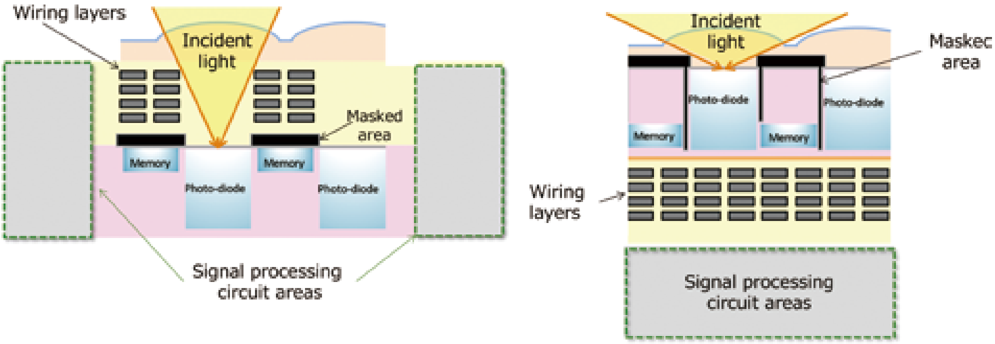
When attempting to improve accuracy for visual processes detecting small defects or contamination, simply increasing the pixels in the image sensor results in larger chip size and larger cameras, which can be an issue. Conversely, if the pixels are made smaller to avoid increasing the camera size, the light-collecting area per pixel decreases, leading to decreased image quality and unavoidable decreases in recognition and detection performance. To resolve this issue, we have developed a layered CMOS image sensor technology called Pregius S™ (Figure 2, 3) that is suitable for industrial applications. It has a "Global Shutter" feature that uses a back-illuminated pixel structure to achieving both high resolution and smaller size. The new structure is able to collect more light per pixel than conventional front-illuminated structures, and we developed technology to mask the memory components in our global shutter function, so that pixel characteristics are not compromised, so we were able to reduce pixel size to 2.74 µm diagonally, or 63% of earlier pixels. By

Figure 1

Figure 2



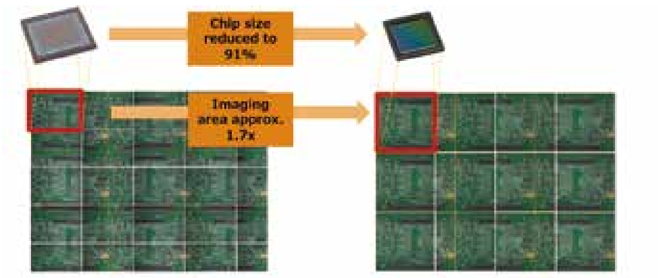
■ Figure 3



Earlier front-exposure structure with Global Shutter function

New layered structure with Global Shutter function

■ Figure 4



Earlier product: IMX253 (12.37M pixels) x 25 images

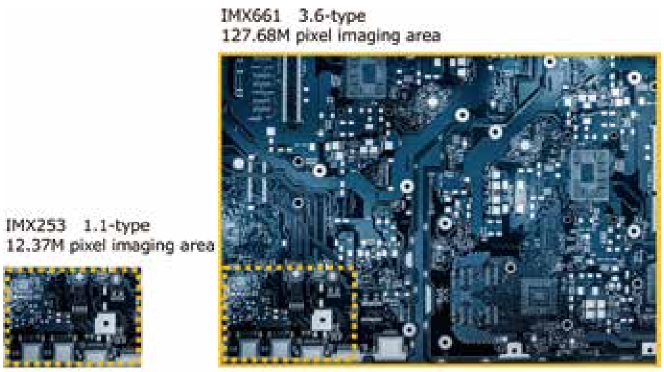
New product: IMX531 (20.35M pixels) » 12 images

layering the signal processing circuits, which were conventionally placed in beside the pixels, we have also increased resolution by approximately 1.7 times for the same optical system (from 12.37 M pixels to 2.035 M pixels) and reduced the package size (to 91% of earlier[*1]) (Figure 4).

