

Sony's Technology 2020

SONY

Sony's Technology 2020

Sony is a "Creative Entertainment Company with a Solid Foundation in Technology."
For Sony, technology is one of the most important elements that empowers our diverse businesses,
creates long-term value, and enables sustainable growth while contributing to society.

"Sony's Technology 2020" is the second technology-focused issue of the Sony Group's magazine,
and follows the "Paving the Way to the Future with Technology" issue of Family published in June 2019.

Sony's technology "inspires emotion." In this issue, we will introduce Sony's cutting-edge technology
with specific examples of projects along interviews with the employees in charge.



sony.net/tech2020

If you wish to access this story online, and watch related video clips, please visit.

Contents

- 4 **Technology That Inspires Emotion**
Three Themes to Get Closer to People's Motivations

Exceed Exceed human capabilities

- 6 Imaging and Sensing Technology
Seven Technologies Explained by Employees who Helped Develop Them
- 10 Hawk-Eye
Making Sports More Exciting Through Visualization Technology

Connect Connecting people with people, and people with products

- 14 Real-Time Transmissions through 5G
A New Way of Live Video Production Using 5G's Strengths
- 16 Dynamic Spectrum Access (DSA)
Optimizing Use of Radio Frequency Resources towards the 5G/Beyond-5G Era
- 18 360 Reality Audio - An All New Music Experience
Creating an Ecosystem to Provide an Immersive Sound Field to Even More Customers
- 20 Eye-sensing Light Field Display
Delivering 3D Creators' Visions to Customers the Way They Intended
- 22 "GOOD DRIVE" - Insurance Service to Reduce Accident Risks
Changing Driver Behavior through Technology and Insurance System

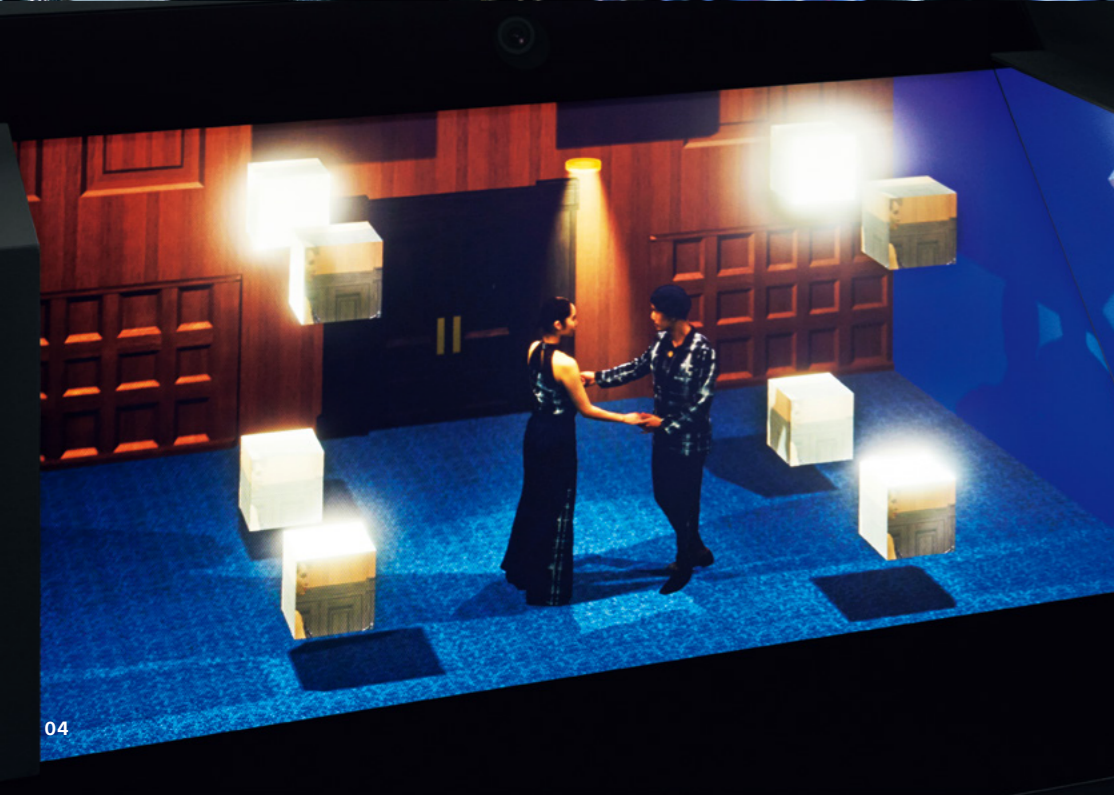
Empower Unleash human creativity and remove limitations

- 24 Aiming for VR Capable of Realizing the Impossible
Volumetric Capture Technology That Goes Beyond Omnidirectional Visualization
- 26 Haptics
Taking on New Challenges with Haptics
— A Technology that Stimulates the Sense of Touch, One of the Five Senses
- 28 Ray Tracing
Evolving Visual Expressions for Game Creators

- 30 Moving Towards Evolution in Mobility with "VISION-S"
Sony's New Initiative Pursues Comfort and Entertainment in the Realm of Mobility
- 32 Knowledge Sharing through Engineering Report
Significance of Reporting Learned from the "Iwama Report"
- 34 Aiming for More Comfortable and Secure Mobile Society with AI and Sensing Technology
Future Mobility Project
- 35 Sony AI
Attracting the World's Best AI Researchers and Engineers to Unleash the Potential of Sony's AI

Aiming for a sustainable society

- 36 Synecoculture
A Farming Method for a Sustainable Future
- 37 Small Optical Link for International Space Station (SOLISS)
Contributing to the Construction of Space Communication Infrastructure through Optical Disc Technology
- 38 Smart Agriculture Solution
Better Agriculture through Imaging Analysis
- 39 Imaging and Sensing Technology
Solving Environmental Problems to Realize a Prosperous Society
- 40 Interview 1
Pursuing Diversity and Globalization to Strengthen Sony's Technology
- 43 Interview 2
Realizing a Better Future through Sony's Imaging and Sensing Technology
— To Spark Imaginations and Enrich Society
- 44 CLOSE UP
Utilizing the Latest Technologies and Getting Closer to Our Creators at Sony Pictures
— With a Vision of One Sony
- 49 Case Studies in Collaboration
Virtual Production: Volumetric Capture for Movie Quality
Audio Source Separation with AI: Reviving the Sound of Classic Movies with AI
- 50 **Meet Our People: Supporting the Technology that Inspires Emotion**
- 51 Sony Technology Website
Introducing the R&D Efforts toward Innovation through Technology



Technology That Inspires Emotion

Three Themes to Get Closer to People's Motivations

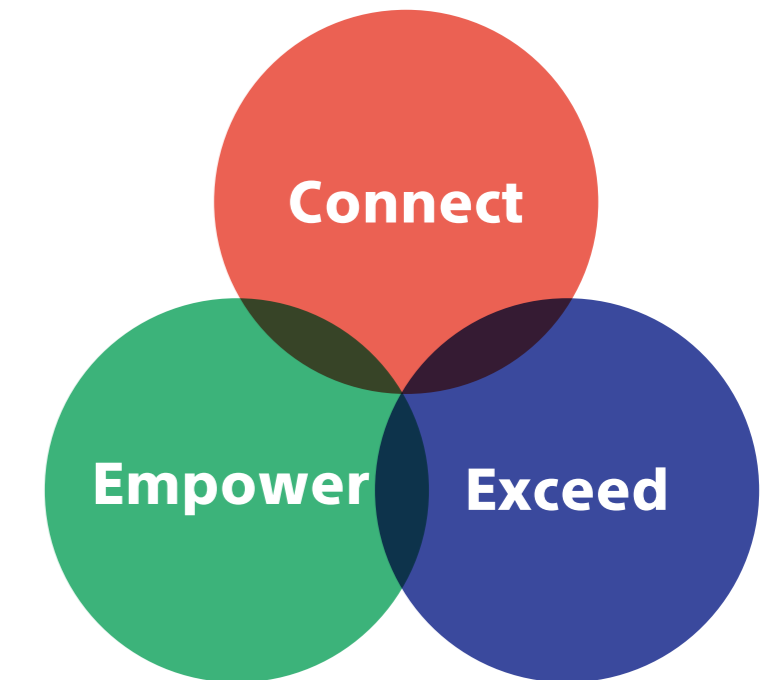
"Fill the world with emotion, through the power of creativity and technology."

In order to achieve Sony's Purpose and corporate direction of "getting closer to people," Sony's technology is a common thread that empowers its diverse businesses, which range from electronics and imaging & sensing solutions to entertainment such as music, movies and games, and financial services.

This magazine, Sony's Technology 2020, features Sony's latest technologies organized into three themes: Exceed, Connect and Empower. Under the theme of Exceed, we highlight technologies related to image sensors that open up new possibilities by going beyond human capabilities. Next, we introduce the technologies that bring creators and users together and deliver *kando* under the theme of Connect. Lastly, we introduce the theme of Empower with technologies that unleash creators' imagination, and create new forms of *kando*. We also feature combinations of technologies for mobility that pursues not only to safety, reliability but also to comfortability, and technologies that contributes to a sustainable society.

As social distancing becomes the new normal, Sony is also seeking ways to apply these technologies to achieve the three Rs: Reality, Real-time, and Remote.

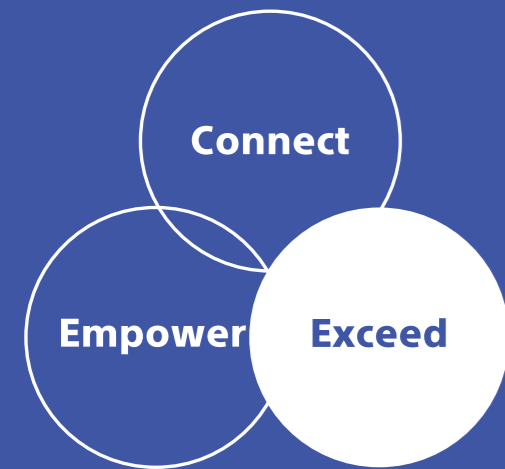
Let's explore the latest examples of our technologies and their extensive applications.



Exceed

Exceed human capabilities

Technologies that create possibilities going beyond human capabilities



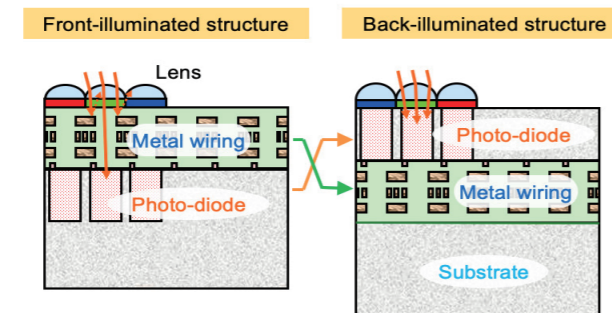
Imaging and Sensing Technology Seven Technologies Explained by Employees who Helped Develop Them

For each of the seven main areas in the imaging and sensing field, an employee will explain the technology, its key points, and its applications in their own words.

Back-illuminated CMOS image sensors

In conventional front-illuminated CMOS image sensors, there is wiring that connects the various elements to the light incident surface. As such, the finer the pixels, the greater the reduction in sensitivity due to wiring blocking the light from reaching the photodiode substrate. The solution to this is the back-illuminated CMOS image sensor, which flips the wiring and the light incident surface. At Sony, we

were able to develop the substrate bonding technology to flip the photodiode substrate, the high precision grinding technology to control the thickness of the substrate, and the technology to suppress the noise during the grinding process ahead of our competitors, allowing us to successfully commercialize the back-illuminated CMOS image sensor.



Tetsuji Yamaguchi
Dept. 5, Research Div. 1
Sony Semiconductor Solutions

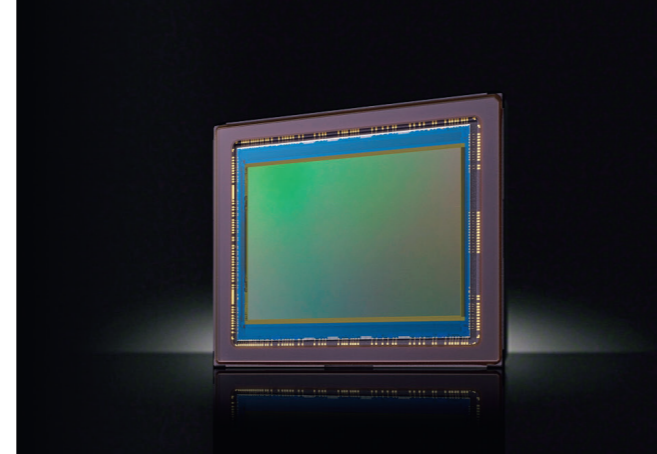
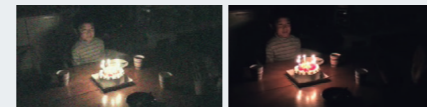
Advantages

- Higher sensitivity and better wiring layout improves image quality and allows for high speed recording.
- Finer pixels allow for the miniaturization of sensor chips, and by extension, miniaturization of products.

Applications

It is used in digital still cameras, interchangeable-lens digital cameras, smartphones. More recently, this structure has been adopted for ToF (Time of Flight) image sensors and has become the standard structure for CMOS image sensors.

■ Front-illuminated structure ■ Back-illuminated structure

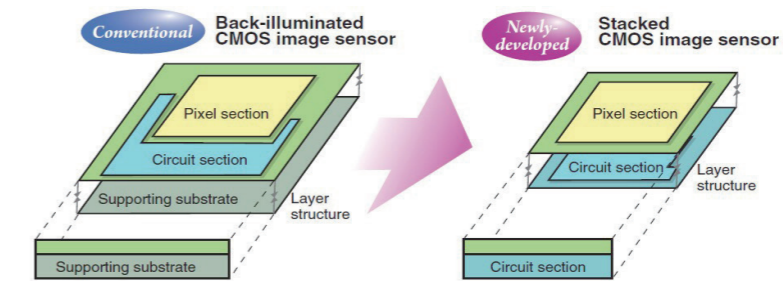


Stacked CMOS image sensors

Back-illuminated CMOS image sensors, which were developed for higher sensitivity, require a supporting substrate to maintain mechanical strength. A stacked CMOS image sensor is a new structure that exchanges this supporting substrate for a circuit chip, allowing for thousands of electronic connections between a pixel chip and a circuit chip. This world-first technology rearranges the pixel and circuit sections, which

were previously placed on the same silicon chip, into two separate layers, realizing the following benefits:

- High capacity logic circuits can be mounted onto a smaller area.
- Optimal manufacturing processes can be used for the separated pixel and circuit layers.



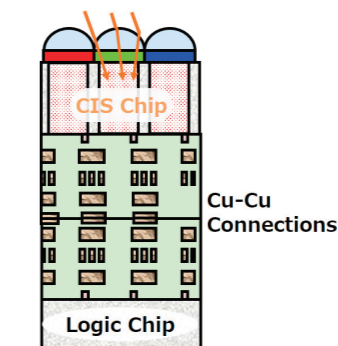
Taku Umebayashi
Dept. 7, Research Div. 1
Sony Semiconductor Solutions

*See "Realizing a Better Future through Sony's Imaging and Sensing Technology - To Spark Imaginations and Enrich Society" on page 43-45.

Cu-Cu direct bonding

Cu-Cu direct bonding, which was world-first rolled out by Sony, adds Cu-connection pads to the lower circuit chip and upper pixel chip of stacked CMOS image sensors to simultaneously establish physical and electrical connections. Miniaturizing the Cu-connection pads allows for smaller chip sizes and higher-density connections, simultaneously realizing greater productivity and functionality of the stacked CMOS image sensor. Additionally, a wafer-level bonding approach makes it possible to stack a lot of chips at the same time, which is faster and cheaper than the conventional

manufacturing process of stacking them one at a time. This technology requires an ultra-flat wafer surface and high precision wafer-bonding, but Sony has developed an original manufacturing process to overcome these issues.



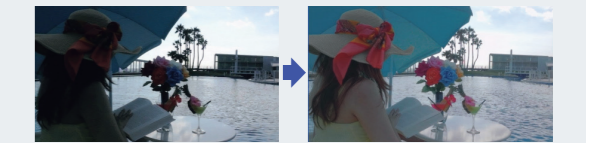
Yoshihisa Kagawa
Dept. 3, Research Div. 2
Sony Semiconductor Solutions

Advantages

- A platform technology that can be used for any image sensor.
- Many benefits including higher speed, lower power consumption, expanded functionality, lower costs, and improved productivity.

Applications

Due to its small size and high functionality, it was initially used in smartphone cameras capable of capturing clear photos against strong backlight. Later, it became a common technology for different types of sensors.

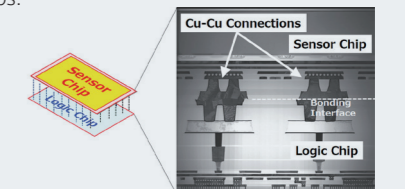


Advantages

- Higher productivity with a smaller chip size.
- Greater functionality through greater flexibility of circuit design.

Applications

Cu-Cu direct bonding technology is mainly used for stacked image sensors for smartphones and contribute to miniaturization and greater functionality of chips.



ToF image sensors

In ToF (Time of Flight) image sensors, depth information is acquired by measuring the time it takes for an emitted light pulse to reflect and return to the sensor surface. However, there are various types of ToF, and we focused on developing an indirect-ToF (hereinafter "iToF") that works by measuring the phase delay of returning light after it has been reflected by the object.

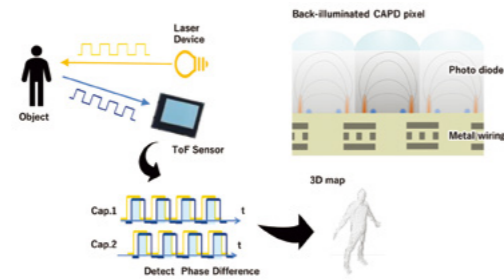
With the iToF method, it is possible to improve performance by converting more light into electrons and distributing the electrons faster and more accurately. To do so, we developed a new back-illuminated CAPD^{*1} by combining CAPD, which is an IP of SDS^{*2}, with Sony's back-



Yohtaro Yasu
CV System Development Dept.
Mobile & Sensing Systems Business Div.
Sony Semiconductor Solutions

illuminated CMOS image sensor technology. This new pixel takes advantage of the merits of the back-illuminated structure to efficiently converts light into electrons, enabling time detection of under 50 picoseconds and greatly improving distance resolution.

*1 SDS: Sony DepthSensing Solutions
*2 CAPD: Current Assisted Photonic Demodulator

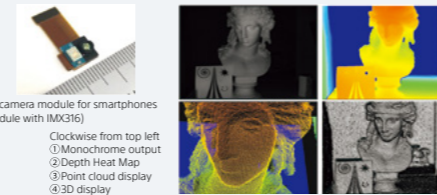


Advantages

- Allows for miniaturization of 3D camera modules.
- Contributes to AR/MR through real-time acquisition of high-resolution 3D depth information.

Applications

Used for face recognition in smartphones, AR/VR, and autonomous robots and drones.



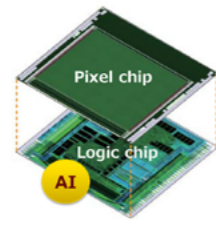
Intelligent vision sensors

On May 14, 2020, Sony announced the world's first* intelligent vision sensor with AI processing functionality capable of high-speed AI processing on the edge that extracts only the necessary data, reducing data transmission latency, addressing privacy concerns, and reducing power consumptions and communication costs, when using the cloud services.

The pixel chip is back-illuminated, and, in addition to the conventional image sensor operation circuit, the logic chip is equipped with Sony's original DSP (Digital Signal

Processor). The DSP is dedicated to AI signal processing, and memory for the AI model. This configuration eliminates the need for high-performance processors or external memory, making it ideal for edge AI systems. Users can also rewrite and update the AI models of their choice to the embedded memory according to its requirements or the conditions of the location where the system is being used.

*Among image sensors. According to Sony's research (at the time of announcement)



Intelligent vision sensor stacked configuration

- <Main functions on the logic chip>
- ✓ Conventional image sensor operation circuit
 - ✓ ISP which processes the image signal
 - ✓ Original DSP dedicated to AI signal processing
 - ✓ Memory for the AI model

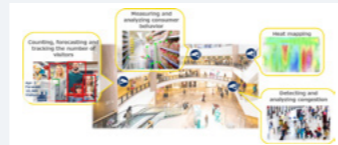
⇒ Eliminates the need for high-performance processor or external memory

Advantages

- A single image sensor that handles from image acquisition to AI processing.
- The AI models can be rewritten and updated with the latest AI algorithms.
- A concept that combines a wide variety of image sensors.

Applications

These image sensors will make it possible to develop cameras with AI functionality, which are expected to enable various applications in the retail and industrial equipment industries. Combined with cloud computing, they will contribute to realizing optimal systems.



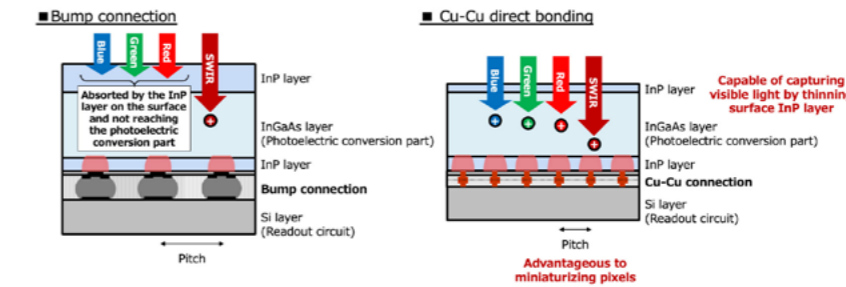
Ryoji Eki
SS Business Development Dept. 2
System Solutions Business Div.
Sony Semiconductor Solutions

SWIR image sensors

SWIR stands for "Short Wavelength Infra-Red." Instead of a conventional silicon (Si) based photodiode, a compound semiconductor indium gallium arsenide (InGaAs) based photodiode captures long wavelength light. However, since it is difficult to form an integrated circuit on a compound semiconductor, a separate Si layer is used for the circuit that reads the photodiode signals. A unique technology called

"SenSWIR" connects these different semiconductors via a Cu-Cu direct bonding, realizing the Sony's innovative SWIR image sensor.

By thinning the indium phosphide (InP) substrate that blocks visible light, the SWIR image sensor is able to capture a broad range of wavelengths, from visible to short-wave infrared, with high sensitivity.



Automotive image sensors

In addition to high resolution and high sensitivity, automotive image sensors need HDR (high dynamic range), LFM (LED flicker mitigation), and safety performance. Automotive cameras need to be able to capture high-quality images, even in situations of dramatic contrast, such as when entering or exiting tunnels during daylight hours, while also capturing periodically LED displays. This image sensor uses technology that secures exposure time to capture the LED without saturating bright subjects as well as unique pixel structure and exposure methods to achieve simultaneous HDR and LFM functions.

Furthermore, our products meet the requirements of the AEC-Q100 automotive electronic component reliability

tests. We also satisfy a design quality that is required for the functional safety requirements of automobiles and have introduced a development process that complies with ISO26262 automotive functional safety standards. We also adhere to the functional safety requirement level ASIL for failure detection, notification, and control in order to develop image sensors that contribute to a safer and more secure society.



Noritaka Ikeda
Automotive Business Dept.
Automotive Business Div.
Sony Semiconductor Solutions

Advantages

- Compact, multi-pixel design made possible by the industry's smallest* 5µm pixels.
- Realization of wideband sensing from visible light to SWIR.

*Among SWIR image sensors using InGaAs. According to Sony research (at the time of announcement)

Applications

SWIR image sensors are used for a wide range of industrial applications such as material selection, contamination inspections, and semiconductor inspections. In the pictures of the apples below, you can see surface information in visible light and subsurface information in the short-wavelength infrared light.



Advantages

- Image sensor technology that achieves high resolution and high sensitivity.
- Circuit design technology that allows for both HDR and LFM.
- Automotive quality that contributes to safety and security.

Applications

Sensing and viewing cameras for autonomous driving (AD) and advanced driver-assistance systems (ADAS).



Hawk-Eye

Making Sports More Exciting Through Visualization Technology

Visualizing moments that officials are unable to judge

In the professional sports world, there are always moments that unfold too fast or are too complicated to be tracked by the human eye. Using visualization technology, Hawk-Eye supports officials who have to make judgements in these situations. The two main technologies that Hawk-Eye provides are ball tracking and Synchronized Multi-Angle Replay Technology (SMART) video replay. Ball tracking technology

has been integrated into various services such as Electronic Line Calling (ELC) as well as Goal Line Technology (GLT), and SMART video replay has been adopted by football Video Assistant Referees (VARs) and rugby Television Match Officials (TMOs).

Hawk-Eye Innovations Ltd. was established in 2001 by Paul Hawkins, the founder of Hawk-Eye, formulated the idea of ball tracking based on missile tracking technology. Initially the technology was developed to make cricket more enjoyable for the viewers, but quickly expanded to cover a variety of other ball sports, such as

tennis, football, badminton, and volleyball. This desire to make sports more enjoyable for viewers is still present in the current business, and making sports fairer, safer, and increasing the engagement of sports fans through visualization has become Hawk-Eye's mission.

Hawk-Eye's strengths, which have brought about great innovation

Hawk-Eye really entered the global spotlight in 2006 following the introduction of the new challenge rule

at international tennis competitions. This rule allows each player to question the umpire's judgement up to three times in a single set. If a challenge is called, the trajectory of the ball and where it landed is analyzed using video footage taken by multiple cameras installed around the court, and within mere seconds, it is replayed on screen at the venue through computer graphics (CG). This technology can accurately analyze the trajectory of high-speed balls in tennis, which of course makes matches fairer, but it also gives rise to scenarios which critically influence the way games unfold. Hawk-Eye's real-time line-calling system (Hawk-Eye Live) is now being used at several international tennis tournaments to remove the need for line judges on-court. This is expected to increase players' concentration levels through shortened and more efficient games, caused by the removal of challenges. "Hawk-Eye will not replace umpires and referees and is a service only intended to support them, but we believe it could be used to make decisions in place of line umpires as a way of limiting the spread of COVID-19. Up to nine line umpires may

be deployed at tennis matches, but by reducing the number of people on the court through judgements made by Hawk-Eye, we can help to ensure social distancing." (Yamamoto-san)

SMART video replay technology became well-known as a tool for football VARs. By the time it was to be introduced, Hawk-Eye had created a multi view solution that would allow officials to check synchronized footage from various different angles taken by multiple cameras. While it develops technology, Hawk-Eye also places a huge amount of importance on the communication required for its adoption. "We were closely involved with the initial stages of football VAR, leveraging our expertise in officiating technology to assist stakeholders in building protocols and procedures that have the maximum impact to the result of the game, whilst having minimal impact to the gameplay. The aim was to ensure fairer outcomes whilst maintaining high fan engagement and enjoyment" (Hawke). "Sony's broadcast technology is also used at various sporting events, and as some of Hawk-Eye's staff is always present at these sports venues, we have been able to gain feedback while providing support, enabling Hawk-Eye to develop better solutions for each sport. Another one of Hawk-Eye's strengths is that we are always on site, listening to opinions 365 days a year, and we believe the expertise we have built up is one of the reasons that we are able to lead this industry." (Yamamoto-san)

About Hawk-Eye Innovations Ltd.

The company was established in 2001 and became a Sony Group company in 2011. It offers officiating systems using ball tracking technology for services such as Electronic Line Calling (ELC) for tennis which helps determine whether a ball is in or out, and Goal Line Technology (GLT) to determine whether a goal has been scored or not in football. It also offers referee judgment assistance services using video replay technology to football VARs and rugby TMOs. Currently, it provides these services, as well as ones that add visual effects to broadcasts, all around the world and for over 20 sports. They are greatly contributing to innovation in the world of sports.



Speakers



Taro Yamamoto
Sports Business Dept.
Consumer & Professional Business Sector
Sony Imaging Products & Solutions



Mathew Richards
Technical Director
Hawk-Eye Innovations



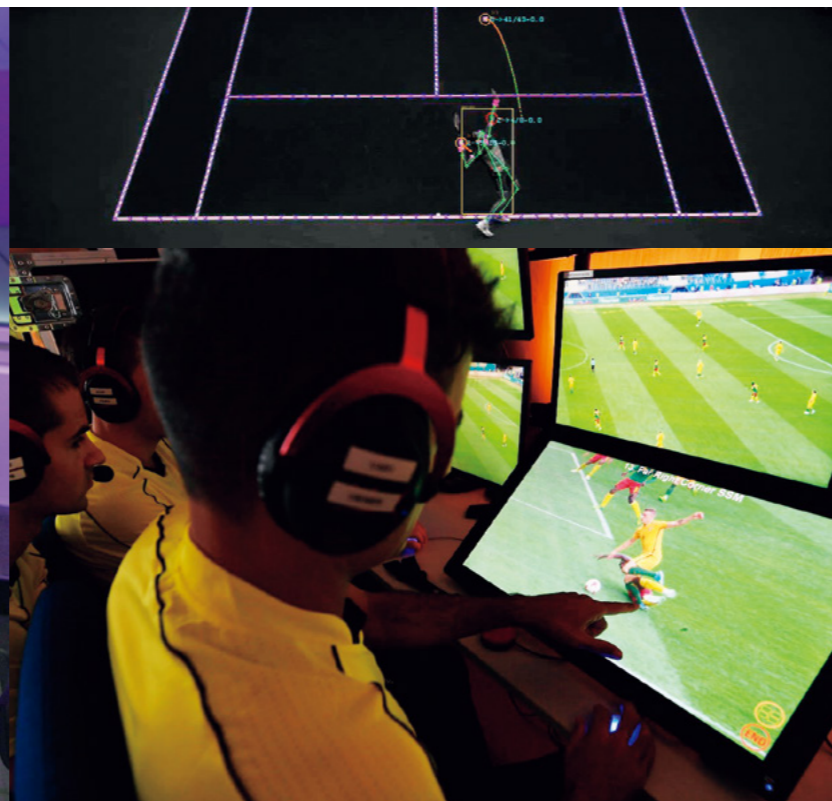
Edward Hawke
Product Director
Hawk-Eye Innovations



Providing support for sports in areas other than officiating

Hawk-Eye's services are currently used in over 20 sports, and, apart from ball sports, they are being used in athletics, horse-racing, and even motorsports. Ball tracking has started to be used for strategy analysis and scouting, and multi-angle viewing for matches shown on television and in videos is also under consideration, making it clear that the possibilities for Hawk-Eye are growing. "Sports definitely move people's hearts, which lines up perfectly with our mission to do the same through technology. Making use of Sony's technological capabilities, we will continue to provide new ways of watching and enjoying sports and boost the passion that sports inspires." (Yamamoto-san)

"Innovations' is a core part of who we are, and part of that is leveraging emerging technologies in new and different ways to provide value to our clients. We have the benefit of being in a position to get direct customer feedback, and there are so many amazing things going on throughout the Sony world that have direct or indirect applications in sport. Let us work together to bring about innovation in sports and we look forward to hearing any suggestions or proposals that you may have." (Hawke)

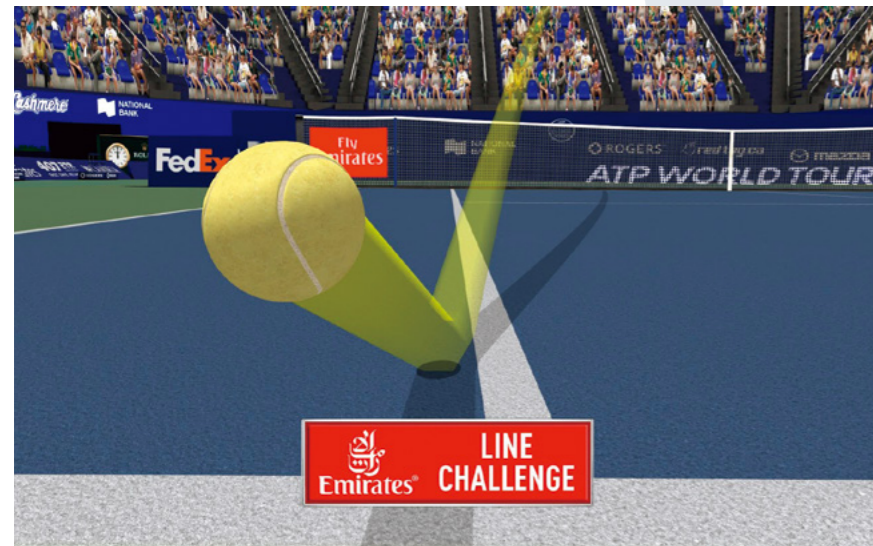


Examples of Hawk-Eye applications

Tennis

Electric Line Calling (ELC)

Hawk-Eye's tracking can accurately determine whether the ball has crossed the line or not, even for top tennis players' serves, which can exceed 200 km/h. The system has incredibly high accuracy, with an error margin of less than 2 mm, and can also produce a CG replay in mere seconds by processing the tracking data. Challenges can have a great effect on the flow of a match, but by making what happened visible to everyone, including the crowd and people watching at home through CG replays, matches will become much fairer. In addition, the time it takes before the CG replay is displayed on the screen can be used to show advertising from sponsors, creating further business opportunities for the event organizers.



Football

Goal Line Technology (GLT)

During football matches, it is often necessary to be able to judge whether the ball has crossed the goal line in real-time. Football presented a number of challenges to overcome, like real-time processing at higher frame rates and resolutions than previously attempted. One of the hardest challenges was occlusion. A key differentiator to previous ball tracking problems was that of ball motion, where modelling ball flight isn't always possible (as the goalkeeper may carry the ball over the line). This is coupled with the problem of noisy scenes where the ball may be obscured by the players and officials. The Hawk-Eye engineering team collaborated with Sony to innovate unique ball pattern recognition and orientation modelling algorithms that are used to determine the position of the ball in the image when only part of the ball is visible.

Video Assistant Referee (VAR)

Hawk-Eye's unique problem-solving expertise is also deeply ingrained into VAR technology, which has come into the limelight and is used even in international football tournaments. The issue with the introduction of VAR into football was communication. During the match, the referees and video assistant referees must constantly be in communication with each other using intercoms, deciding together when is the best time to stop play. Hawk-Eye not only set up the system with multiple cameras to ensure appropriate angles for judgements, but also provide training for referees who will actually use it as well as support for the acquisition of qualifications and certifications. Hawk-Eye have also held training camps with referees in preparation for its use at a selection of Japanese professional football league matches in the 2020 season.

Rugby

Television Match Official (TMO)

Hawk-Eye also provides video judgement assistance tools used by TMOs for rugby, where aggressive tackles and violent clashes are not uncommon. Depending on the matches, feeds from over 30 cameras may be aggregated, fed into servers, synchronized, and then displayed on the operation screen. Feeds that officials want to inspect in detail can be dragged and dropped, and judgements checked. Stills can be extracted, and manipulations such as zooms and slow-motion can be performed smoothly, allowing officials to check for illegal tackles, or whether or not a try was scored. Medical staff at rugby matches can use tablets to check where and how players have been injured, which contributes towards more accurate treatment. While increasing the safety of matches, better treatment also allows players to recover more quickly, providing great strategic and financial benefits for their teams.

SMART (Synchronized Multi-Angle Replay Technology) Technology

SMART technology is a flexible video platform that facilitates the capture, storage, and playback of video feeds from a huge number of different sources. By synchronizing multiple video feeds, the footage can be checked from different angles, but the simultaneous rendering and supply of several different video streams is necessary to realize this system. Hawk-Eye developed a codec to achieve visually lossless encoding able to compress feeds of up to 340 frames per second in real-time, and introduced the ability to create multiple encoded proxies, which allows for the dynamic selection of the optimum video size on a per-frame basis. As a result, officials, medical staff, and broadcasters can access scenes of the footage from the angle they want at the same time. "The parts of the footage that officials, coaches, and medical staff want to check differ,

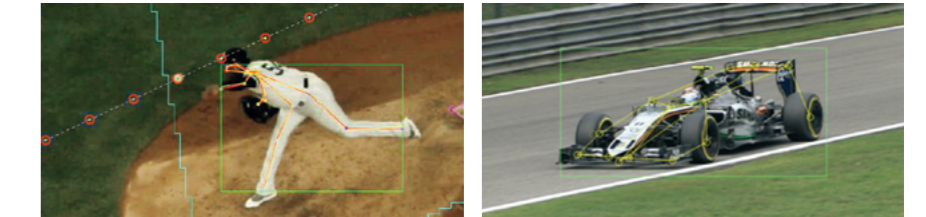
and as it used to only be possible to send the same footage to everyone, the selections were left up to the operator. SMART Replay solves this problem without the need for further equipment or operators." (Hawke)
Following the outbreak of COVID-19, Hawk-Eye have started providing remote replay services, allowing a replay operator to use the system from their home to make live-to-air cuts. "In golf matches, we have linked official data to the video feed, creating a filtering system which enables the operator to quickly jump to any shot of any player on any hole. This, and the fact that the operator can now provide broadcast replays from home on a 10Mbps consumer internet connection, significantly changes their workflow." (Hawke)

Technical Explanation

Ball tracking

Ball tracking was first used in 2001 as a broadcast enhancement tool for cricket. The technology uses 2D vision processing to find the center of the ball, and 3D triangulation to model the ball flight over time. Typically, this requires between eight and twelve cameras running at up to 340 frames per second. The data captured is fed into a central control system that can deliver a variety of real-time services, including officiating solutions, broadcast enhancements, and data streams.

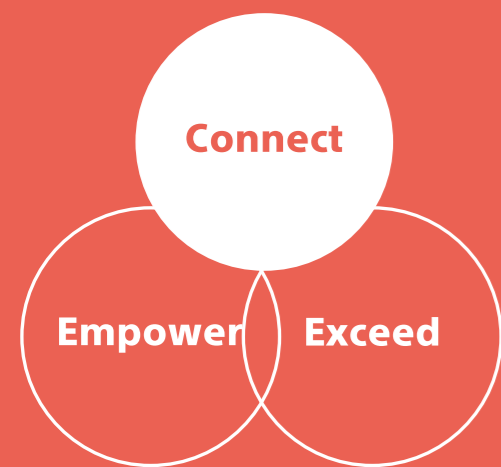
"Hawk-Eye has over 20 years of experience in delivering ball and player tracking services and one of our key strengths is our ability to innovate. Through the introduction of machine learning algorithms, we have become able to finely track not just the ball, but also the players' movements. We have already extended this to different kinds of use cases, such as baseball bats/balls tracking, as well as car tracking." (Richards)



Connect

Connecting people with people, and people with products

Technologies that bring creators and users together and deliver *kando*.