2.2 Image sensor technologies for larger size and faster readout

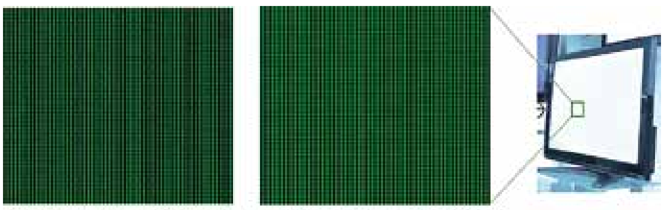
Some machine vision cameras use an image sensor that supports ordinary C-mount lenses, but further productivity increases can be obtained by using an image sensor with a larger optical size to increase the imaging area. For example, comparing our IMX235 image sensor, which is 1.1-type (diag. 17.6 mm) and has 12.37 M pixels, and our large-aperture IMX661 image sensor, which has our Global Shutter function, is 3.6-type (diag. 56.7 mm) and has 127 M pixels, productivity can be increased by reducing the number of images captured, and recognition accuracy can be improved with the higher resolution (Figure 5). For inspection of flat panel displays, if the image sensor resolution is too low relative to the resolution of the panel, moiré patterns occur as shown in Figure 6, so inspection with oversampling using an ultra-high-definition image sensor is very useful. On the other hand, when the number of pixels is increased, generally the amount of signal processing required also increases, the frame rate decreases and more time is required to read out the data. With the IMX661, we used a Chip-on-Wafer process technology to create an original device structure, layering a chip with some of the functionality onto the pixel wafer and increasing processing performance by implementing AD converters in an optimized location. We also used a high-speed interface called Scalable Low Voltage Signaling with Embedded Clock (SLVS-EC) to achieve a four-times increase in image read-out speed* . For inspection

■ Figure 5



* Using a lens with the same focal distance, the IMX661 on the right captures approximately 10-times the area of the IMX253 on the left.

■ Figure 6



Capture at low resolution (moiré pattern)

Capture at high resolution (no moiré pattern)

＊1 Comparing our IMX531 and IMX253 CMOS image sensors with the Global Shutter function. “Pregius S” is a trademark or registered trademark of the Sony Group and related companies.

of devices such as flat-panel displays and printed circuit boards, cameras with large-aperture image sensors are being used more and more. Larger areas to be imaged in a single shot by using of larger image sensors and fast read-out technology, reducing both the number of images taken and the inspection time, and inspection accuracy can be improved by increasing resolution.

3. Extending capabilities to sensing

Recently, the use of sensing beyond the capabilities of human vision is advancing in the field of industrial machinery. In addition to conventional inspection and recognition using visible light, new information such as near-infrared, polarized light, and distance data is being captured, making it possible to solve problems that could not be solved earlier with sensing. In this section, we describe four of these various new sensing technologies: Short-Wavelength InfraRed (SWIR) image sensors, Ultraviolet (UV) light image sensors, Time-of-Flight (ToF) range-imaging sensors, and polarized-light image sensors.

3.1 SWIR Image sensors

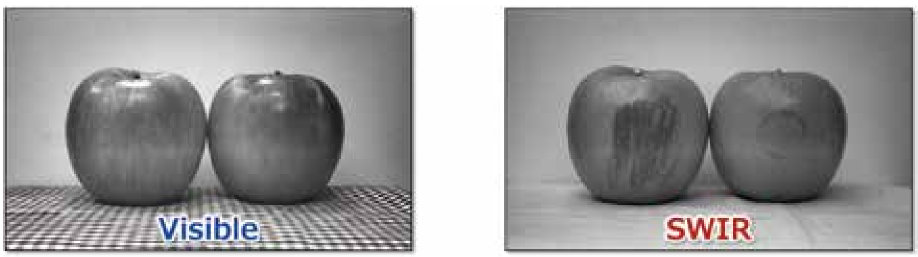
SWIR is a type of infrared light with relatively short wavelengths. In 2020, we announced our IMX990/IMX991 image sensors, able to capture images over a wide range of wavelengths that include visible light, from 0.4 µm to 1.7 µm. When developing SWIR sensors, we formed photodiodes in a layer of the compound semiconductor, Indium-Gallium-Arsenide (InGaAs) and the read-out circuits in a silicon layer, making copper-copper (Cu-Cu) connections between them. This enabled us to reduce the pixel pitch, achieve wide bandwidth and create an image sensor supporting SWIR, which was not possible earlier.