Real-Time Transmissions through 5G

A New Way of Live Video Production Using 5G's Strengths

The possibilities 5G brings to live sports broadcasting

5G has several strengths including 'enhanced Mobile Broadband (eMBB)', 'Ultra Reliable Low Latency Communications (URLLC)', and 'massive Machine Type Communications (mMTC)'. While a number of usages are being discovered in the field of sports, one of the areas of technology that Sony is developing currently is a real-time transmission system using a 5G network, where encoded video can be sent with low latency to a production device, or streamed through a cloud service. With current marathon broadcasts, data shot on site is sent through antennas affixed to aircraft circling above to the editing site, but "with 5G, which enables data to be sent real-time, current burdensome system can be greatly simplified, reducing costs and load on environment" (Yoon-san). At stadiums, cameras with 5G wireless communication will enable more flexible shooting angles and positions, remote editing and broadcasting of high-quality video on the cloud services,



Shoot using a broadcast camera connected to an Xperia 5G device

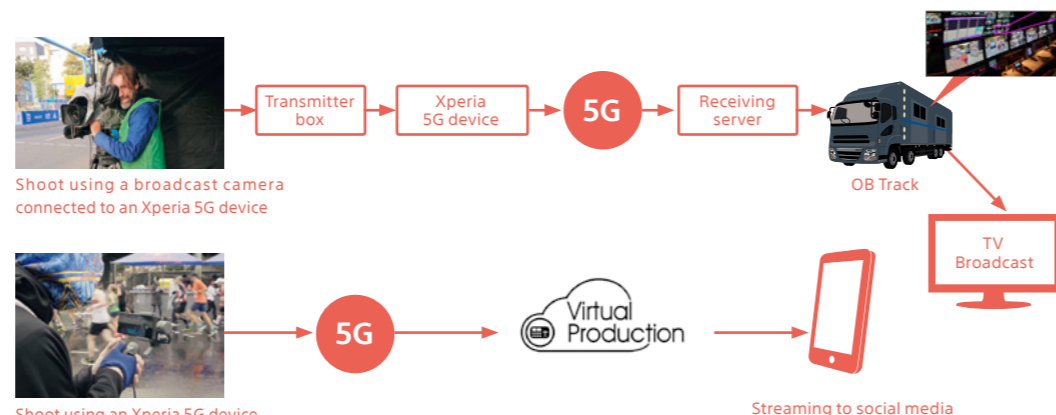


Shoot using an Xperia 5G device

regardless of the venue.

Success in experiments at the Berlin Marathon and American Football matches

In September 2019, the team carried out the first two 5G real-time transmission experiments at the Berlin Marathon. "The first experiment related to TV broadcasting. Video streams from broadcast cameras placed around the course were sent through a transmission box using Xperia 5G devices, to the Outside Broadcasting (OB) Track where the video production took place. The second experiment was focused on live streaming on social media. Video streams from three Xperia 5G devices were sent to a cloud server, where the feed switching was handled using Virtual Production developed by Sony Imaging Products & Solutions (SIPS), before being streamed on social media." (Yoshino-san) "At this Proof of Concept it was used relatively low frequency bands close to 4G, known as Sub-6, which fall into the 5G category, but the straightness of the radio waves



were unexpectedly high. So we had a great deal of difficulty juggling the shooting position while maintaining fast uplink speeds for a stable video stream." (Shimizu-san) "The day of event was full of unexpected surprises, but we managed to adapt up to the very last minute. I'll never forget the moment 5G connected images at the half marathon point were broadcasted on the live TV." (Yoon-san)

Around two months later, we carried out further experiments at an American Football match. 5G mmWave technology, which is in the commercialization process in the U.S., uses a much higher frequency band than Sub-6, and is expected to provide a higher capacity and speed allowing for high-definition video transmission. However, it also comes with a number of technical challenges, such as the waves being easily blocked by buildings, and not traveling well

over large distances. "One of the most difficult things is that camera operators and people moving in the vicinity can have a large effect on the radio wave conditions, and there is a high risk that the transmission speed may suddenly drop. The engineers from SIPS and Sony Mobile Communications (SOMC) got together, improved video compression and transmission technology, and worked very hard to preserve image quality and provide a stable transmission." (Sato-san)

On game day, in addition to broadcasting the whole game from the camera operator booth, they also transmitted from camera operators on the field. "Our activities were fairly restricted at the football stadium, however, we managed and adjusted our plan quickly so that we were able to demonstrate proof of concept in our use case for live production" (Gondoh-san).

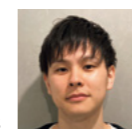
Integrating 5G technology with a wide variety of content and services

"5G brings with it a huge number of possibilities. By using our experiences and integrating 5G transmission technology with Sony's wide variety of content and services, we would like to pursue our goals of reality, real-time, and remote, and contribute to new *kando* experiences and development of new businesses for Sony." (Shimizu-san) "There is support from a lot of people, and I myself learnt a lot from this experience. With no barriers to fields or usages, I will do everything I can to further improve technology to create new values through 5G." (Sato-san)

Speakers



Shigeru Yoshino
Media Solution Business Div
Consumer & Professional
Business Sector
Sony Imaging Products & Solutions



Hiroki Sato
System Solutions Technology Dept.
System Software Technology Center
Sony Imaging
Products & Solutions



Yojiro Shimizu
Software Div. SW3
Sony Mobile
Communications



Takashi Gondoh
Mobile Communications
& Solutions
Sony Electronics Inc.



SungHyuk Yoon
Mobile PBU
Advanced
Technology
Sony Europe

Technical Explanation

Xperia 5G devices which efficiently receive signals and keep heat to a minimum

Especially with mmWave frequency band, the radio waves travel straighter and are more directional, so in order to maintain stable transmissions, it is essential to ensure radio waves are continually received. In comparison to 4G devices, 5G devices generates a lot more heat as a result of the processing of high-speed, high-capacity transmissions, so it is also necessary to improve heat dissipation in these devices. At SOMC, they are developing smaller antenna modules using the communication technologies they have nurtured over the years. Modules are carefully placed in the device to ensure that they can pick up transmissions from any angle. While monitoring the state of wave reception, the antenna modules efficiently turn on and off, contributing to reduced transmission loss and suppressed heat generation. They are also reconsidering the materials of the devices themselves, to ensure there is no negative effect on the mmWave transmission properties.

Transmission boxes that provide high image quality, low latency, and stability

Transmission boxes compress the video data sent from cameras and transmit it over IP. During live broadcasts, high image quality, low latency, and stability with no signal drops are absolutely essential. With these 5G experiments, compression technology and IP transmission algorithms were designed to guarantee high-quality video transmission with the lowest possible delay based on the network conditions. A system which adjusted network capacity and loss compensation was also implemented.

Virtual Production, which allows for remote live production

Switching between camera feeds at live events is usually done by an on-site operator using a switcher, but Sony's Virtual Production provides switching features on the cloud. Operators can switch between video feeds sent to the cloud, mix audio, and then transmit the finalized stream. Through the implementation of Virtual Production, operators will be able to produce video without having to be on site, which among other benefits will lead to reduced production costs.

Dynamic Spectrum Access (DSA)

Optimizing Use of Radio Frequency Resources towards the 5G/ Beyond-5G Era

Centralized management of frequency bands to optimize utilization of radio frequency resources

Wireless communication is now an indispensable part of the social infrastructure. 5G commercialization will lead to increase of the communication traffic. Under these circumstances, scarcity of allocable frequency bands is increasingly becoming a major problem. Currently, in order to prevent radio interference (where radio waves of the same frequency interfere with each other and cause disruptions), national regulatory authority (NRA) in each country/region assigns a specific frequency band to each operator. While increasing wireless communication devices such as smartphones and IoT devices, it is getting difficult for NRAs to assign new frequency bands to operators for their new usage such as 5G due to the scarcity of frequency bands.

Sony's Dynamic Spectrum Access (DSA) technology can solve that problem. As a matter of fact, it is known that there is underutilized spectrum in the already-assigned frequency bands at specific location and time. In DSA-based spectrum regulation, a centralized spectrum management database unleashes such underutilized spectrum for new entrant operators per their demands with a consideration not to cause harmful radio interference from them to the incumbent operators, maximizing the efficient use of finite radio frequency resources. Use of the unleased underutilized spectrum enable

a mobile network operator (MNO) to increase its available radio frequency resources in addition to its licensed bands when necessary, leading to higher quality communication services with greater bandwidth. In addition, use of the underutilized spectrum is open also to non-MNOs (i.e. private network operators), and they can utilize the underutilized spectrum to deploy and operate their own private/local networks at the specific area (e.g. stadiums, factories, etc.).

Sony has been researching and developing DSA technology for over 10 years and has been granted many important patents in this area.

From legislation and standardization to commercialization

DSA cannot be realized without the corresponding regulatory regime and relevant technical standards. In the United States, in parallel with the technology development, Sony has been actively involved in the legislation and the standardization of "Citizens Broadband Radio Service" (CBRS), which is the regulatory body overseeing DSA technology. The CBRS was established by the Federal Communications Commission (FCC) in the United States. Sony had also developed a Spectrum Access System (SAS), which is a spectrum management database defined in the CBRS regime. Sony's SAS has successfully completed the FCC certification tests for commercial operation and Sony was certified by the FCC as a SAS administrator in January 2020.

"The standardization work kicked off in 2015, and Sony, as a prospective SAS administrator, have been involved in the development of the technical specifications and ecosystem for CBRS. The first version of a package of the technical specifications was published in January 2018, but many issues have intermittently been identified after publication. As the FCC certification test is conducted with these technical specifications, we have had to revise the specifications upon identification of an issue – the revision work was continued to just before the start of the certification test. To our best knowledge, there is almost no precedent anywhere in the world for discussions on large-scale standardization involving technical specifications for DSA mechanism, ecosystem establishment, and certification tests for commercialization. I think the CBRS commercialization was achieved thanks to the close and active collaboration among the many participating companies." (Furuichi-san)

"Previously we developed a database that can unleash underutilized spectrum in the digital television broadcasting band of the United Kingdom, and it was certified by the UK Office of Communications (Ofcom) in 2015. The requirements for the SAS certification test were extremely strict, but we were able to meet those requirements by leveraging our technical assets and previous experience. As for the repeated specification changes during development, we overcame those by having repeated discussions with the intellectual property, standardization, implementation, and operation teams and improving each other's accuracy. With regard to technical issues outside wireless communication technology, the diverse knowledge within the Sony Group helped us to reach the successful completion of SAS development and the certification." (Matsumura-san)

Utilizing Sony's technologies to create future social infrastructure

The activities towards national implementation of DSA is spreading to countries and regions outside the US. In

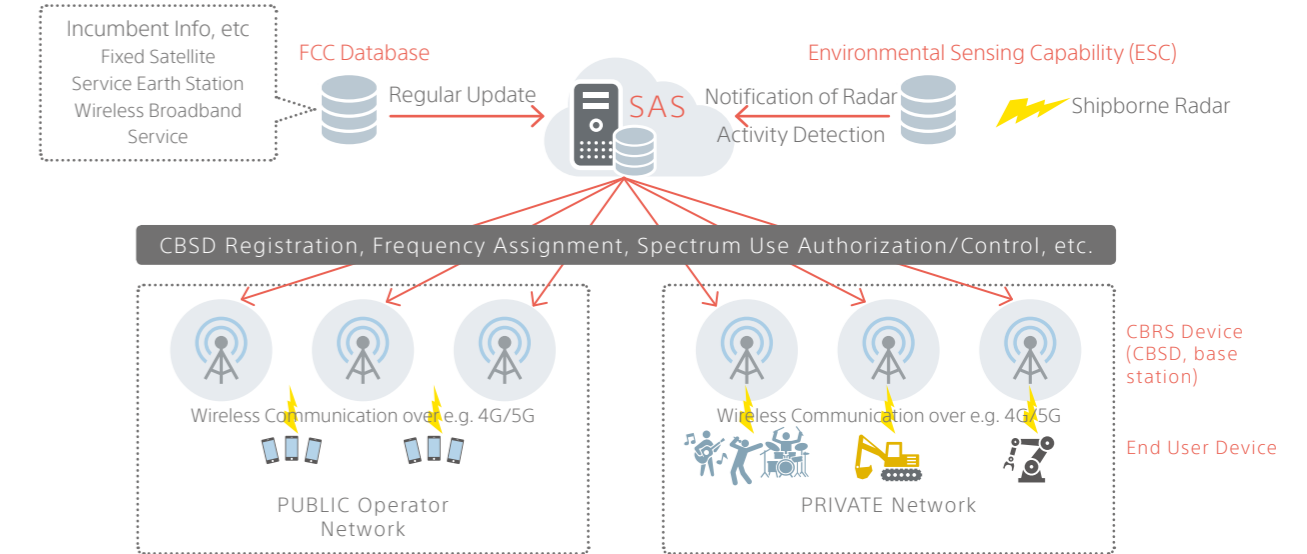
addition, studies on spectrum allocation for limited areas (i.e. local licensing) are progressing worldwide. Sony's DSA and other technologies will help solve the problems associated with the rapidly expanding use of wireless communication technologies.

"Over 10 years ago, when I was involved in the standardization of 4G, I asked myself, 'What would be coming to the next generation? Would it be possible to create a technology that changes how communication is utilized?' That was the beginning of the DSA technology development. This project is based on many years of steady R&D. Without Sony's diverse human resources and technologies, I don't think we could have implemented this system in the 5G era while at the same time incorporating trends in legislation and standardization. In addition, due to the influence of COVID-19, people currently have great expectations for technology related to remote operations. As a technology company, we feel high expectations and responsibilities for contributing to the building of a new social infrastructure." (Sawai-san)

A wide range of businesses will utilize 4G and 5G. As a leading DSA company, Sony will work to enhance the CBRS system and the relevant technologies in the US and also promote the introduction of technologies suitable for environments in other countries and regions.

Dynamic Spectrum Access (DSA) Technology

Example of commercialization in US; Citizens Broadband Radio Service (CBRS*)



*Citizens Broadband Radio Service (CBRS)

CBRS is the name of Title 47 Code of Federal Regulation Part 96 and the collective name of wireless services utilizing the spectrum in accordance with Part 96. Part 96 governs the use of underutilized radio frequency resources in the 3550-3700MHz band primarily assigned to the Department of Defense (mainly the US Navy), fixed satellite services, wireless broadband services, etc. Under the Part 96, SAS is defined to manage the use of underutilized radio frequency resources by CBRS Devices (CBSDs, refer to base stations). In addition to Sony, other SAS administrators (Amdocs, CommScope, Federated Wireless, and Google), operators (AT&T, Verizon, etc.), and numerous vendors (Ericsson, Nokia, Qualcomm, etc.) were involved in the CBRS standardization work within the Wireless Innovation Forum. The FCC and other federal agencies such as the Department of Defense also participated as observers.

Technical Explanation

Radio interference protection technology

There are two technologies that were adopted in the technical specifications for SAS to manage radio interference. The first is a propagation model that takes the terrain into account. It is able to estimate the amount of radio interference to the incumbent radio systems with high accuracy and expand opportunities for CBRS users to use underutilized radio frequency resources. The second is the US Navy's radar protection algorithm. A SAS is informed whether a shipborne radar is in use, but its detailed location information cannot be disclosed to the SAS for national security reasons. To protect such sensitive incumbents, at first, the coastal area was divided into multiple Dynamic Protection Areas (DPAs). Then, the protection algorithm was designed so that a SAS can suspend the radio transmission by potentially interfering CBRS Devices (CBSDs) located at the neighborhood area of a DPA where a shipborne radar is detected.



The ocean areas surrounded by red lines are DPAs. A portion of the CBSDs in the red land area are subject to restrictions for use of underutilized radio frequency resource when shipborne radar signal is detected. Controlling this huge number of CBSDs is a complex and burdensome operation.

SAS Complexity Reduction

A SAS needs to perform complicated calculations for radio interference protection in synchronization with other SASs once per day. However, due to the large-scale deployment of CBSDs, it takes a huge amount of calculation time if the SAS is simply implemented with no special design according to the relevant technical standards. In cooperation with Sony Global Solutions, Sony's SAS have adopted a highly scalable cloud architecture and added unique innovations to speed up the calculations. Sony's SAS have achieved high system stability by incorporating multiplexing on the cloud and multiple fail-safe mechanisms.

Speakers



Ryo Sawai
Tokyo Laboratory 22
R&D Center
Sony Corporation



Sho Furuichi
Tokyo Laboratory 22
R&D Center
Sony Corporation



Tomoaki Matsumura
Tokyo Laboratory 22
R&D Center
Sony Corporation

360 Reality Audio – An All New Music Experience

Creating an Ecosystem to Provide an Immersive Sound Field to Even More Customers



The sense of immersion produced by a three-dimensional sound field

Sony's 360 Reality Audio makes listeners feel as if they are immersed in sound from all directions. It almost feels as if a band is playing right in front of you. When content is created, 360 Reality Audio utilizes Sony's object-based audio technology to map sound sources such as vocals, chorus and instruments with the position and angle information. In order to smoothly introduce more users to this new form of entertainment, Sony is proposing a wide range of technologies for the creation, distribution, and playing of compatible content to creators and artists and is attempting to create an ecosystem that enables people to enjoy 3D audio. These technologies have already been distributed to multiple streaming services in Europe, the US and Asia, and compatible music was released in Autumn 2019.

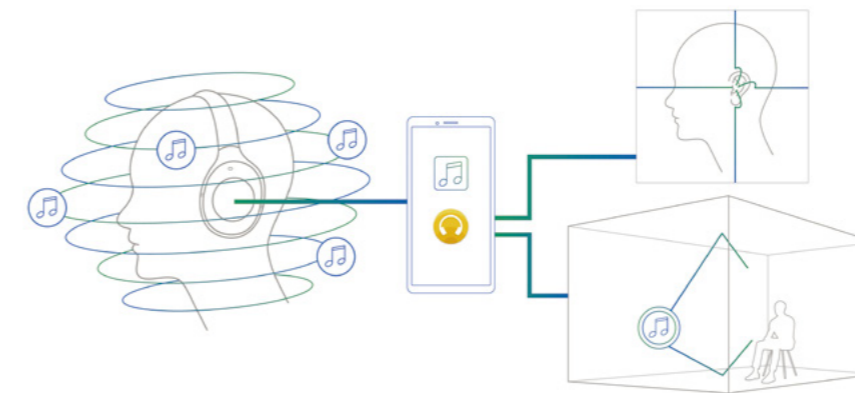
Involving the whole music industry in content production

The key to forming an ecosystem is to produce a wide range of high-quality, attractive content. Sony's R&D Center, Sony Home Entertainment & Sound Products, and studio engineers are closely collaborating to promote content production leading up to the service launch. "The production tools are also equipped with our spatial audio technology so that not only speakers but also headphones can be used to confirm the location of each instrument when reviewing songs." (Fukuda-san) "We have introduced the production infrastructure at Live Nation Entertainment, Sony Music Entertainment (SME), and other affiliated studios and trained their

engineers on how to produce content. Then, after discussing potential content with streaming services, we began working on the label side to remix the content." (Tomioka-san) "Through many trials and experiments, we have put together a method of effectively producing 360 Reality Audio's key characteristics of auditory localization, spaciousness, and movement." (Unno-san) "Battery studios has worked hand-in-hand with each team offering ideas for software and technology advancements, helping with preparing content from SME and other record labels. Since Battery Studios is committed to the idea of One Sony, this has been a very fulfilling process." (Wilder)

Technical Explanation

Headphone optimization technology



By the time a sound reaches your eardrum, it has already been reflected and diffracted on several different surfaces, including the floor, walls, and even your own body. This changes the sound's characteristics. People perceive which direction a sound is coming from based on these changes. 360 Reality Audio uses these auditory characteristics to create the perception that sounds are being heard from outside of the headphones, thus establishing a spatial sound field. However, people perceive sounds differently depending on the shape of their ears and head, and therefore individual optimization is necessary for deeper immersion. We have created a method of optimizing the sound experience for individuals on Sony's headphones by having them take pictures of their ears with the smartphone application "Sony | Headphones Connect," and then analyzing their aural characteristics with an estimation algorithm on the cloud. The estimation flow process has been repeatedly reviewed and modified to improve the accuracy of the algorithm.



Although you can enjoy 360 Reality Audio compatible content with headphones from any manufacturer, Sony's headphones are needed to create an optimized musical experience based on an analysis of the hearing characteristics. The best in class* WH-1000XM3 noise canceling headphones pictured above are one of Sony's recommendations. *As of December 1, 2019, according to research by Sony, measured using JEITA compliant guidelines. In headband style of noise canceling headphones market.

Speakers



Kazumi Fukuda
Tokyo Laboratory 20
R&D Center
Sony Corporation



Yukiko Unno
Product Technology Dept.2
V&S Business Group
Sony Home Entertainment &
Sound Products



Maki Tomioka
Business Development Dept.
V&S Business Group
Sony Home Entertainment &
Sound Products



Mark Wilder
Sound Engineer
Sony Music Entertainment
Battery Studios



Mike Piacentini
Sound Engineer
Sony Music Entertainment
Battery Studios

Delivering moving music experiences to customers around the world

Recently, 360 Reality Audio has been steadily increasing its presence with the distribution of a number of songs by popular artists, including SME artists The Chainsmokers and Kane Brown. Going forward, Sony intends to build partnerships in each country, including Japan, with the aim of further expanding their user base. "I think that we were able to create this new musical experience in the emerging

field of 3D audio thanks to the diverse knowledge of our employees." (Unno-san) "It's been a great honor and pleasure over the past few years to see the collaborative efforts of all Sony group employees come together to launch a product, across many different business groups in different countries." (Piacentini) "With entertainment continuously evolving in our rapidly changing social environment, I would like to provide new musical experiences to our customers and search for new ways to deliver *kando* to them." (Fukuda-san)



Kane Brown released his last two albums in 360 Reality Audio

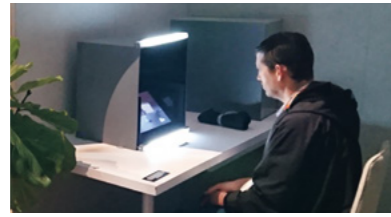
Eye-sensing Light Field Display

Delivering 3D Creators' Visions to Customers the Way They Intended

Delivering "spatial-reality experience" with Sony's unique technologies

Even viewed with naked eyes, the objects can be seen in 3D volumetrically as if they were right in front of you. The reality experience does not change even if you change the viewing angle. This is what Sony's Eye-sensing Light Field Display (ELFD) is committed to providing to customers: exceptionally high precision and contrast 3DCG images. "We expect this technology to be applied in a wide range of applications such as monitors for 3DCG creators, showroom displays, and entertainment." (Kawamura-san)

ELFD uses three of Sony's original unique technologies: (1) High-speed, high-accuracy, real-

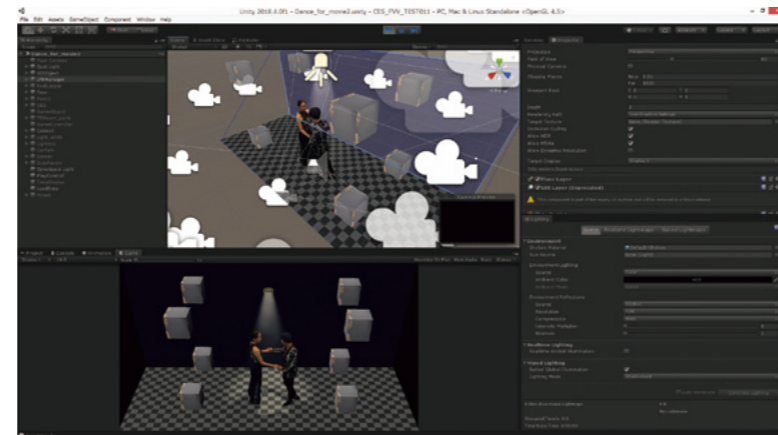


15-inch prototypes were showcased at CES 2020. Any object that fits the size constraints can be reproduced 3D volumetrically with super high precision.

time sensing technology, (2) Real-time light field rendering technology, and (3) High-precise 3D display technology. "ELFD is specially designed to track the viewer's eyes, and in combination with Sony's high-speed vision sensor, it can produce super high precision spatial reality experience in real-time. This combination of technologies delivers natural and close-to-reality effect as if the objects on the screen are actually there." (Kurihara-san)

Faithfully reproducing "Creator's Intent"

The main concept behind the development of ELFD is facilitating and helping bring the "Creator's Intent" to life, which is very important to Sony. This technology is not only impressive on a technical level, but it's also a vehicle through which creators can express their ideas. Therefore, during the development process, great emphasis was placed on dialogue with creators. "We want creators to be able to produce ELFD content with tools they are familiar with, so we created a software development kit (SDK) that supports Unity and Unreal Engine, two of the most widely used platforms in the 3D contents production field. This SDK was distributed to creators both inside and outside the company



Content production process using tools

early in the development process so that we could get feedback and make improvements." (Kimura-san) "In order to convince people of the appeal of ELFD, it is important to create opportunities for the public to interact with it. At CES 2020, we received many excellent suggestions from users who tried it out. And at InfoComm 2020, the largest professional audiovisual trade show in North America, we won the AV Technology Best of Show Special Edition. Collaboration with internal and external partners helps expand applications of our product. That's the beauty of bringing new technology to the world and seeing

people use it in various functional ways to improve their lives. (Yamamura-san)

Exploring new possibilities for 3D content with creators

"Content is essential for conveying the appeal of ELFD hardware. We believe that new use cases will be created from the imaginations of creators. Moving forward, we will continue developing technologies that allow creators to develop and showcase their work in the way in which it was intended." (Kimura-san)

"I have long dreamed of creating a visual experience realistic enough to be mistaken for the real thing. We would like creators in a wide variety of fields to produce high-quality content so that we can spread this technology and make it a permanent part of people's daily lives." (Yokoyama-san)

"In the future, we are looking to apply it to the education sector, VR display devices, and expand into B2B solutions, content distribution, etc. Since this is a new field with a wide range of potential business possibilities, we would like to get the whole Sony Group involved with the world of ELFD." (Kawamura-san)

Speaker



Kazuki Yokoyama
Tokyo Laboratory 09
R&D Center
Sony Corporation



Takayuki Kurihara
Tokyo Laboratory 01
R&D Center
Sony Corporation



Takaomi Kimura
Tokyo Laboratory 10
R&D Center
Sony Corporation



Ban Kawamura
Product Design Div.,
TV Business Group
Sony Home Entertainment
& Sound Products



Thaisa Yamamura
Business Development
Sony Electronics Inc.

Technical Explanation

High-speed, high-accuracy, real-time sensing

In order to make the viewer feel as if the object is real, it is necessary to continuously display the correct viewpoint image based on the position of the user's eyes. ELFD uses Sony's unique high-speed vision sensors and face recognition algorithms to achieve accurate eye detection with minimal delay. The positions of both eyes are calculated in real-time, not only for the horizontal and vertical planes but also for depth.

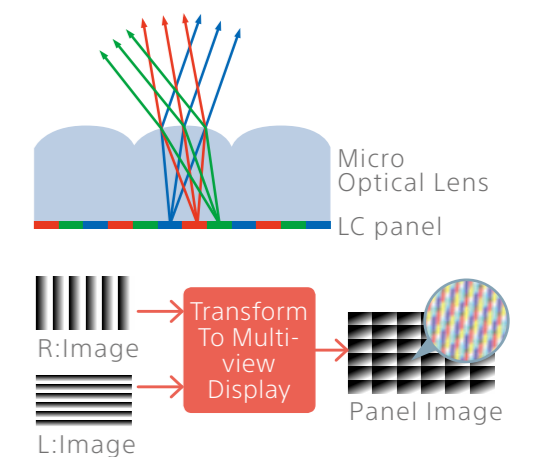
Real-time light field rendering

Based on the user's position, ELFD acquires the image of each eye seeing the object as if it were placed within the display and converts this information into a sort of deceptive picture on the display's surface. In combination with micro-optical lens technology that constantly delivers images for both eyes, a light source image is emitted from the display panel. Since this image is created in real-time with high speed and high accuracy, the correct viewpoint always reaches both of the viewer's eyes, making them feel as if the object was actually there.

High precise 3D display (micro optical lens)

Although there have been other 3D displays that do not require glasses, they could not accurately present 3D images due to low resolutions and crosstalk between the eyes. The ELFD display makes full use of Sony's high-speed vision sensor with a unique micro-optical lens that utilizes eye-tracking, significantly reducing crosstalk compared to conventional 3D displays.

Binocular Display with Micro Optical Lens



“GOOD DRIVE” - Insurance Service to Reduce Accident Risks

Changing Driver Behavior through Technology and Insurance System

Cashback on automobile insurance with calculating accident risk by advanced technology

Is it possible to reduce accidents through car insurance? GOOD DRIVE, an automobile insurance system that is linked to driving behavior, wants to find out. GOOD DRIVE's smartphone application is used to measure and score driving behavior, with cash back insurance premiums of up to 30% awarded to drivers with low accident risk. The score is calculated

based on factors such as travel time, acceleration, braking, steering and smartphone use while driving. The driver can check their current score on the app, see what the score is based on, and get advice on how to improve it. From May, this system has also been linked to the smartphone application “Yahoo! Car Navigation” provided by Yahoo Japan Corporation. When driving with this app, you will be evaluated on the same criteria as GOOD DRIVE and information is available from the GOOD DRIVE dedicated website. “If fully autonomous driving becomes more widespread,

the risk of accidents should decrease considerably. However, in countries and regions such as Japan with networks of narrow roads, autonomous driving is much more challenging, and it will take considerably more time for the accident reduction effect to become noticeable. Until then, I think that this product, which can reduce the number of accidents by changing driver awareness and behavior, is of great significance.” (Ishii-san)

Specifications tailored for driver convenience

GOOD DRIVE was developed using assets from three different Sony companies: Sony's AI technologies, cloud computing, signal processing, and sensor technologies; Sony Assurance's insurance service know-how and data; and Sony Network Communications' software development knowledge. As a result, we have developed a product that accurately and precisely measures risky driving that is also very convenient for drivers. After the initial setup, which involves installing the dedicated device in your vehicle's accessory socket and installing the application on your smartphone, everything is done automatically. An in-house developed AI algorithm that utilizes deep learning is used to analyze car behavior based on data obtained from the sensor in the smartphone. This behavior is then quantified through linking to accident data held by Sony

GOOD DRIVE

Assurance to determine the risk of an accident.

“If you try to pick something up while the car is stopped and your smartphone is in your pocket, it won't recognize it as a risky action. That is because our in-house developed algorithm incorporates an enormous amount of data collected from actual driving tests to find out which behavior is risky.” (Umemura-san)

There is also an emergency button on the dedicated device. Pressing it will display an emergency contact on the app that you can call immediately. Your location and information will be shared with Sony Assurance's accident personnel for a smoother response.

Accident risks reduced by 15% Insurance that makes driving more fun

In the Proof of Concept, we found that accident risk was reduced by about 15% using GOOD DRIVE. “Naturally, I was very happy with the results, but I also delighted that some of the participants reported that everyday driving became more fun as a result. I was worried that having their driving rated would make them nervous, but the response was very positive. Still, we're not going to stop here. We will continue making improvements so that things get even better.” (Arakuta-san)

GOOD DRIVE reduces accident risks by changing driver awareness and behavior. In this way, we will contribute to not only the safety and security of the driver but also to society as a whole surrounding mobility.

Technical Explanation

In-house developed AI Algorithm

The dedicated application measures driving characteristics based on data obtained from the acceleration sensor, gyro sensor, and GPS, regardless of the location or model of the smartphone while driving. The measurement results are collected in the cloud, and accident risk is calculated using a prediction model created in association with accident data held by Sony Assurance. AI algorithms developed by Sony's R&D Center are used in both the application and the cloud to measure driving characteristics and estimate accident risk.



Driving score display screen

Checking advice to improve your driving score



A dedicated Bluetooth device. Also has an emergency button.

Speakers



Eisuke Ishii
Direct Marketing Dept.
Marketing Div.
Sony Assurance



Chihiro Umemura
Contents-Marketing
Planning Dept.
Marketing Div.
Sony Assurance

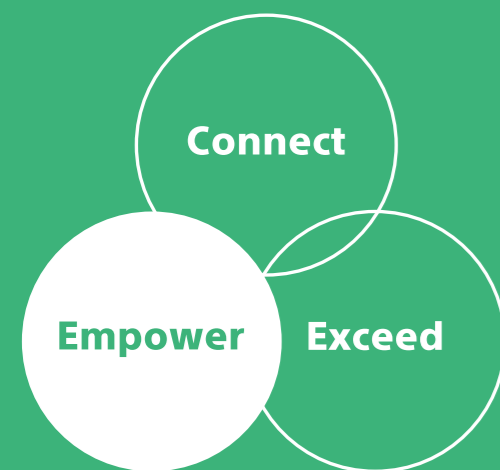


Koji Arakuta
Direct Marketing Dept.
Marketing Div.
Sony Assurance

Empower

Unleash human creativity and remove limitations

Technologies that unleash creators' imagination, and create new forms of *kando*



Aiming for VR Capable of Realizing the Impossible Volumetric Capture Technology That Goes Beyond Omnidirectional Visualization

Technology to capture an entire space

Free-viewpoint video technology has been used in sports broadcasting for several years and has also recently come into use in the field of video content production. In particular, omnidirectional visualization technology, which allows one to capture 360-degree images, is being supported through online services provided by various companies, and creators are producing a variety of new, immersive content. With

the evolution of free-viewpoint technology, the researchers at Sony's R&D Center believe that "free-viewpoints" and "reality" will be key elements. They are currently working on volumetric capture technology that goes beyond omnidirectional visualization. Volumetric capture technology converts a person, object, or place into 3D digital data and reproduces it as a high-quality image. This technology captures the entire real world and allows it to be viewed later from any viewpoint. In addition to providing a new video experience, it also has potential as a new content generation method. It is expected to break through



Thanks to: Professional Double Dutch team J-TRAP.

conventional video production limitations and find various applications in the entertainment field.

Creating the feeling that you are actually there

Using current omnidirectional visualization technology, you can use a head-mounted display to look around 360 degrees from a certain viewpoint by turning your head. However, it is not possible to move around objects and view them from behind. This is the major difference with VR contents created with computer graphics (CG). A more flexible point of view will be essential for immersing users in VR environments.

Therefore, it is important to generate an image from a viewpoint where there no camera (virtual viewpoint) by using a captured 3D model. By arranging multiple cameras around a subject and shooting, we can create an image that can be viewed from any direction or location. Sugano-san, who initially participated in the project as a "subject," oversees software implementation and image quality evaluation. "Creating a virtual viewpoint involves a process of calibrating multiple cameras, generating 3D models of subjects, texture mapping to 3D models, and generating camerawork." (Sugano-san)

Synchronizing multiple cameras is an area where the unique challenge of volumetric capture technology comes into play, as all the cameras need to shoot at the same time and transfer/aggregate the images to make them 3D. We have been repeatedly developing and evaluating software and hardware, and, in January 2020, we opened one of Japan's largest volumetric capture studios with these technologies at Sony's headquarters. The first thing shot in this studio was a game of Double Dutch, which involves two skipping ropes swung in opposite directions. "A game of Double Dutch with five people was optimal for making maximum use of the studio's characteristic

5-meter shooting area. The thin ropes moving at high speeds meant that filming and signal processing were challenging, but the shoot was a great success. We were able to demonstrate the technologies potential not only for visual expressions but also for sports analysis." (Hirota-san) Moving forward, they are aiming to accelerate technology development and business verification in collaboration with parties both inside and outside of the company.

Creating a new video experience

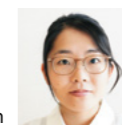
"Seeing our footage broadcast in live concerts and TV music shows was very rewarding. When our content was projected on a huge screen at a concert venue, we could feel a welling-up of emotion in the crowd. At the same time, it was a chance for us to see the work of professional artists up close, and that inspired us to work even harder." (Sugano-san)

"This technology, which was initially used in sports, has now expanded into the entertainment field, and video content creators are recognizing it for the new value it could bring to concerts and commercials. By leveraging Sony's existing businesses and imaging/video technology assets, we will be able to capture low-cost, high-quality free-viewpoint video, thereby contributing to the creation of a new business that will reach everyone, from professionals to everyday customers." (Hirota-san)

Speakers



Yoichi Hirota
Tokyo
Laboratory 09
R&D Center
Sony Corporation



Hisako Sugano
Tokyo
Laboratory 09
R&D Center
Sony Corporation



Technical Explanation

Pursuit of playback quality

With volumetric capture technology, it is necessary to use 3D computer vision to create virtual viewpoints where there are no cameras. The problem here is the sense of unnaturalness that people sometimes refer to as the "uncanny valley." Sony has solved this problem by combining its advanced 2D image processing technology with machine learning technology. These might be manufactured images, but it is the image quality on the final display that is ultimately important. With the resolution of display devices evolving from 2K to 4K and 8K, it has become possible to produce more realistic images. The range of movement and number of subjects that can be captured has also improved greatly since development began.



Comparative image of camera image (left) and volumetric (right)

Haptics

Taking on New Challenges with Haptics—A Technology that Stimulates the Sense of Touch, One of the Five Senses

Implementing Haptics technologies for DualSense™, the PS5™'s new wireless controller

Humans experience touch, one of the five senses, through a variety of stimulating elements such as vibration, pressure, texture and temperature. Haptics is a technology that stimulates the sense of touch. Since I studied haptics when I was a student and joined the company at a time when the development of DualSense was being accelerated, I had the opportunity to get involved in the practical applications of haptics technologies for DualSense.

Offering game creators an environment to easily incorporate haptics

Although DualSense will allow for more realistic game experiences, creators will also need more time and know-how to create high quality vibrations. To reduce this burden, we have created a haptic vibration waveform design environment that anyone can use easily. In this way, we have not only developed a tool that allows game creators to design an impactful,

Speaker



Yukari Konishi
Development Dept. #1
Global R&D Tokyo Division
Sony Interactive Entertainment

natural and comfortable vibration waveform in fewer steps, but also created a method of almost automatically generating vibration patterns from a game's sound effects. The focus of our development was deep neural network technology, but the problem was that there were few past studies that applied this technology to the sense of touch rather than to images and sounds. In the beginning, we spent many days just agonizing over the data. Later, we studied and examined different algorithms while getting advice from experts. This allowed us to automate the generation of high-quality vibration waveforms to a certain extent, making it look as if they were created manually by the creators.

Creating extraordinary *kando* experiences

At Sony Interactive Entertainment's R&D department, we have a certain degree of leeway when choosing a field of study. If you can produce good results, then you will have many opportunities to promote your research, such as making proposals to commercialize the product, applying for patents, publishing a thesis or even exhibiting at internal technical exchange meetings. Many young employees are entrusted with large and important projects, which raises our motivation. Best of all, it is highly rewarding to work on the PlayStation® platform, which has over 100 million users worldwide.

Sony Group has a diverse range of human resources and experts, and I think the synergy created

by its cross-organizational developments and projects is a major strength. It seems that there are still very few female engineers, but I have never experienced any difficulties because of that. Currently, internal systems and infrastructures are being set up to promote more flexible work styles. You might say that this is to be expected, but I am proud to be part of a group that makes good on these commitments.

In the future I want to develop new technologies and content that bring me a step closer to my childhood dream of "completely immersing myself in a game and becoming a different person." The audio, visual and VR technologies that Sony has been cultivating over the years are significant technological assets that allow us to immerse ourselves in a different world. I would like to combine haptics and other new technologies to create a *kando* experience that makes us forget about reality and transports us through our five senses.



Technical Explanation

DualSense, the new wireless game controller for PlayStation®5

The DualSense wireless controller will offer an experience unique to PlayStation®5. It is an innovated version of the DualShock®4 wireless controller for PlayStation®4, which garnered a lot of positive feedback from gamers and game

creators. Aiming to captivate more of the players' senses, we offer game creators the ability to explore how they can heighten the feeling of immersion by incorporating the sense of touch.



© Sony Interactive Entertainment Inc. All rights reserved. Design and specifications are subject to change without notice.