SWIR wavelengths can be used to visualize damage to fruit below the surface (visualizing differences in moisture density) as shown in Figure 7, or to select materials utilizing differences in absorption of short-wavelength infrared light. The new sensor can be used as a more versatile inspection device to reduce system costs, by using a single device for inspection that previously required separate cameras for visible and SWIR light, or to increase throughput, by accelerating image processing.

3.2 UV image sensors

Sensing with ultra-violet (UV) light can be useful for selecting materials difficult to differentiate with visible light, or to detect fine scratches or defects. UV light has wavelengths that are shorter than visible light, generally in the range of 10 nm to 400 nm (Figure 8). Our IMX487 image sensor detects wavelengths from 200 nm to 400 nm, and is suitable for industrial sensing using UV wavelengths. Used with a UV light source, it shows promise for a wide range of use cases, including detecting semiconductor pattern defects, differentiating materials for recycling (Figure 9), and detecting minute scratches on the surface of parts. This product has a structure specialized for sensing UV wavelengths, and is equipped with our Pregius S technology, so it produces high frame-rate images without motion distortion. We expect it to expand the range of applications for UV image sensors, including those requiring high speed.

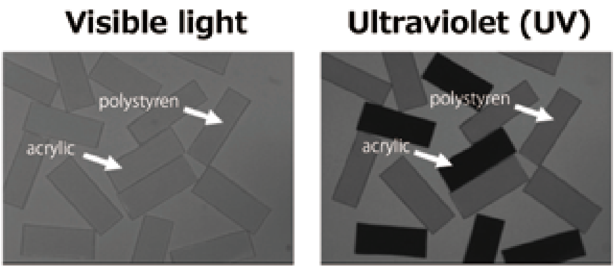
■ Figure 7



■ Figure 8

＊2 Comparing our IMX661 and IMX253 sensors with the Global Shutter feature.

■ Figure 9



Differentiating acrylic and polystyrene using UV light

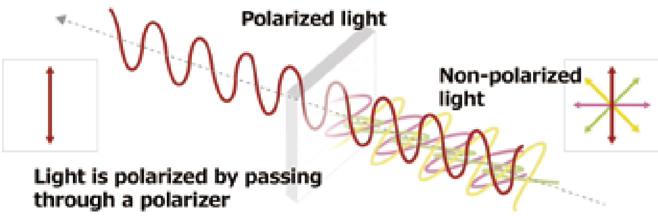
3.3 Polarized light image sensors

Normally, when looking at an object, we see both light that is reflected and light that is diffused from the surface of the object. This light oscillates in different directions and it is possible to select light oscillating in a particular direction (polarization) by passing it through a polarizer (Figure 10). Our polarizing image sensors (e.g.: IMX253MZR) are equipped with internal polarizers for four directions and are able to capture polarization data for these four directions in a single image (Figure 11). As shown in Figure 12, this polarized light data can be used to increase the accuracy when detecting scratches, impurities or distortion on the surface of objects or to eliminate reflected light, which are difficult using conventional visible-light sensing,. We expect this to enable a range of other applications in the future.