New features that allows for a variety of sensations

With two new features, haptic feedback and adaptive triggers, DualSense is able to offer more realistic and immersive tactile feedback. Haptic feedback adds a variety of powerful sensations to gameplay, such as the slow grittiness of driving a car through mud, the small impact of an object hitting the surface or the recoil of shooting a gun. Adaptive triggers have also been incorporated into the L2 and R2

buttons so that players can truly feel a sense of tension in actions such as drawing a bow to shoot an arrow.

Depending on the ideas of game creators, it also has the potential to produce a wide variety of other sensations in combination with visual and sounds effects and other game features.



© Sony Interactive Entertainment Inc. All rights reserved. Design and specifications are subject to change without notice.

PlayStation®5 is scheduled to be released during the year-end holiday season. The body design was recently revealed.

Ray Tracing

Evolving Visual Expressions for Game Creators

Simplicity expands various possibilities

The Vision of Sony Interactive Entertainment (SIE) is to provide customers with the "The Best Place to Play." Consisting of 14 studios worldwide, SIE will continue leveraging its strengths to provide engaging content that can be enjoyed by a wide range of customers while collaborating with game creators. One of the technologies used to enhance this content is ray

tracing. The PlayStation®5, which is scheduled to be released during the year-end holiday season of 2020, will be equipped with a custom GPU from AMD that supports ray tracing.

Many people may associate the term "ray tracing" with rendering technology used in computer graphics. However, the ray tracing that Watanabe-san is researching and developing is a simple yet widely applicable technology that detects intersections between rays and objects. Rendering is just one of its applications. "Through the ray tracing technology, we are hoping to solve problems related to

rendering in video games."

The problem with the rendering process lies in the complexity of the programs. A separate program is required to draw a character's shadow or their reflection in the water. And there are also compatibility issues when putting these programs together, so game creators need to constantly make fine adjustments. "The rendering process is extremely burdensome for creators, so if we can replace it with ray tracing and simplify it, the creators will be able to focus on more creative aspects of game design."

Maximizing hardware performance with software

To replace the conventional rendering process, it will first be necessary to speed up ray tracing. Using ray tracing in games will depend not only on hardware performance but also on software efficiency. In order to improve hardware performance, Watanabe-san oversees the creation of algorithms and data structures for accelerating ray tracing and the development of libraries to provide to creators. "During development, I'm focused on continuously improving quantitative indicators. We're constantly measuring the hardware performance under various conditions, and this gives us a sense of steady progress in the course of our trial and error."

"The most important thing is communication with game creators. As a platform provider, we would like game creators to be able to maximize their powers of expression. When creators integrate their games, they may find errors or issues that we did not anticipate. Therefore, we quickly respond to feedback from creators and constantly make improvements to our library."

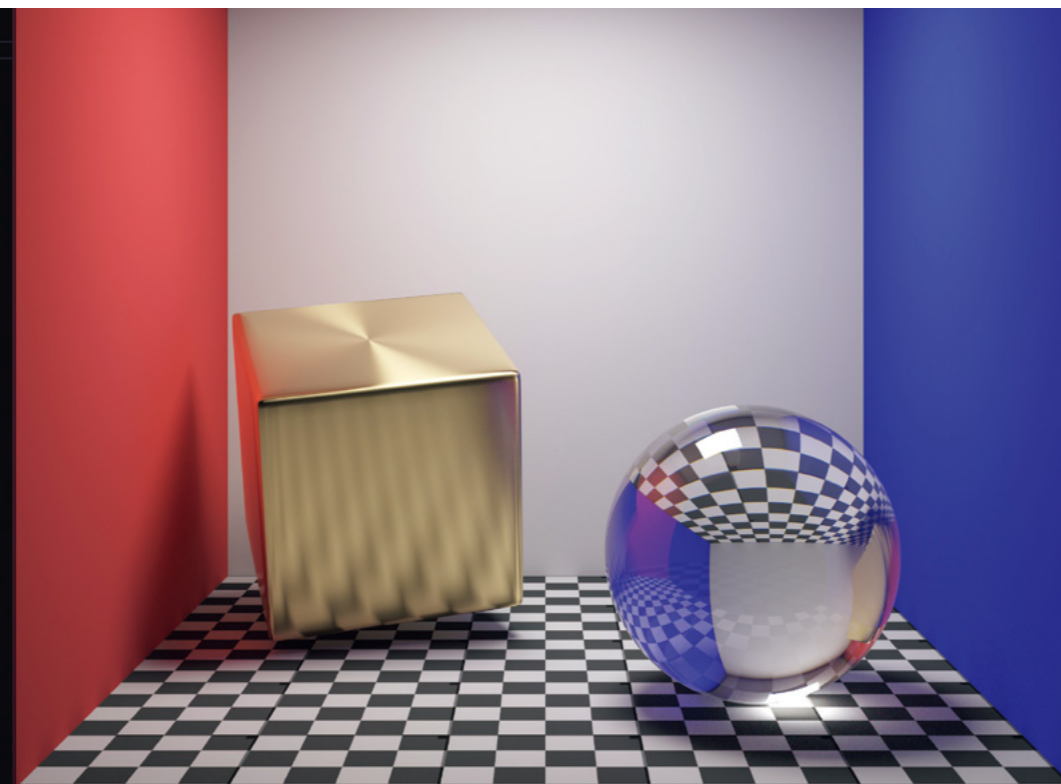
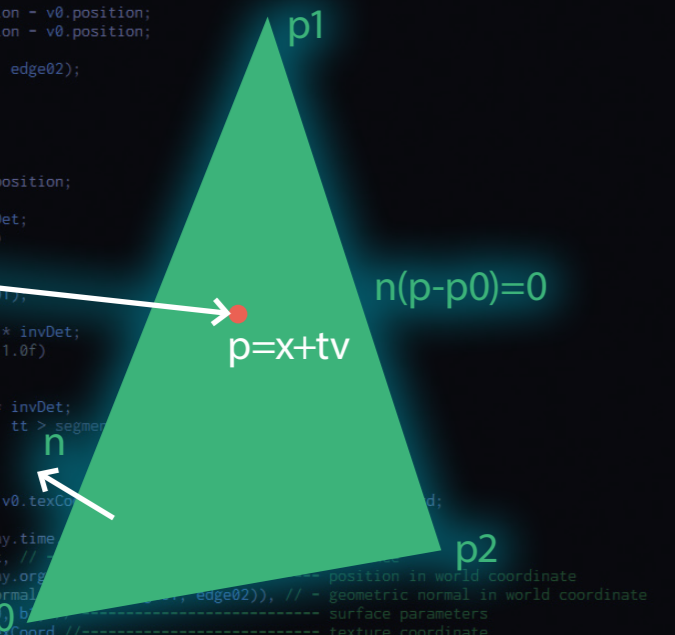
"The innate strength of ray tracing is that it gives us an accurate understanding of the world around us. Outside of graphics, there are also other applications, such as acoustics simulation. We may discover completely new sounds by reverberating sound waves or wrapping them around from behind. In order to provide users with even more fun and surprises, I would like to take on new challenges while listening to feedback from creators."

Speaker



Shin Watanabe
Platform Software Design Div.
Hardware Engineering & Operation
Sony Interactive Entertainment

```
162 const Vertex &v0 = *v[0];
163 const Vertex &v1 = *v[1];
164 const Vertex &v2 = *v[2];
165
166 Vector3D edge01 = v1.position - v0.position;
167 Vector3D edge02 = v2.position - v0.position;
168
169 Vector3D p = cross(ray.dir, edge02);
170 float det = dot(edge01, p);
171 if (det == 0.0f)
172     return false;
173 float invDet = 1.0f / det;
174
175 Vector3D d = ray.org - v0.position;
176
177 float b1 = dot(d, p) * invDet;
178 if (b1 < 0.0f || b1 > 1.0f)
179     return false;
180
181 Vector3D q = cross(d, edge01);
182
183 float b2 = dot(ray.dir, q) * invDet;
184 if (b2 < 0.0f || b1 + b2 > 1.0f)
185     return false;
186
187 float tt = dot(edge02, q) * invDet;
188 if (tt < segment.distMin || tt > segment.distMax)
189     return false;
190
191 float b0 = 1.0f - b1 - b2;
192 TexCoord2D texCoord = b0 * v0.texCoord + b1 * v1.texCoord + b2 * v2.texCoord;
193
194 *si = SurfaceInteraction(ray.time,
195     tt, // position in world coordinate
196     ray.org + ray.dir * tt, // position in world coordinate
197     normal, // geometric normal in world coordinate
198     b, // surface parameters
199     texCoord // texture coordinate
200 );
201
202 return true;
203
```



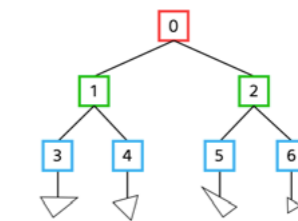
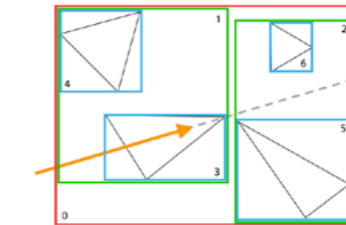
Technical Explanation

Ray tracing

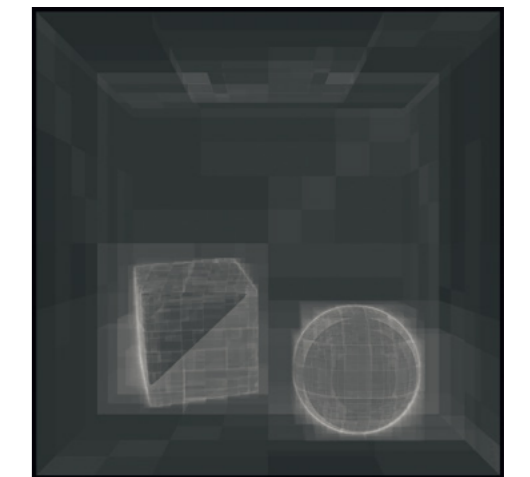
"Ray tracing" has several meanings depending on the context, and we can roughly divide into "ray tracing in a broad term" and "ray tracing in a narrow term." In a broad term, it refers to determining intersections between rays and objects. In a narrow term, it refers to the rendering of computer graphics by simulating the process of light going from a light source to our eyes. This type of ray tracing refers to various rendering methods, including a method that traces the path of light reflection from the eye back to the light source, and a method that has been actively used in film production in recent years.

Speeding up ray tracing

Computing simple ray-object intersections can be calculated with the brute force method, but this grows increasingly time-consuming as the number of objects increase. One method used to speed up ray tracing is a spatial data structure that divides a region into cells. Improving this data structure reduces calculating time since it only runs calculations for objects in the regions that the ray passes through. A Bounding Volume Hierarchy (BVH) is a typical data structure. In BVHs, objects are subdivided into a hierarchy of disjoint sets, allowing for efficient, and therefore faster calculations.



An example of a BVH's hierarchy of disjoint sets.



A visualization of the number of intersections within a BVH set (the larger the white part, the higher the number of intersections).

Moving Towards Evolution in Mobility with "VISION-S"

Sony's New Initiative Pursues Comfort and Entertainment in the Realm of Mobility

Changing the established concept of mobility and creating a new mobility experience

In January 2020, Sony announced the new VISION-S initiative, which combines Sony's technologies with the aim of contributing to the evolution of mobility, along with a prototype vehicle. "To change the established concept of mobility and to create a new mobility experience, we have developed a new vehicle and its platform from scratch. Given that Sony is not a car manufacturer, this was a huge challenge." (Shoji-san)

VISION-S was created through discussions between members of the business planning, design, and technology departments over a two-year period. It represents Sony's mobility vision of pursuing comfort and entertainment as well as safety and security. A total of 33 sensors are used to monitor the environment outside the vehicle in real time to support driving. Each seat is also equipped with 360 Reality Audio speakers for allowing listeners to feel as if they are immersed in sound

from all directions. Furthermore, the car's systems and applications are constantly updated through a network connection.

Overcoming issues and deriving optimal solutions

Sony has produced a wide array of products in the past, but the development of a vehicle, for which safety and security are paramount, is a major challenge, and there are still a number of issues that need to be overcome. Sony is carefully checking applicable laws and ISO standards required to put these vehicles on the road and having thorough discussions on what the future of cars should look like. "The position and specifications of each device, such as cameras, heavily affect styling and performance. We are always conscious of overall optimization and have to keep various conditions in mind when searching for new solutions." (Shoji-san) "During the two-year joint development with various partners in the automotive industry, we have done everything possible to convey Sony's values and

to translate their suggestions into concrete ideas." (Arikado-san)

Continuous evolution to provide new value

Sony is aiming to have the prototype on public roads within fiscal 2020 and accelerating the verification of its functions to further evolve Sony's technologies. "VISION-S is an example of an initiative that symbolically captures Sony's purpose, megatrends, and sustainability, so we will strengthen internal collaboration to incorporate more technologies and ideas. We also aim to build a new mobility ecosystem by working together with various partners while refining our own technology. In the current rapidly changing environment, the demand for a comfortable space to enjoy quality time through the incorporation of entertainment and other elements is only going to rise. Moving forward, we will continue making proposals for the future of mobility while taking the social situation and customer needs into consideration." (Koeda-san)

Speakers



Tomohiro Arikado
VISION-S Promotion Office
AI Robotics Business Group
Sony Corporation



Takuya Shoji
VISION-S Promotion Office
AI Robotics Business Group
Sony Corporation



Tatsuya Koeda
VISION-S Promotion Office
AI Robotics Business Group
Sony Corporation



Hidehiro Komatsu
Studio 6
Creative Center
Sony Corporation



Takahiro Hayasaka
Automotive Business Div.
V&S Business Group
Sony Home Entertainment &
Sound Products



Atsushi Homma
Automotive Business Div.
V&S Business Group
Sony Home Entertainment &
Sound Products



Takashi Nakanishi
Automotive Sensing Development Dept.
Automotive Business Division
Sony Semiconductor Solutions

VISION-S Prototype

DESIGN CONCEPT

Three OVALs to envelop occupants

The VISION-S design concept "OVAL" has the meaning of enveloping its occupants. There are three ovals, 1. Directly protects the passengers, 2. 360-degree sensors to confirm safety around the vehicle, and 3. A connection between the vehicle and society to deliver information and entertainment. "We aimed for a user experience that combines fun, relaxation, and a sense of security by merging the inner and outer environments to embrace occupants." (Komatsu-san)



ENTERTAINMENT

An unprecedented entertainment space through 360 Reality Audio

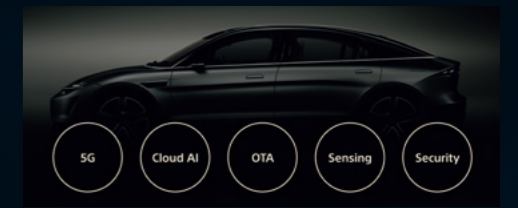
Each seat is equipped with 360 Reality Audio speakers, realizing a surround sound experience in pursuit of a feeling of immersion and realism that is unprecedented in in-vehicle entertainment. "The driver and passenger seat both have two seat speakers and acoustic signal processing, allowing each occupant to experience a personalized space without interference from the other seats." (Hayasaka-san, Homma-san)



ADAPTABILITY

A system that becomes more polished, more diverse, and richer over time

Through its network connection, VISION-S is constantly evolving without model changes. The driver can always enjoy the most up-to-date and easy-to-use UI/UX. "The AI automatically maintains comfortable conditions within the vehicle based on data collected through the 33 sensors, the infrastructure outside of the car, and your smartphone. For example, you can set navigation, compile playlists, and turn on the air conditioner before you get into the car." (Arikado-san)



SAFETY

33 Safety Sensors

The vehicle uses an optimal combination of sensors of different strengths, including cameras (CMOS image sensors), Radar, and LiDAR. The aim is to make the car safer to drive in a variety of conditions such as night, rain, fog, and backlight. "There are still issues, such as the complexity of processing information from multiple sensors. However, in order to realize a safe and secure car society, we will overcome those issues by utilizing Sony's rich development assets and image processing technology." (Nakanishi-san)



The sensors can pick up traffic conditions 360 degrees around the car.

Knowledge Sharing through Engineering Report

Significance of Reporting Learned from the "Iwama Report"

At Sony, technical knowledge gained by engineers through research, development, and design activities is compiled into Engineering Reports (ER) and registered in an in-house database. Creating and browsing these reports enables knowledge sharing across organizational boundaries and helps employees improve their logical thinking skills. The most symbolic ER is what we called the "Iwama Report," created in 1950's by Sony's fourth president, Kazuo Iwama, who laid the foundation for Sony's semiconductor business.

In this column Sony's Executive Chief Engineer Teruo Hirayama and four Distinguished Engineers* explain the lessons learned from this over sixty-year-old report and the significance of reports today.

*An engineer who has the highest level of expertise and technological insight in Sony at important technology fields for Sony.

The Origins of the "Iwama Report"

In 1954, Sony founders Masaru Ibuka and Akio Morita were focusing on transistors as the next development theme after tape recorders. After negotiating with Western Electric Co., Ltd. (hereinafter "WE"), which had a transistor patent, Sony was able to acquire a license, but the manufacturing technology was not included. Iwama-san volunteered to go to US and study this technology at WE and Bell Laboratories. During his time in America, he wrote over 100 pages and sent them back by airmail. The engineers who read this report in Japan decided to start development without waiting for his return and succeeded in trial production. The following year Sony released the TR-55, the first transistor radio to be made in Japan. Iwama-san traveled to the US intermittently until 1958, and his report grew to a total of 256 pages finally.



ER is the Business Tools with Various Functions

Back then, airmail was the quickest way to send information. Although about seven years after the development of the transistor was announced by other companies, it still did not have an established manufacturing technology. This report, which provided a major impetus for Sony to advance along the path of semiconductor development, is written in a concise and focused manner, with excellent illustrations help to deepen one's understanding. In addition to recording and communicating information, it also contains instructions for engineers and advice on management decisions. This document greatly contributed to Sony's semiconductor development and business success.



Teruo Hirayama
Executive Chief Engineer
Sony Corporation

Making a "Copy of Yourself"

Writing an ER is like making a copy of yourself. It has two meanings. The first copy conveys your message to many people, almost as an alter ego. The other is the copy that helps improve your logical thinking. Documents like ERs help to spread the writer's experience, knowledge, and ideas across time and space. I remember ERs on signal processing being extremely helpful when I was trying to develop new camera technology in my youth. The "Iwama Report" is a document that transcends space and time.



Ken Nakajima
System Solutions Business Div.
Sony Semiconductor Solutions



Don't Spend Time, Get in the Habit

I often hear that there is no time to write ERs. Engineers often leave it for last, but by then, the freshness of the information has already been lost, and peripheral details such as struggles, and failures tend to be left out. Developing a habit of saving information in a concise manner during the work process not only prevents this but is also useful for other purposes, such as collecting your thoughts and utilizing information for reporting and advising others. It is important to write and utilize ERs in a more natural way.



Tetsuya Tatsumi
Research Div.2
Sony Semiconductor Solutions

Share with the Whole Company, not just the Team

In software development, the concept of "agile" development to maximize customer value has become mainstream, and various tools that emphasize development speed, efficiency, and cooperation have been created. On the other hand, much of the information that exists within a team is lost once the team is disbanded. Sony's ER does not rely on any one organization, so accumulating information in this way helps to preserve it. Moving forward, we will also have to consider using AI and evolving our technology to leave this information for the future more effectively.



Yoshifumi Ueno
Tokyo Laboratory 17
R&D Center
Sony Corporation

Let's Accumulate and Utilize Know-how Unique to Sony

There are two types of data in the world. One is publicly disclosed data, and the other is so-called "dark data," which includes in-house proprietary data or ER. As dark data cannot be searched or obtained from outside the company, it is a powerful tool to differentiate ourselves from other companies. Therefore, it is important to properly write and accumulate ER. However, simply accumulating reports is not enough. Tools for automatically analyzing the contents of scientific literature are currently under development, so it will become even more important to utilize ER in the future.



Shigetaka Tomiya
Tokyo Laboratory 27
R&D Center
Sony Corporation

Value of Reporting is Growing Now

During the days of the "Iwama Report," there were only handwritten texts and diagrams to communicate information, but we are now living in the age of electronic data and the internet. That being said, old-fashioned handwritten texts and diagrams can stimulate the minds of both the receiver and the sender, so we encourage engineers to write these reports and learn from them.

Note: Although the "Iwama Report" was written 65 years ago, this article introduces learnings and ideas about ERs are still applicable today. When dealing with information from outside the company, please do so with a full understanding of the relevant contracts and laws and comply with the Sony Group Code of Conduct and other regulations. Further information related to compliance can be found on the Compliance Portal Site on the intranet.

Aiming for More Comfortable and Secure Mobile Society with AI and Sensing Technology Future Mobility Project



Hiroki Takakura
Cloud Service Development Dept.
AI Robotics Business Group
Sony Corporation



Takahito Migita
Cloud Service Development Dept.
AI Robotics Business Group
Sony Corporation

Optimizing transportation with demand prediction service

Under the title of "Future Mobility Project," Sony is collaborating with Minnano Taxi (Everybody's Taxi) Corporation^{*1} to promote initiatives in the mobility field using AI and sensing technology. As part of this project, we launched a demand prediction service for taxis last November. During the development of this system, we collected status data from approx. 10,000 taxis in Tokyo and set about visualizing the data while accounting for inaccuracies and missing elements. Using this data and the information obtained from interviews with drivers, we collaborated with Sony's R&D Center to test various machine learning technologies such as decision tree models^{*2} and deep learning and selected the best method from a cost and accuracy perspective.

^{*1}The joint venture of Sony Corporation, Sony Payment Services, and five Tokyo taxi companies.

^{*2}A machine learning method that performs classification and regression using a branching tree-shaped diagram.

This system emphasizes not only demand prediction accuracy but also ease of use for taxi drivers. This is done by reducing the number of touch operations required to access information and incorporating features such as sound notifications so that drivers need not take their eyes off the road. Since the launch of the service, we have been collecting feedback to improve and expand functionality.

The occupancy rate of drivers using this service is increasing, which is expected to lead to an increase in revenue for taxi companies. Additionally, more efficient driving will help to shorten working hours as well as contribute to social issues such as the environment. "We believe that by expanding this technology to public transportation and car and bicycle sharing in the future, we will be able to optimize the entire transporting system." (Migita-san)

Exploring technologies and data that can contribute to safe and secure driving

In addition to demand prediction, another pillar of the Future Mobility Project is supporting safe driving. Using

a test vehicle equipped with nine image sensors, acceleration and rotational angular acceleration sensors, LiDAR, and so on, we are collecting data on driving operations such as acceleration, braking, and steering angles, as well as sensing data on the environment outside of the vehicle to develop technologies and services that contribute to safety and security.

For this data acquisition, we obtained the cooperation with a professional driver who has chauffeured Sony's executives for ten years to drive the test vehicle. Quantifying comfortable driving from a qualitative sense and reproducing it using technology is an important theme. By collecting data related to operations when humans are driving, we hope to realize technologies that allow AI to evolve naturally.

"Vehicles will be 'moving sensors' in the future. We think about what kind of value can we create with these connected sensors. In this rapidly changing social environment, the way that customers and markets think about mobility is changing, so we will need to consider how to expand our activities from a broader perspective." (Takakura-san)



A test vehicle (left) and the tablet application (right)



The prototype developed in collaboration with the Creative Center visualizes information collected based on the data collected from taxis in Tokyo. In this way, we will continue verification to create new value for the evolution of mobility using the big data obtained from "town sensing."

Sony AI

Attracting the World's Best AI Researchers and Engineers to Unleash the Potential of Sony's AI



Michael Spranger
COO
Sony AI

Sony AI to pursue three flagship projects in collaboration with Sony Group companies

Sony AI was established as a wholly owned subsidiary of Sony Group in April 2020. The organization has offices in the U.S., Europe and Japan. Sony AI is committed to achieving its mission to "Unleash human imagination and creativity with Artificial Intelligence," which is aligned with Sony's Purpose: "Fill the world with emotion, through the power of creativity and technology."

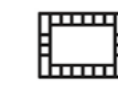
In collaboration with Sony's business units and R&D Center, we are currently working on three flagship projects: Gaming, Imaging & Sensing, and Gastronomy. Gaming and Imaging & Sensing are promising growth drivers for Sony's businesses and Gastronomy is a completely new domain for Sony that offers great potential for technical explorations. In the

meantime, we are also actively working on adding flagship projects.

Flagship Projects



Gaming



Imaging & Sensing



Gastronomy

Research and development of AI is a fast-growing field, and the competition has become more intense than ever. A question that everyone is asking is: how can we create competitive advantages? The answer is simple. Hire the best talent in the world and allow them to work on exciting, ground-breaking projects. The types of projects that Sony AI can carry out by leveraging Sony's assets in gaming and imaging and sensing –

as well as in music, movies, and electronics— is what will really distinguish us in the global AI research and development landscape.

AI is a ubiquitous technology that will affect all areas of Sony businesses. As seen from the recent announcement of the Intelligent Vision Sensor with AI processing functionality, AI presents an opportunity for Sony to transition from being a sensor producer to an AI integrated sensing solution provider that could potentially support the next generation of cars, manufacturing robots, and kitchen appliances, to name a few. In addition to partnering within Sony, to stimulate creativity in Sony and allow businesses within Sony Group to push the state-of-the-art technology quickly, Sony AI will also actively seek collaboration with external partners. To develop and use this technology is not just Sony AI's mission; it is an important goal for all of us. So, my hope is that together, we can make Sony the best AI technology company in the world.

The dawn of the next generation AI



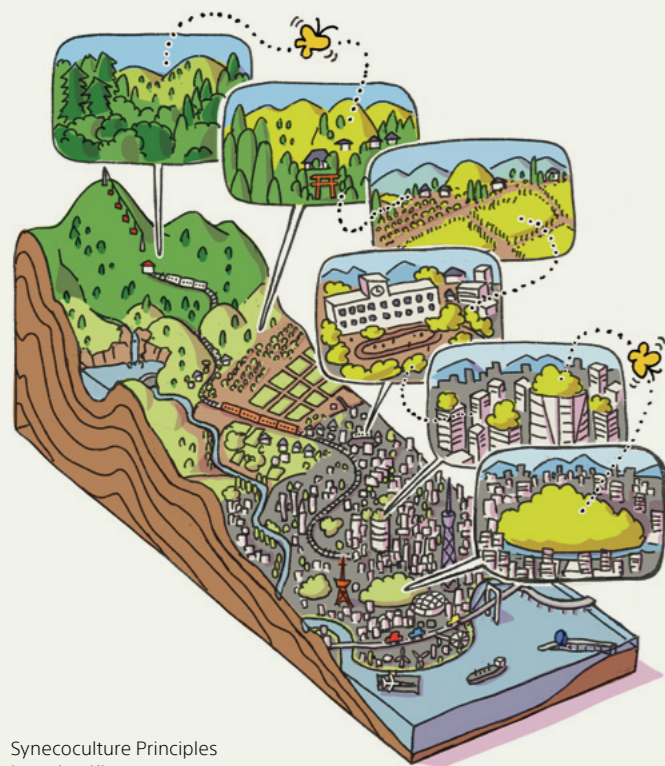
Peter Dürr
Director
Sony AI Zürich

Our perception of AI today is very much influenced by deep learning-based classifiers, which use training data that is labelled in advance. The next generation of AI systems, however, will not rely on such carefully prepared data. They will generate the necessary data by computation, for example by using simulations, or gather it by interacting with the environment, which is the domain of robotics. Therefore, we should not treat AI and robotics as entirely separate research topics.

Moreover, in the very near future, the learning algorithms for AI will no longer be constrained to big servers. Computation will happen very

close to the sensors, which will enable new applications through lower latency, lower power consumption, and enhanced privacy.

At Sony AI Zürich, we are currently working on combining new sensor technologies developed at Sony Semiconductor Solutions with new machine learning methods and robotic actuators. If we can unlock the full potential of these sensors by developing new learning and control algorithms, as well as the computing hardware to handle the sensor data properly, I believe that the resulting systems will open new applications in areas such as factory automation, autonomous driving, or drones.



Synecoculture Principles Learning Kit concept
<https://www.sonycscl.co.jp/tokyo/9337/>



The bounty of nature harvested with Synecoculture

Synecoculture

A Farming Method for a Sustainable Future

Aiming for cities that coexist with nature

Synecoculture is a method of artificially creating an ecosystem that spontaneously produces useful plants and restoring ecosystem functions that have been impaired by tillage, fertilization, and agrochemicals. It involves densely packing a wide variety of plants into an area to create an ecosystem where plants and their symbiotic animals and insects can grow together. During a 2015 proof-of-concept trial in Burkina Faso in West Africa, a piece of desertified land was turned back into a rich agricultural area in about a year, securing a harvest of about 20 times the gross national income per capita of Burkina Faso.

Since March 2019, Sony Computer Science Laboratories (Sony CSL) has also been collaborating with Mori Building Co., Ltd. on a proof-of-concept trial at Roppongi Hills in Tokyo. "We have been using Synecoculture to introduce an augmented ecosystem into the highly urban area of Roppongi Hills with the aim of creating a city that integrates nature. This is the first step in our challenge of realizing new cities that can coexist in harmony with nature." (Ohta-san) During the proof-of-concept trial, Synecoculture proved effective even in the planters and roof gardens with no access to underground water. The diversity and activity of microorganisms in the soil was also increased to a certain degree. There are expectations that it will function as a place to study a new method of food production that, unlike conventional agriculture, is based on ecosystem mechanisms.

Building a sustainable value chain

A Synecoculture Principles Learning Kit is being developed so that children can learn about the mechanisms of Synecoculture and the knowledge gained during experiments in an easy-to-understand manner. This hands-on learning kit recreates a small section of farming land in a planter with consideration on the fundamental notions of ecosystems such as the soil structure and plant interactions to teach children about how life on Earth emerged and the evolutionary process of land plants. In Japan currently, elementary school students are usually given the task of growing Morning Glories using conventional monoculture methods. However, this kit teaches students about food production in a mixed-plant environment that uses ecosystem mechanisms sustaining biodiversity in nature.

Regarding the future, "The important thing will be how we manage the variety of useful plants grown through Synecoculture and build a sustainable value chain for production, distribution, consumption, and lifestyle. We expect to incorporate technologies from Sony's diverse range of business fields, such as sensing, information processing using AI, assistive technologies linked with robotics, and education and entertainment that help people learn about ecosystems and enrich first-person experiences." (Funabashi-san) "Mankind developed civilization and culture through farming. Just like 10,000 years ago, the cornerstone of modern culture is food production. I think that we are at a turning point where we need to reevaluate this cornerstone. Synecoculture is expected to become the basis for a new culture created by Sony through which we will move people." (Ohta-san)



Masatoshi Funabashi
 Researcher
 Sony CSL

Kousaku Ohta
 Assistant Researcher
 Sony CSL

Small Optical Link for International Space Station (SOLISS) Contributing to the Construction of Space Communication Infrastructure through Optical Disc Technology

Joint research between Sony and JAXA

In collaboration with the Japan Aerospace Exploration Agency (JAXA), Sony has developed a Small Optical Link for International Space Station (SOLISS) with the goal of realizing broad-bandwidth, real-time data transmission using optical disc technology.

There are two issues with establishing a link for communication between satellites and between satellites and the Earth. One is that as radio wave frequencies are limited even in space, they are becoming no longer usable by anyone. The second is that satellites need to be downsized from a launch cost perspective. As such, Sony attempted to create a small, energy-saving transmission device using a concentrated laser beam that would not degrade over distance like radio waves.

Laser communication in space requires highly accurate pointing control. Therefore, we focused on applying Sony's optical disc technology. The surface of an optical disc is covered with small indentations called pits and lands, which are scanned by a laser beam as the disc rotates. A small optical control mechanism is used to read how the light is reflected during this process. However, while optical discs are reading optical signals over a distance of less than 1 mm, Sony has been able to extend that distance to several hundred kilometers or more to achieve laser communication in space.

Optical disc technology cultivated by Sony

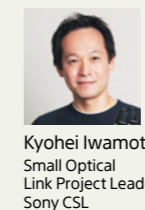
Optical disc technology was developed by Sony in the 1970s and is highly reliable. However, demonstrating that it can be used for long-distance optical communication in space has been extremely difficult. "We didn't know if we would succeed, but that's exactly why we had to try. Our team believed this, and we did our best leading up to the launch. In March 2020, we verified that bidirectional communication between the International Space Station and the optical ground station was successful, confirming that our direction on related R&D was on the right track." (Iwamoto-san)

This joint research won the Prime Minister's Award in Japan, the highest award at the Fourth Space Development and Utilization Grand Prize. Currently, we are conducting R&D that will enable higher-bandwidth communications, including inter-satellite communications, and focusing on establishing it as a technology that contributes to society.

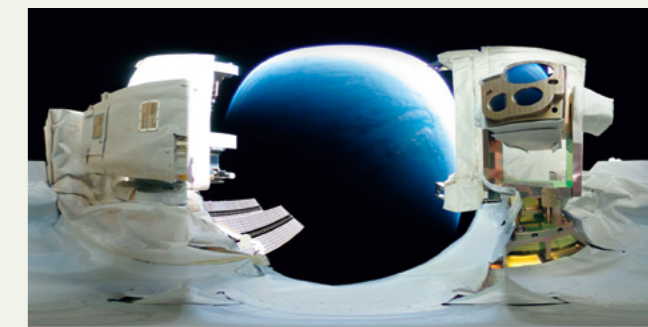
Sony's technological prowess is evident

The space optical communication technology became the important field as an infrastructure for a sustainable society. In this era, it was extremely meaningful for JAXA that we could contribute development of SOLISS that was a new technology of optical communications for space in collaboration with SONY CSL. Optical communication technology is expected to become the standard for communications near Earth. In the situation that international competition of optical communication became intense, Sony CSL was able to develop SOLISS and demonstrate it at ISS in a short period, and we realized high technical capabilities of Sony CSL was evident.

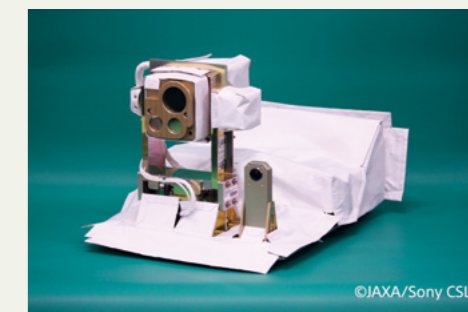
Hiroataka Sawada, Associate Senior Engineer
 Space Exploration Innovation Hub Center, JAXA



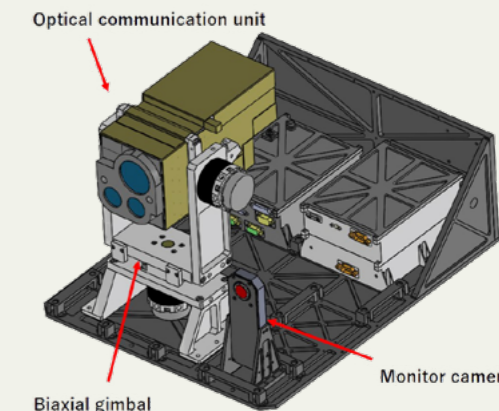
Kyohei Iwamoto
 Small Optical Link Project Leader
 Sony CSL



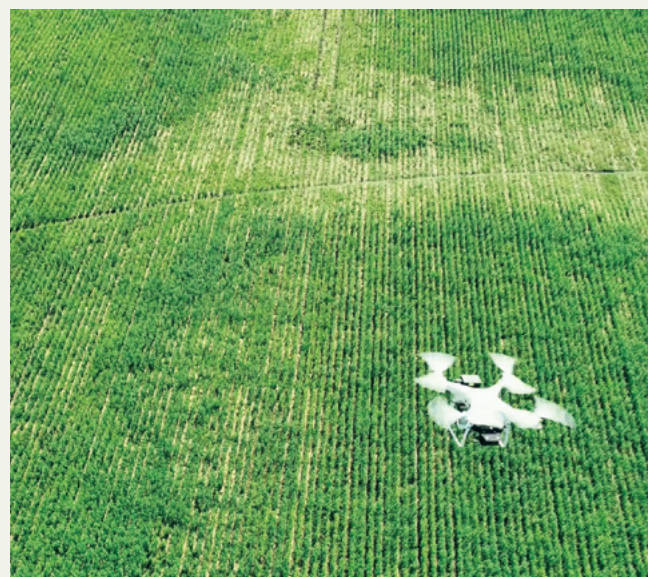
An HD image sent through laser communication of SOLISS



A SOLISS flight model. The optical communications unit, the 2-axis gimbal, and the monitor camera are on the outside. The optical communications unit uses optical disk technology, which is small, highly accurate, uses minimal power, and can easily be mass produced.



SOLISS flight model diagram



Smart Agriculture Solution Better Agriculture through Imaging Analysis

Changing agriculture with imaging and sensing technologies

As the world is expected to face a food crisis by the year 2050, increasing productivity in the field of agriculture is a task of paramount importance. One method that is considered to have great potential is "precision agriculture," which involves collecting and analyzing crop production data and using it to make fine adjustments to comprehensively improve yield and quality and reduce environmental burden. In this field, Sony offers its proprietary "Smart Agriculture Solution" for North American market.

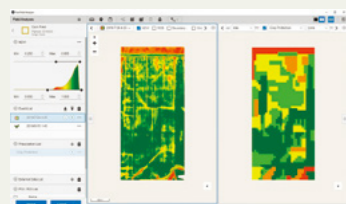
Smart Agriculture Solution makes use of Sony's sensing and image processing technology to better manage large farms. "By using a wide variety of sensor data, we believe it is possible to reduce costs related to fertilizers, crop protection including herbicides, pesticides and fungicides, and irrigation, while increasing yields through proper management, and easing the environmental burden through reduction of crop protection." (Okada-san)

This solution consists of MSZ-2100G multispectral sensing unit and Fast Field Analyzer software for map generation and analysis. MSZ-2100G is a piece of hardware consisting of a camera unit and a sensing unit that is capable of simultaneously capturing visible and near-infrared light images. Capable of detecting position and orientation with high accuracy, the sensing unit associates the images taken and information acquired in real time and saves it as metadata. "Using this metadata to stitch together multiple images reduces the time taken to generate a color map to visualize the quantity and status of vegetation in



Multispectral sensing unit MSZ-2100G

Drone equipped with MSZ-2100G



Fast Field Analyzer program. NDVI* is used to display the quality of farmland (left) to determine the amount of additional crop protection or fertilizer required. Once the amounts have been determined (right), the crop protection or fertilizer can be applied with a GPS-equipped tractor, thus supporting the user from analysis to implementation.

*NDVI (Normalized Difference Vegetation Index) is a graphical indicator used to determine the status of plant life based on remote sensing data by using the visible and near-infrared light reflected by vegetation. It represents both the quantity and vitality of plants.