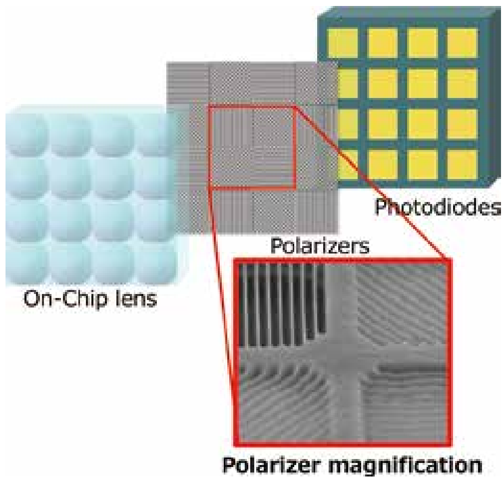
3.4 Time of Flight depth-image sensors

A Time-of-Flight (ToF) depth-image sensor uses light from a laser or LED to measure the distance to the object, by measuring the differences in time required for the reflected light to reach the sensor. We announced the IMX570 image sensor in 2021, as a compact, high-resolution sensor capable of sensing in 3D space

■ Figure 10



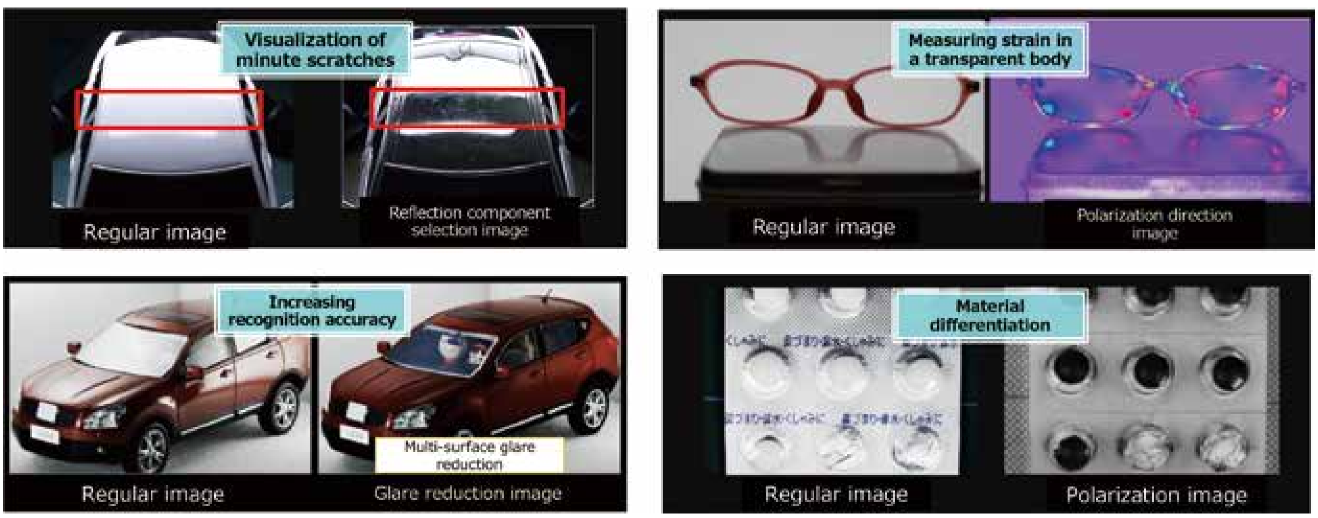
■ Figure 11



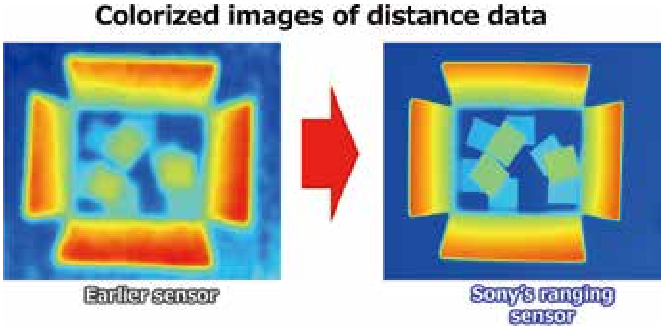
(Figure 13). It was developed for applications that are difficult to implement with conventional 2D images, such as those requiring detection of volume or shape, or overlapping of objects.

By providing this lineup of various sensing devices, we are contributing to solving problems in manufacturing settings such as eliminating failure, increasing throughput, eliminating line stoppage, reducing labor requirements and automation.

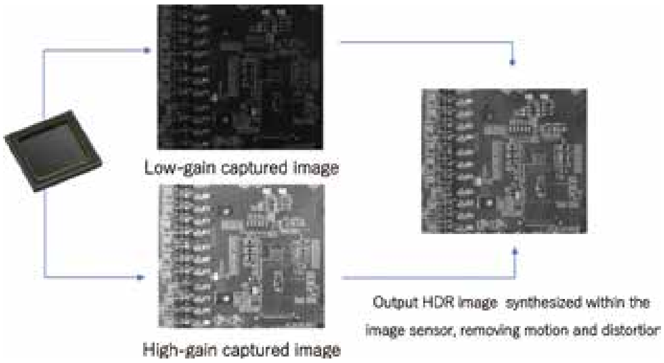
■ Figure 12



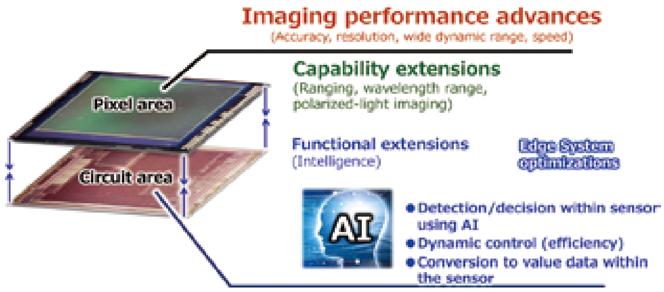
■ Figure 13



■ Figure 14



■ Figure 15



4. Functional extensions optimized for edge systems

Conventionally, image sensors have been developed with the assumption that human eyes would be looking at the images, and sensors would output images in terms of effective pixels. However, when used by AI or other machines, all of the pixel data will not necessarily be required. For example, when inspecting printed circuit boards, it may be enough to inspect only specific components or locations. In such cases, pixel data from other locations is not needed and capturing the extra data increases the time required from image capture till peripheral devices can take action. Even when considering the simple imaging devices described in earlier sections, the amount and types of data is increasing greatly, with more pixels, faster speeds, and additional data such as polarization and distance. As inspection of components advances and camera resolution increases, the volume of information will increase dramatically, also increasing the processing load for image processing and interface circuits at later stages.

As such, when considering AI and other machine processing, it will be useful to extract only the regions needed, to reduce the amount of data and the required processing time. Our image sensors have a Region of Interest (ROI) function to extract only the area needed, and a self-triggering function to output only data from the instant required. They are also equipped with two AD converters in a layered implementation, which can read data at two different levels of gain, and they have functions to synthesize these values internally. High Dynamic Range (HDR) processing, which is normally implemented by overlapping multiple images, can be performed by synthesizing the images within the sensor, without producing artifacts, and we have implemented highly-robust sensors able to output the same amount of data as earlier sensors (Figure 14).

This sort of extended functionality can be implemented using layering technology. As shown in Figure 15, a key point regarding the layering technology is that the wafer process is separated into a pixel region and a circuit region. This makes further image-quality improvements and functional enhancements both more scalable. Techniques applied to the wafer process can also be extremely useful in reducing latency, implementing feedback to pixels and reducing power consumption. Extending functionality will surely be helpful as AI is used more and more in the future. It will be extremely important how this overall issue is handled, including later-stage system processing, and we are continuing to work on both hardware and software solutions for these issues.

5. Conclusion

This article has introduced directions for advancement of image sensors (advancing and extending performance and functionality) as considered by Sony Semiconductor Solutions. We have over 120 types of products developed along these directions, to meet a wide range of requirements in industry. We will continue advancing innovation in image sensor technologies, cultivating new applications, accelerating smart industry, and contributing to improving lifestyles and solving societal issues. For product details and inquiries regarding image sensors for industrial equipment, please see the following address.

https://www.sony-semicon.com/en/products/is/industry/index.html

= A Serial Introduction Part 2 = Winners of ITU-AJ Encouragement Awards 2022

In May every year, The ITU Association of Japan (ITU-AJ) proudly presents ITU-AJ Encouragement Awards to people who have made outstanding contributions in the field of international standardization and have helped in the ongoing development of ICT.
These Awards are also an embodiment of our sincere desire to encourage further contributions from these individuals in the future.
If you happen to run into these winners at another meeting in the future, please say hello to them.
But first, as part of the introductory series of Award Winners, allow us to introduce some of those remarkable winners.