Ryunosuke Kawashima
Consumer & Professional Business Sector
Sony Imaging Products & Solutions

Teissie Alexis

Takashi Okazaki
Product Technology Center
Sony Imaging Products & Solutions

Hiroyuki Kobayashi
System Software Technology Center
Sony Imaging Products & Solutions

Kazuhira Okada

the area. You can immediately check agronomic results and collect and analyze the data contributes resulting in greater efficiency." (Okazaki-san)

Another benefit of this solution is "stand counting," which analyzes aerial images and calculates the number of new shoots emerging. Utilization of non-visible light makes it easy to identify emergence (which is harder to spot in visible light), and then a highly accurate algorithm is applied to detect and count emergence rates in each area. "This stand count is very important to our customers, since it allows them to identify problem areas and replant them to increase yields." (Kobayashi-san)

Solutions from Sony will contribute to improving agricultural productivity

Smart Agriculture solutions has been launched in North America and will soon be introduced to Australia and New Zealand. "Those two markets are some of the most advanced in term of precision agriculture adoption and digitization. Market reception has been good, and a strong interest has been expressed for Sony entering this industry." (Alexis) In the future, Sony will aim to expand into other regions, realize a total workflow that supports users from problem identification to solutions, and aim to collaborate with agricultural researchers and fertilizer developers.

"The opportunities to utilize Sony's technology are continuously expanding. We will actively collaborate with both Sony Group companies and outside partners to both solve social issues on a global scale and succeed in business." (Kawashima-san)

Imaging and Sensing Technology

Solving Environmental Problems to Realize a Prosperous Society

Supporting the automation of plastic waste collection and sorting

In recent years, the problem of marine plastic waste has drawn considerable attention, and improving the rate of plastic recycling has become a global issue. Improving the recycling rate will require both a better mechanism for collecting used plastics and the technology to sort the collected plastic resources. The collection and sorting process has become more automated in recent years, with typical examples being automatic collection machines for plastic bottles and automatic sorting machines for plastic materials.

A deposit system has been introduced for plastic bottles, and automatic collection machines have been installed in various places such as supermarkets and stores primarily in Europe, where recycling awareness is relatively high. These machines identify the types of plastic thrown inside them using global shutter image sensors, which are capable of high-speed, distortion-free image capture. "Sony's Pregius global shutter technology contributes to improving collection machine performance through its high speed, high image quality, and functions such as Region of Interest (ROI)."

Distinguishing between different types of plastic materials

The Short-Wavelength InfraRed (SWIR) image sensor* is also expected to contribute to the efficient sorting of plastic waste materials. Using the compound semiconductor Indium-

Gallium-Arsenide (InGaAs) as a photodiode, this sensor is capable of capturing short-wavelength infrared light that cannot be detected by conventional CMOS image sensors, allowing it to distinguish between visually similar substances. "Up until now, we have identified plastic materials based on color differences, but with the SWIR image sensor, we can efficiency differentiate between various types of colorless plastic materials such as polypropylene, polystyrene, and acrylonitrile butadiene styrene (ABS)."

As environmental awareness rises, automatic plastic bottle collection machines using global shutter image sensors are expected to become widely used worldwide, including in emerging countries. The SWIR image sensor is also capable of capturing a wider emission spectrum than conventional image sensors, so it may also find use in environmental and energy fields for tasks such as CO₂ flow monitoring in botanical observations and weather observation in solar power generation.

"Industrial activities and environmental issues are inextricably linked. Solving complicated industrial issues will lead to the resolution of environmental problems and the realization of a prosperous society. Through Sony's image sensor technology, we will contribute to environmental load reduction and conservation by solving industrial problems."

Please refer to the technical explanation on page 9.



Plastic has become a constant part of our lives



Sony's imaging and sensing technology contributes to improving recycling rates



Photos of salt, sugar, and potato starch in visible light and short-wavelength infrared light. Certain differences that are hard to distinguish in visible light can be identified based on different absorption rates of short-wavelength infrared light.

Pursuing Diversity and Globalization to Strengthen Sony's Technology

Based on his time working abroad as well as his experiences working with various businesses, Katsumoto-san, head of R&D at Sony, has stated that diverse backgrounds and ideas lead to the strengthening of organizations and individuals, and he has also been strongly promoting the globalization of Sony's R&D Center. Katsumoto-san took on the role of interviewer to lead this discussion with Wasowska-san and Nelles-san, both of whom have been dispatched to Japan from Europe, and Sumiyama-san, who has ample experience working abroad and for other companies, about the strengths of Sony's R&D and possible contributions the company can make.

Participants

Toru Katsumoto
Executive Deputy President,
Sony Corporation
Officer in charge of R&D
Officer in charge of Medical
Business
President, R&D Center

Magdalena Wasowska
Deputy Senior General
Manager
R&D Center, Sony Corporation
Responsible for Security,
Blockchain, AI, Human
Sensing etc. Also serves as
General Manager, R&D Center
Europe Brussels Laboratory



Gabriele Nelles
Deputy Senior General
Manager
R&D Center, Sony Corporation
Responsible for Material Science,
Environment Compliance,
Failure Analysis etc. Also serves
as General Manager, R&D Center
Europe Stuttgart Laboratory 2.

Allan Sumiyama
Senior General Manager,
Corporate Technology
Strategy Division,
Sony Corporation
Responsible for planning
and promotion of Sony's mid
and long term technology
strategy. Also serves as R&D
Center, Business Exploration,
Technology Strategy Division,
Business domain liaison
Department

*This interview was held online on June 2.

Katsumoto-san (Hereafter, Katsumoto): Many people are working from home due to COVID-19. How are you handling this kind of work style?

Wasowska There are pros and cons. A pro is that it is easy to focus on my work, but at the same time there is less face-to-face communication, so it can feel lonely.
Nelles I agree. It's convenient to be at home after work without having to commute, still, for me, speaking with my colleagues would also be a great opportunity to practice Japanese, so I miss that.

Katsumoto You both really like travelling around Japan, so it is unfortunate that you can't do that right now.
Wasowska, Nelles That's very true.

Sony's R&D from the perspective of having worked outside Sony

Katsumoto: You all have experience working in companies other than Sony. From that perspective, what do you think of R&D at Sony?

Sumiyama-san (Hereafter, Sumiyama) Sony has a lot of variety, not just in its businesses but in technology as well. In addition to being broad, in some areas it is also very deep. Based on the six months since joining Sony, I feel that Sony is extremely unique in terms of diversity in its business portfolio, and there is still a lot that I'm learning. At the same time, in terms of structure, it is still mostly comprised

of Japanese males who have been educated in Japan. I also sometimes get the sense that the way of thinking is too centered on technology, which can be a concern.

Wasowska I think everyone at Sony has vision and passion. While it's true that many of the employees are Japanese, I think Japanese people are very respectful and value harmony. In an environment in which there are many different opinions, it can take a long time to reach a consensus, but the process of respecting cooperation and reaching consensus is very important.

I think this attitude of respecting cooperation is typical for Japanese companies, but I personally think it is a very good thing. In addition, Katsumoto-san has introduced an organization system that strongly promotes diversity within R&D and allows us to engage with a wide range of people. I really appreciate Katsumoto-san's efforts in creating such an environment.

Diversity allows for competing opinions and ideas

Katsumoto: Do you have any advice for Sony concerning promoting diversity and also creating a better environment for R&D?

Nelles For me, diversity is about people's mindset, cultural and education background which shape their ways of thinking and determine the perception and



What kinds of contributions can

we make to help Sony contribute

to a sustainable society?

interpretation of information. Communication and the desire to learn from others are also key factors. In order to properly understand people's actions and ways of thinking, inter-lab exchange activities might be most efficient; intercultural workshops and study the language are also helpful to create a better mutual understanding. While the opportunities for face to face communication are limited due to the spread of the new coronavirus, it is also important to consider what kind of platforms can be used to communicate with each other in a way that is as close to real as possible.

Sumiyama We are seeking not just diversity, but searching for a way to allow differing ideas and ways of thinking to compete. One of the most difficult things in R&D is to bring about innovation, but I think diversity is also effective for this as it helps us identifying different problems and priorities. While it can be difficult to have a disagreement with something, that disagreement is with the idea, not the with the person himself. It may be necessary to have some sort of training to allow people to realize that fact and have disagreements in a positive and respectful manner. As team leaders, it is our responsibility to cultivate such environments within our organizations. I understand that diversity is a strength of Sony, so I just want to keep that up going forward.

Katsumoto That's true. Even when I became the head of the R&D Center, at times I felt that employees were avoiding necessary discussions in an effort to keep the peace. Currently, I think that an environment for open discussion is being created, but I would like to improve it even further.

Katsumoto: At the R&D Center/Corporate Technology Strategy Division Meeting held this April, we discussed that deglobalization will not lead to the resolution of the COVID-19 crisis. What are your views on this matter?

Wasowska In a pandemic like this, I think deglobalization is not an answer. As the situation is becoming more complex, people are becoming overwhelmed with feelings of anxiety, and even the opinions of scientists and experts are being disregarded. But real protection can only come from the sharing of reliable scientific information, and from global solidarity. At the R&D Center, we research and develop privacy preserving technologies – from privacy preserving sensing to privacy preserving computations. With the strength from blockchain technologies we hope to achieve solutions which can be used in many scenarios where user data is utilized. One of the interesting cases is, of course, tracking of health of individuals and early warning in case people may have been in contact with a person infected with a virus. These solutions will be essential in avoiding spread of illnesses like



In a pandemic like this,

I think deglobalization

is not an answer.



COVID-19. At the same time anonymous or pseudonymous information about the spread of infection will be essential for epidemiologists to develop appropriate cure.

Sumiyama I agree. Sustainability is defined as one of Sony's Values, and it is important to think about what is truly necessary in order to contribute to a sustainable society. Also, as human error can occur at any time, it is important to utilize technology to avoid such errors. I think such exploration will lead not only solutions for the current situation, but also to long-term solutions that are important for the children who make up the next generation.

Nelles The markets are global and people are connected – deglobalization will not happen; maybe the geopolitical situations will lead to changes in the alliances, which are also not unusual looking back in history. Often, great ideas are born from these kinds of extreme situations, so right now I think it is very important for us to think up new ideas together.

How technology can contribute to a sustainable society

Katsumoto: Since becoming Sony's CEO, Yoshida-san has stated the importance of contributing to society and the environment. What kinds of contributions can we, as leaders in R&D, make to help Sony contribute to a sustainable society?

Nelles The issue of climate change is having a major impact globally, especially on the poor. Furthermore, there are new issues that have been caused by COVID-19, such as social distancing and

goods distribution. I think that Sony's technology can contribute even in these areas.

Wasowska Sony's image sensor technology is very impressive. This is a great opportunity for Sony's businesses to use that technology to contribute to society, and it is a responsibility for us as members of society. Additionally, I think that strengthening our AI technology will accelerate our contributions to this field. While Sony is already involved in projects using AI, I hope to see further efforts focused in the agriculture field and in creating management systems for safe and secure autonomous driving.

Sumiyama I think it's great that the Sony Global Relief Fund for COVID-19, announced this April, is also there to support artists and creators. They are also vital for contributing to the sustainability of our business and society. Even after the resolution of the corona crisis, I want to keep supporting them through our technology.

Katsumoto: A long-term perspective is important for R&D. How will you and your teams contribute in the long term?

Wasowska I think managers have two roles. The first is to determine the direction of the whole organization along with the other team leaders. In order to create an environment in which engineers can fully demonstrate their creativity, we need to pay attention to global megatrends and think of technologies that can have a positive impact on Sony's business. This is where the diversity that we were talking about earlier will play a big role. The second role is that of a leader for my own



At a time when the situation is changing

drastically, it is a big opportunity

to contribute new ideas.

I think that the interdisciplinarity and scientific exchange on a global level created a spirit of innovation.



team. Looking forward, I think we need to carefully consider various fields such as AI, biometrics, digital authentication, blockchain, data transparency technology, drones, robotics, and more, to determine where Sony can contribute while maintaining competitiveness.

Nelles We just talked about people, society, the planet; building on this, sustainability, UX, and autonomous era are domains I would like to see Sony expand into. Also research for multispectral sensing technologies to support urban and precision agriculture new technologies to support human interaction, bringing people closer by providing shared experience.



Sumiyama When dealing with technology, strategy is important from a logical perspective, but the non-logical part—thinking about what makes people feel passion and excitement—is also important. It's my job to figure out what Sony's engineers are interested in, and to let them imagine what success will look like.

The core of Sony is people. Believe in yourself and keep going even if you have small failures.

Katsumoto: Finally, do you have a message for current employees and students who are thinking of working for Sony some day?

Sumiyama When things are changing, old knowledge become less useful. So, at a time when the situation is changing drastically, such as during the current pandemic, there is a great deal of opportunity for young and new employees to contribute fresh ideas. If you can find an agenda that you are passionate about, then you won't be discouraged by small failures. And if you feel what you are doing is necessary, you can continue moving forward even if a higher-up disagrees. I think this kind of attitude will also lead to personal growth.

Nelles When I look back to my time as a student, I think that the interdisciplinarity and scientific exchange on a global level created a spirit of innovation. Also in Sony's R&D, we have to constantly strive to keep the creative spirit. Continuous learning is a permanent companion in R&D, combining aspects from various technical fields. Stay curious, be passionate, stay healthy.

Wasowska The core of Sony is people. I think Sony is a great place for people who are looking to create a better world on a global scale and where they can make a real difference. If you are looking for such a place, please join us. Let's work together.

Interview 2

Participants

Terushi Shimizu
Representative Director,
President and CEO
Sony Semiconductor Solutions
Senior EVP, Officer in charge of
Imaging & Sensing Solutions
Business, Sony Corporation

Also serves as Representative Director and President of Sony Semiconductor Manufacturing, which is responsible for development and manufacturing of semiconductor and Sony LSI Design, which is responsible for design of semiconductor.



Albert Tumewu
Automotive Design Dept.
Automotive Business Division
Sony Semiconductor
Solutions

Joined the company in 2009. Performs design work for signal processing blocks. After designing image processing blocks for televisions and surveillance cameras, he was put in charge of developing automotive image sensors in 2015.

Taku Umabayashi
Dept.7
Research Div.1
Sony Semiconductor
Solutions

Contributed significantly to the development of the stacked CMOS image sensor with multiple functions*. Awarded the Medal with Purple Ribbon in spring 2020 for his achievements.

*See the Umabayashi-san's technical explanation on page 7 for more details.



Makoto Aoki
Automotive Development
Dept.
Automotive Business
Division
Sony Semiconductor
Solutions

Joined the company in 2007. Performs design work for analog circuits. After designing products for cameras and mobile devices, he was put in charge of developing automotive image sensors in 2015.

*This interview was held online on June 8.

Realizing a Better Future through Sony's Imaging and Sensing Technology – To Spark Imaginations and Enrich Society

With megatrends in society shifting from "mobile" to "mobility," Sony's imaging and sensing technology is set to become even more relevant in the future. After releasing the world's first intelligent vision sensors with AI processing functionality, Sony continues to expand its solution business using image and sensing technologies. We interviewed Shimizu-san, who leads the Imaging & Sensing Solution (I&SS) business, Umabayashi-san, who contributed significantly to the development of the stacked CMOS image sensor, and two employees in charge of developing automotive image sensors and asked them about the future that they are trying to realize.

The stacked CMOS image sensor is a highly versatile platform

—Please tell us about the merits of the stacked CMOS image sensor and the value that stacked technology has brought to the semiconductor industry and society.

Umabayashi-san (Hereafter, Umabayashi) The stacked type is a structure that can be used for a wide range of image sensors. It allows you to select functionality based on needs, such as speed, multi-functionality, low power consumption, and low cost. This gives you more options when developing a product, so in terms of versatility, I think the stacked CMOS image sensor is closer to a platform.

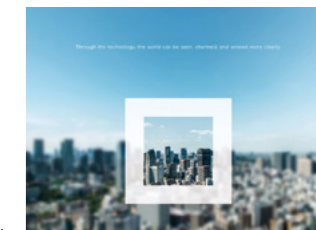
Shimizu-san (Hereafter, Shimizu) The stacked CMOS image sensor has made things more convenient for camera users all over the world. For example, Sony's share of the mobile image sensor market is over 50%, and I believe that the significant progress in smartphone camera performance is due to this stacked technology. Stacked technology has contributed to higher quality photos in the imaging field and provided many people with *kando* experiences. It is these achievements that led to Umabayashi-san

receiving the Medal with Purple Ribbon in the spring of 2020.

Contributing to society and realizing safety and security

—The I&SS business' technological advancements contribute not only to Sony Group profits but also to society. What kind of social contributions would you like to achieve in the future through imaging and sensing technology?

Shimizu Based on Sony's Purpose and Values, the Sony Semiconductor Solutions (SSS) Group's mission was redefined and it now "To spark imaginations and enrich society through the power of technology." SSS is aiming to have the largest share of the imaging and sensing markets in the world. Through imaging and sensing technology, we would like to support people, realize safety and security, and contribute to society. Additionally, with automobiles moving closer to full automation,



the development of automotive image sensors is one of SSS's most important initiatives to contribute to society.

Aoki-san (Hereafter, Aoki) Automotive image sensors need to be able to see in situations that the human eye cannot, such as when exiting a dark tunnel into bright light or driving on a dark road at night. This is where we take advantage of one of the great strengths of Sony's image sensors: pixel and circuit design technologies that achieve high image quality. Image sensors for cameras need to be able to capture an image exactly as the human eye sees it so, in 2007, image sensors with a column A/D conversion circuit were commercialized to improve image quality. This technology, which is capable of taking beautiful pictures even in dark places with low noise, was adapted to expand the dynamic range (brightness range for image recognition) for automotive image sensors. In this way, the know-how and assets cultivated by the I&SS business, including stacked technology, is being used to develop automotive image sensors.

Tumewu In addition to Sony's wide range of assets, communication and brainstorming with other departments and feedback from customers has also greatly advanced development.

Shimizu I definitely think that the presence of SSS automotive image sensors is increasing. As employees involved in the development, how do you feel?



I value issue recognition and cross-cultural exchange. When I have a problem, I try talking to people in different fields and consider whether I can apply a technology or way of thinking that seems unrelated at first glance.

It moves me to know that these products are contributing to society, just like the SSS mission says.

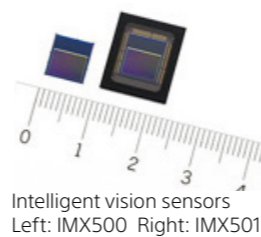


Aoki When we explain our products to customers like car manufacturers, we sometimes receive requests not only for demonstrations but also for specific customization options. I'm really happy that we are getting this kind of reaction to the products that we developed.

Tumewu It is also very rewarding to see the products that we developed mentioned in the news. It moves me to know that these products are contributing to society, just like the SSS mission says.

Shimizu In addition to automotive image sensors, we can also expect to contribute to society through intelligent vision sensors with AI processing functionality, another product developed with stacked technology. The AI processing functionality allows for the development of smart cameras that we expect will be taken up in the retail and industrial equipment industries. For example, in retail, these cameras

could count the number of customers entering a store, detect missing items on shelves, and create heat maps to determine where people gather. These applications would allow owners to analyze the behavior of customers in their stores. In the industrial equipment industry, they could be used for danger alarms, detecting intruders, and handling dangerous materials. We also think that these sensors will be increasingly used to confirm whether people are wearing masks, thereby helping to prevent infections.



Intelligent vision sensors
Left: IMX500 Right: IMX501

Sony's culture and values provide a tailwind for development

—Why was Sony able to develop the world's first stacked image sensor?

Umebayashi There were two main reasons. The first is the compatibility of the manufacturing process with the back-illuminated CMOS image sensor released in 2009. Back illumination is a technology that realizes high sensitivity and low noise by illuminating the backside of the silicon substrate. However, the silicon substrate needs to be very thin for this to work, so we use a laminating technique

to join the chip to a support substrate to maintain durability. Now, while the stacked type uses different techniques, we were able to apply some of the same principles, thus moving the development along more quickly. The second reason was a focused purpose. In the semiconductor industry, there was a trend of making ultra-multifunctional products by stacking various types of chips. However, we didn't follow this trend. Instead of trying to pack in as many functions as possible, we made a smaller product with performance comparable to conventional image sensors.