Yuichi Kumaki

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Fields of activity: Global business development

Technical support for optical access at the PT Telkom Group in Indonesia

It is a great honor to receive this prestigious encouragement award from the ITU Association of Japan at this time. I would like to express deep gratitude to all who lent their guidance and encouragement, leading to this award.

I have worked with PT Telekom Indonesia since 2010. During that time, I was involved in planning and executing various technology exchange efforts, mainly related to optical access.

Beyond simply sharing procedures and specifications from the experience and know-how of NTT East, I also worked carefully to build their understanding of why particular methods or specifications were adopted, history, and background from each generation, to build a trust relationship. Then, since 2016 and at the request of PT Telekom, we have operated a paid technical support consulting project. In this technical support activity, we first carefully explain why the methods and tools we introduce are needed, so that they will adopt them, and then, through repeated discussion with local members, select methods and components that can be procured locally, tuning them to the local environment as much as possible. This sort of effort has been well accepted, and we are currently providing support to train technicians for deploying the methods we have proposed throughout the country.

To be involved in projects in an environment that is completely different from Japan, and to work with many local team members has been an irreplaceable experience for me. I was able to see energetic, cheerful and enjoyable workplaces in Indonesia with my own eyes and to learn many things. I would like to continue to work, contributing to the expansion of telecommunications in Indonesia in the future.

Kazuhiro Kumamaru

Japan Broadcasting Corporation (NHK)
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Fields of activity: ITU-R SG4, SG6

Activities in ITU-R

It is an honor and a great pleasure to receive this ITU-AJ Encouragement Award. I would like to express my sincere gratitude to the ITU-AJ and all the others for their guidance and support.

I first participated in ITU-R activities at the ITU-R SG4 (Satellite Services) meeting in 2017. Since 2020, I have been actively involved in SG6 (Broadcasting Service), contributing to technical studies and standardizing satellite broadcasting and broadcasting technology. This award recognizes work I have done in various areas as follows.

I contributed to revision of the recommendation (BT.1871) outlining the requirements and operational characteristics of radio systems necessary for broadcasting services, such as wireless microphones. In particular, I compiled information on frequencies of wireless microphones used by Japanese broadcasters and added the data to the recommendation. I hope that this revision will lead to harmonization of frequencies used by wireless microphones both regionally and globally. In compiling this information, I received helpful support from the Ministry of Internal Affairs and Communications (MIC), the Japan Commercial Broadcasters Association (JBA), the Association of Radio Industries and Businesses (ARIB) and others.

Another part of my work pertains to a new report (BO.2497) on the criteria for sharing broadcast satellite frequencies. The report, proposed by NHK/B-SAT, summarizes the results of technical studies reviewing possible changes to satellite coordination procedures. This was for an agenda item at the World Radio Communication Conference (WRC-19) in 2019. The contents are also relevant to Japan's BS left-handed circularly-polarized frequencies registered for 4K/8K satellite broadcasting in 2016. There were several problems, and discussions among concerned parties continued until the final plenary meeting. Ultimately, we reached a mutual agreement. I hope that this report will promote the stable use of frequencies for 4K/8K satellite broadcasting in the future.

I hope to continue utilizing my experience with ITU-R and contributing to further development in the broadcasting industry.

Susumu Saito

Japan Broadcasting Corporation (NHK)
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Fields of activity: ITU-R SG4, SG6, Broadcasting Service, Satellite Broadcasting

Activities related to broadcasting services

I would like to offer my sincere thanks for this ITU Association of Japan Encouragement Award at this time. I would also like to offer thanks to all those who have provided their guidance.

I have participated in ITU-R activities since 2010, protecting satellite broadcasting operations and requesting new satellite broadcast frequencies from ITU-R as needed for advanced satellite broadcasting.

I currently participate in SG4 for satellite services, SG6 for broadcasting services, and SG5 for terrestrial services. In SG6, I participated in discussions of sharing and compatibility studies between broadcasting and mobile service, and contributed to creation of a new recommendation (BT.2136). In SG4, I contributed to creation of a new report (BO.2497) clarifying relationships among satellite frequency sharing criteria (PFD and EPM criteria). In SG5, I contributed revisions to recommendations M.1824 -1 and F.1777-2, adding information on Japanese standards for 4K and 8K FPUs.

I hope to continue contributing to maintaining and expanding the broadcasting services built by my predecessors, in areas including study of sharing between broadcasting and other businesses and standardization work to advance broadcasting further in the future.

Hidekazu Shimodaira
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Fields of activity: 3GPP/O-RAN

Contribution to standardization through development of commercial equipment

I am very honored to receive this prestigious ITU Association of Japan Encouragement Award. I would like to express sincere gratitude to everyone at the ITU-AJ and others involved.

Since I first joined NTT DOCOMO, I have been involved in study of commercial equipment specifications and technology for interconnection interfaces in cross-vendor configurations. Originally it was just commercial equipment specifications, but I gained recognition for my knowledge of 3GPP standards and the clarity of technical elements in interconnection interfaces for cross-vendor configurations, and have been doing standardization work with 3GPP since October, 2018, and with the O-RAN Alliance since October, 2020.

At 3GPP, I initially worked on standardization of functions such as positioning in RAN1, but now I am working on overall standardization of Radio Resource Management (RRM) functions in RAN4. In O-RAN standardization, I worked on a proposal for a standard function that will enable more flexible use of Fronthaul Multiplexer in 5G. In both of these standardization activities, I worked to bring a perspective of commercial equipment development to the standardization process. In FY2022, study for 5G Advanced began, and I have been given the role of joint-rapporteur (responsible for summarizing results of discussion) for a Work Item studying extended functions for Non-Terrestrial Networks (NTN). The rapporteur's abilities can affect whether study of a 3GPP specification can complete on schedule with agreement from all parties, so I will continue to work hard to ensure that our study completes as planned.

Hiroki Takeda
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Fields of activity: 3GPP RAN Plenary and RAN2/3 standardization

3GPP RAN Plenary and RAN2/3 Standardization Activities

To begin with, I would like to say that I am sincerely thankful on receiving an ITU-AJ Encouragement Award. I would also like to extend my heartfelt appreciation to all concerned for their guidance and support in past activities.

I have been participating in 3GPP RAN standardization activities for about nine years since 2013 and have submitted a variety of proposals at RAN Plenary meetings. These include a work-item proposal on the standardization of LTE carrier aggregation and a proposal for early standardization of a 5G NSA (Non-Stand Alone) system (technology for providing 5G using the existing LTE network) toward the launch of commercial services in 2020. Furthermore, in RAN2/3, I have submitted contributions and have been involved in drafting standards for LTE functional extensions for drones and for diverse technologies such as RAN slicing by holding discussions with engineers from various companies. I have also served as a joint Rapporter with representatives of overseas operators and vendors for study items in 5G Technology Integrated Access and Backhaul (IAB) toward a base-station wireless backhaul.

It was not an infrequent occurrence at these standardization discussions for my opinion to clash with those of others, but despite these difficult situations, I came to learn the importance of respecting the ideas of others and to steer discussions toward a common objective. Additionally, given that LTE and 5G are technologies used widely by people around the world, I take great pride in my involvement in drafting these technical standards.

Going forward, I would like to make an even greater effort to contribute to the further development of the communications industry by applying my expertise and experience to date.

通巻百三十七号

定価　一冊　一、六五〇円（本体価格 一、五〇〇円、消費税 一五〇円）　年間購読料　六、六〇〇円（本体価格 六、〇〇〇円、消費税 六〇〇円）

The ITU Association of Japan