Tumewu So that's what happened. During development, I often wanted to add in as many functions as possible, so the idea of going against that was very interesting.

Aoki When you are faced with a difficult problem, how did you go about solving it?

Umebayashi I value issue recognition and cross-cultural exchange. When I have a problem, I try talking to people in different fields and consider whether I can apply a technology or way of thinking that seems unrelated at first glance. Then, I slowly and methodically brush up on each of the issues.

Shimizu I think the reason Sony was able to develop stacked technology lies in the challenger spirit that has been passed down until now. Sony's culture encourages "doing what nobody else can." Even if you



Our supervisors often say things like, "Give it a shot!" or "We can gain experience." These remarks are very encouraging from a development standpoint.

Sony's culture encourages "doing what nobody else can." Even if you don't get results, people respect that challenger spirit.



don't get results, people respect that challenger spirit.

Aoki Yes, even with high-risk projects, our supervisors often say things like, "Give it a shot!" or "We can gain experience." These remarks are very encouraging from a development standpoint.

Tumewu When I was involved in signal processing, the development schedule changed a number of times due to various issues, but the people around me responded flexibly.

Shimizu We tell young employees in particular to "always be sincere." You should convey your thoughts to everyone with a sincere attitude.

Umebayashi Sony has always had a culture of treating people equally, regardless of their job title. This corporate culture makes it easier to convey your thoughts to others.

—Please tell us about the future outlook for the I&SS business.

Shimizu We're thinking about our hardware and software strategies together. In addition to selling hardware—our sensors—we also plan to expand sales of services incorporating software. In terms of software strategy, we will focus on solutions that combine devices with edge AI, such as our intelligent vision sensors. We are also collaborating on smart camera solutions with Microsoft, with the goal of establishing a more advanced sensing solutions business by linking their cloud AI services with our edge AI. I believe that imaging and sensing technology can move people and contribute to a safer society. I hope that everyone involved with development will work with pride, knowing that what they are doing will benefit society.

Umebayashi We want to combine software and hardware to produce a system and provide new value to society. Under the mission of SSS, "To spark imaginations and enrich society through the power of technology," I would like to continue developing new technologies while considering their social significance.



Bill Baggelaar

Executive Vice President & General Manager,
Sony Innovation Studios
Executive Vice President & Chief Technology Officer,
Technology Development
Entertainment Innovation & Technology Group
Sony Pictures Entertainment

Utilizing the Latest Technologies and Getting Closer to Our Creators at Sony Pictures

— With a Vision of One Sony

Sony Pictures Entertainment has dedicated teams to support film and television production with technology. Bill Baggelaar, who is leading these teams, talks about the missions of these teams and shares a future outlook.

— **You were appointed as EVP and General Manager of Sony Innovation Studios and EVP and CTO of Technology Development Group at Sony Pictures Entertainment (SPE) this April. What are the primary roles and functions of each group?**

I am grateful and excited to be in this new dual role at Sony Pictures. **Sony Innovation Studios** is focusing on some very exciting technologies in volumetric virtual production. This comes at a time when there is a clear demand for these kinds of tools and services to help production, especially with the current COVID-19 challenge. We have a toolset called Atom View that allows the capture of a production set or real-world location, and we can faithfully reproduce that asset on an LED wall or green screen environment. You can put actors and props in the captured environment and shoot as if you were on the real set.

The **Technology Development** department's primary role is to work with internal and external partners to find, create and develop new technologies that can be deployed at the studio to drive new methods of production, post-production, archiving and distribution. We bring together industry partners, creatives and various groups around Sony along with the Sony's R&D Center to develop new solutions. We are bringing these technologies to the studio in order to help creators realize their vision and to deliver those experiences to our customers.

— **What is the mission for each group?**

Sony Innovation Studios is pioneering production technologies to deliver state-of-the-art entertainment experiences. We advance Sony's entertainment technologies through global partnerships and industry collaborations with creative visionaries.

Technology Development fosters innovation at SPE through the discovery, exploration, creation, and socialization of new technologies. We serve as a conduit for SPE, other Sony Group companies, tech companies, and industry standards bodies. We strive to maintain Sony's commitment to *kando* by identifying and influencing technology applications to improve efficiency, maximize quality, and enhance user experiences while protecting SPE's intellectual property.

— **"Getting Closer to People" is Sony Group's corporate direction. How do you translate this direction into your work?**

I have always seen my role to be a conduit between creative and technology. The strength of our team is that we embody that same ethic, we can translate between creative and tech. We speak both languages and therefore, we make technology accessible to our creative teams so that they can best determine how to use those technologies to deliver their vision. As we identify new opportunities that can enhance the viewers' experience, like 4K, HDR and immersive audio,

we are helping creators embrace new technologies like new cameras, virtual production, real-time game engines, new audio formats, machine learning and AI, all in pursuit of creating content for movie and TV fans that can deliver those experiential technologies.

Realizing more than ever the power of Sony teams

— **We understand that you have experience working at different entertainment companies. Having such a background, what advantages do you think we have for film production as part of the broader Sony Group?**

I came to SPE in 2011 to help bring to life the vision of One Sony. We are realizing this now, more than ever, as we combine the power of the Sony teams. On the technology side, we have teams who are creating displays for consumers and professionals, teams creating cinema cameras, along with the R&D teams focused on new production and post-production tools. And on the creative front, we have fantastic IP at SPE and Sony Interactive Entertainment. Only Sony can bring all of these together to deliver a truly unique perspective and new entertainment experiences for our fans.

— **Having those advantages, what sort of activities have you recently worked on with Sony's R&D team and/or business groups?**

We are working on a variety of projects with the Sony R&D team and other Sony business groups. We have several projects focused on AI and machine learning to provide enhanced methods for up-converting the resolution of original content to 4K. New opportunities have opened up, thanks to Sony's AI Sound Separation technology that was used on the new UHD HDR + Atmos releases of the feature films, *Lawrence of Arabia* and *Gandhi*, as well as some



Bill with a Sony Innovation Studios team at CES 2020

projects still in development that are aiming to allow creators to focus on truly creative work with AI tools supporting them.

Virtual production tools and techniques are still being developed and we are working with several teams at Sony such as Sony's R&D Center and Sony Imaging Products & Solutions among others to make this happen. We are also working on future technologies that can bring machine learning to tagging, cataloging, archiving and preserving our content for generations to come.

In addition, we have a long history of collaboration with the Sony professional camera and display teams and have worked closely with our internal teams to give Sony an expanded reach into the Hollywood community. Also, we worked with Sony Pictures Animation and Sony Pictures Imageworks to get Sony's OLED displays into the production process and are currently working with studio operations to get Sony OLED and LED displays into employee's homes for continuing stay-at-home work for quality control

and master review.

— **You have been working with various creators in the field of entertainment. Can you tell us how our technologies are perceived by those creators in the industry? Are there ways in which our technologies can help transform or affect the art of filmmaking?**

Sony is and always has been considered the highest quality in the industry. The perception from consumers to professionals is extremely positive. Sony continues to transform the industry and the art of filmmaking with professional cameras, professional displays, consumer displays, audio technologies, as well as new cloud-based tools. We pushed hard for the use of 4K cameras and HDR deliverables which have been adopted across the industry. We are now entering a new age where Sony will bring its unique perspective to virtual production in order to help filmmakers realize their creative vision that may have been impossible or impractical in the past.

Keeping us up and running

— Currently, physical production has been suspended and many of us continue working from home. Under such conditions, how have you leveraged technology and what steps have you taken to continue film production?

While we have kept post-production running and working remotely for both picture and sound at the studio, Sony Innovation Studios has been working closely with Columbia Pictures and Sony Pictures Television to help determine the way forward once physical production can resume. The use of virtual production technologies can allow productions to bring remote locations onto a controlled stage environment, and help reduce travel. COVID-19 will possibly have a long-term impact on the production environment and we are optimistic that virtual production will be a key component to keeping us up and running.



Gandhi (left), Lawrence of Arabia (right)

— For the past few years, you have been at the intersection of technology and creators at SPE by leading several projects. As Yoshida-san advocates, Sony has been pursuing “Reality” and “Real-time” solutions to provide *kando* to our users. Against the backdrop of the recent coronavirus pandemic, Yoshida-san added a new value, “Remote,” at the Sony Corporate Strategy Meeting in May. Are there any possibilities for adding this value to these solutions, and if so, how will your initiatives contribute?

I have been lucky and proud to be a part of several One Sony initiatives, from the initial launch of 4K and then with the addition of immersive audio formats, to the subsequent launch of HDR. It has been a very exciting period where we have provided *kando* to our Sony creators and customers. My teams are well positioned to deliver on all three R’s of Yoshida-san’s vision for the company. Sony Innovation Studios provides the Reality and Real-time components, while the Technology Development team is focused on

Remote collaboration. Both Sony Innovation Studios and TechDev sit at the intersection of content creation and technology and are helping to bring the studio teams together with the Sony groups to further our overall collaboration.

— How do you think innovation and technology can contribute to find new approaches in the world with and after coronavirus?

Innovation and technology are critical for our success, now and in the future. We need to create, develop and harness new technologies in order to become better at what we do. We are already seeing this at SPE where we are driving new methods and technologies that I discussed earlier to help deliver continued results. We will be living with Coronavirus for some period of time and so we need to adapt to the times. Real-time, Remote collaboration will become an ever increasing imperative, especially after production resumes.

— How do you plan to pursue Sony’s Purpose, “Fill the world with emotion, through the power of creativity and technology,” through further collaboration with Sony’s R&D Center and other group companies?

SPE embraces and is aggressively pursuing Sony’s Purpose by collaborating on a multitude of projects. We are committed to bringing together the best minds to help build on Sony’s fantastic IP to deliver new and engaging experiences; the stories that our filmmakers want to tell. We also have the ability to use technology to transform the way we operate as a studio, to harness technology to reduce friction and make content creation and distribution easier and more consistent. All of this will further lead to opportunities that we cannot yet imagine. Only Sony has all of these facets, from technology, R&D, movies, episodic shows, games and the professional and consumer products to bring together in a unified way to deliver on that promise.

Case Studies in Collaboration

Virtual Production Volumetric Capture for Movie Quality

The visual production team at SPE expressed their interest in Sony R&D’s volumetric capture technology before Sony Innovation Studios (SIS) was established. At the opening ceremony for SIS in June 2018, we revealed the real-time volumetric capture system that we developed together with SPE and the guests were astonished by the photorealistic image quality. After that, we chose to apply this technology in the Japanese music industry* while SIS pursued even higher image quality, and we have continued aiming for new heights with volumetric capture technology. Our technology can be utilized for virtual production at SPE. Virtual production allows the remote creation of images that appear to have been taken on location. Highly accurate calibration and alignments are important to create high-fidelity 3D models, and we are known for placing importance on “Real-time” and utilizing an automated process. Quality is the top priority in film production at SIS, and there are many artistic works that require manual



Junichi Tanaka
Yosuke Kaji
Tokyo Laboratory 09
R&D Center
Sony Corporation

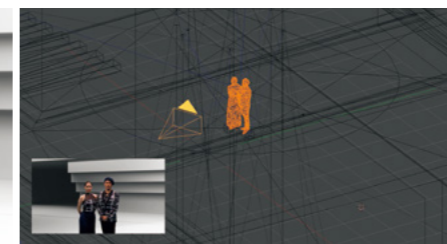


processing. However, virtual production requires the handling of a huge amount of data, which takes a long time to process and edit, and Sony’s automation technology can be useful in improving production efficiency. We believe that SIS provides the optimal environment to deliver the highest picture-quality volumetric capturing. As we continue striving to realize better image quality while collaborating with partners in various fields, we believe these activities will lead to the creation of new experiences.

*See page 24-25 “Volumetric Capture Technology That Goes Beyond Omnidirectional Visualization.”



Sony’s rendering technology is capable of remotely creating an image (left) that appears to have been taken on location.



Audio Source Separation with AI Reviving the Sound of Classic Movies with AI

Audio source separation is a technology that makes it possible to remove unnecessary noise from audio data and extract specific instruments or sounds. Until recently, this was extremely difficult to do. Some people compared this task to mixing two juices and extracting one of them afterwards. Audio source separation is carried out by machine learning and we can teach our computers to fulfill this task. For example, a guitar has a specific sound or frequency that is recorded in the neural network. Regardless of how many sounds are mixed, our AI system is capable of picking out these characteristics. It is just like how a person knows the shape and color of an apple, and can therefore easily identify one against a background.

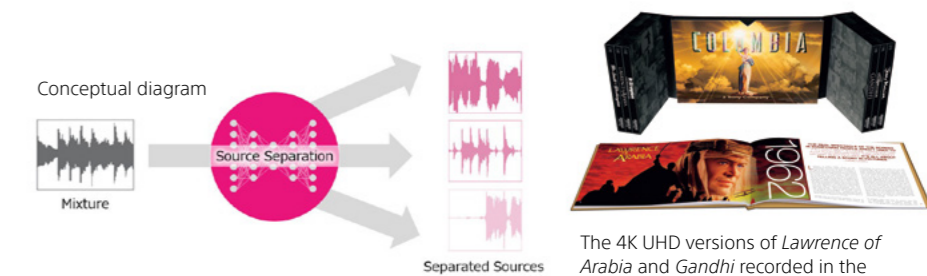
We think audio source separation is one of the few technologies that can rewind time. For example, you can take a piece of old music and extract the vocals to remix them or separate all the instruments to recombine them in a new format. Classic movies have the dialogues and sound effects on the same track, but



Yuki Mitsufuji
Stefan Uhlich
Tokyo Laboratory 21
R&D Center
Sony Corporation



after learning from a sound effects (called Foleys) library, our AI system was able to successfully extract individual sound effects from the master copy. For the 4K UHD versions of *Lawrence of Arabia* and *Gandhi* released in the U.S., SPE sound mixers took sounds extracted with this technology and remastered them using Dolby Atmos to create an immersive sound field. This technology is also expected to find non-movie applications such as cleaning up human voices recorded through microphones, converting streaming music to Karaoke, and dubbing drama and anime.



The 4K UHD versions of *Lawrence of Arabia* and *Gandhi* recorded in the Columbia Classics Collection Vol 1.

Providing an Immersive Sound Experience Fully Optimized for Individuals



Sony Corporation
Kazumi Fukuda
① Spatial audio technology, R&D
② Electrical Engineering and Information Systems, Graduate School of Engineering
③ 2013
④ Page 18-19 – 360 Reality Audio

Striving to Develop Volumetric Capture Technology that Makes Creators' Visions Possible



Sony Corporation
Hisako Sugano
① Software/Signal, data processing, R&D
② Electrical, Electronic and Computing Systems, Graduate School of Science and Engineering
③ 2011
④ Page 24-25 – Volumetric capture technology

Continuously Evolving Signal Processing Technology to Realize a Safe Mobility



Sony Semiconductor Solutions
Albert Tumewu
① Developing signal processing for automotive image sensor
② Computer and Mathematical Sciences, Graduate School of Information Sciences
③ 2009
④ Page 43-45 – Interview 2

Meet Our People: Supporting the Technology that Inspires Emotion

Sony was born out of its founders' dream of enriching people's lives through the power of technology. Having inherited this dream, Sony employees from a wide variety of backgrounds and experiences continue to take on new challenges to fill the world with emotion.

① Work ② Majors ③ Year joined ④ Appeared on page

You can read the Sony Group members' interviews and recruitment information on the Global Careers page of the Sony Group's corporate website. Please take a look!
Interviews with People at Sony (Global Career)
<<https://www.sony.net/SonyInfo/Careers/>>



We are Aiming for a Future Where AI and Robotics Technologies Augment Human Capabilities and Creativity in Harmony with People



Sony AI
Peter Dürr
① AI/Robotics, R&D
② AI/Robotics, Graduate School of Mechanical Engineering
③ 2011
④ Page 35 – Sony AI

Creating the Future of Mobility by Bringing Together the Passion and Knowledge of Experts



Sony Corporation
Takuya Shoji
① Development of autonomous driving for VISION-S
② Mechanical and Control Engineering, Graduate School of Science and Engineering
③ 2019
④ Page 30-31 – VISION-S

Bringing Sony's Unique Technology and Products to the Global Markets by Strong Partnerships



Sony Electronics Inc.
Thaisa Yamamura
① Business development
② Marketing, Graduate School of Business Administration
③ 2004
④ Page 20-21 – Eye-sensing Light Field Display

Sony Technology Website Introducing the R&D Efforts toward Innovation through Technology

The Sony Technology Website, which can be accessed via the Sony Group's corporate website, was established to share information on technology in accordance with the Sony Group's Corporate Strategy to improve corporate value, attract human resources, and stimulate open innovation. In addition to the technologies themselves, this website also shines a light on the people who create them. Under "Stories" you can find articles that convey the beliefs and passion of the researchers and engineers developing Sony's technologies; under "Activities" you can read about different external events conducted by Sony; and under "Awards & Publications" you can learn more about Sony's achievements at academic conferences and in other circles. We will continue proactively sharing information about initiatives based on Sony's purpose of "Filling the world with emotion, through the power of creativity and technology." Please check it out and stay tuned for further content.



Creating things that don't yet exist, five to ten years from now

Sony's new R&D structure was introduced in April 2018. Toru Katsumoto discusses his vision and responsibilities as the Officer in charge of R&D for the Sony Group. How does he promote next-generation R&D to support Sony as a "Creative entertainment company with a solid foundation of technology"? This story tells us how he sees the new way forward.



Sony Technology Day (September 18, 2019) Report

Sony Technology Day was held to enhance understanding of the technologies that connect Sony Group's diverse businesses, while also promoting general awareness of the technological aspects of Sony. Kenichiro Yoshida, Chairman, President and CEO, and Toru Katsumoto, Vice President and Officer in charge of R&D, explained the role of technology and R&D strategies within Sony and exhibited some technologies.



Perspectives from the creators of the image sensor "microcosm"

In July 2018, Sony launched its IMX586 stacked CMOS image sensor for smartphones. What kind of challenges and breakthroughs did the team encounter in the process of developing higher image quality for an image pickup device? We interviewed the engineers in charge of pixel design, image processing algorithms and devices.



Sony Outstanding Engineer Award

There are a wide range of technological challenges that Sony will have to take on in order to develop products and services that appeal to customer sensibilities. We will introduce the award-winning employees who created new values by developing fundamental technologies or proactively taking on difficult challenges such as fusing unique technologies and optimizing complex systems.

Other contents such as the Sony's Technology 2020 special will be added soon!

Sony Technology Website
<https://www.sony.net/technology/>



Your comments are welcome!

We love hearing from our readers. Please send your feedback to Sony.Family@jp.sony.com

Handling of personal information

All personal information provided by you, such as name, department name, age, email, etc. (hereinafter referred to as "personal information") is strictly handled by Sony Corporation's Corporate Communications Department only in accordance with the Sony Group Privacy Policy (<https://www.sony.co.jp/privacy/en/>). Personal information will not be used for any purpose other than feedback unless required by law. For inquiries regarding personal information, please contact us at Sony.Family@jp.sony.com.

*Department names and titles are published as at the time of the interview.
*Contents are accurate as of the time of editing but may be subject to change.
*Company names and product names are registered trademarks.

SONY

July 2020 Sony's Technology 2020 (Family special combined edition No.212, No.213/No.44)

Publisher: Corporate Communications Department, Sony Corporation Person in Charge: Mami Imada Email: Sony.Family@jp.sony.com

Planning & Editing: Corporate Communications Department, R&D Center, Corporate Technology Strategy Division, Electronics Human Resources Division, Finance Department, Creative Center, Sony Corporation

Cooperation: Corporate Communications, Sony Corporation of America

Editorial Cooperation and Design: Sangyo Henshu Center Co., Ltd. Printing: Nikkei Printing Inc. All rights reserved.