DIGITAL HUMANITY

2021 ETRI
TECHNOLOGY
REPORT

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REPORT

ETRI 한국전자통신연구원
Electronics and Telecommunications
Research Institute

DIGITAL HUMANITY

2021 ETRI Technology Report

Striving to be a Revolution-driven Leader

We live better lives than yesterday amid the wave of new emerging industries such as artificial intelligence, Big data, Cloud and next-generation mobile communication.
ETRI strives to become an agent of transformation that can lead innovation without being overwhelmed by the changes across the economy.
We usher the Digital Transformation era for all people through creative research and perfect technological development.

Beyond Only Change

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Beyond Only Change

While the core value of the industrial development era has been 'growth', the future core value of local AI-based businesses to be realized is 'love for humanity'.

Robots on screen act as assistants in our daily lives and digital twin non-face-to-face technology that ensures our everyday safety have come to fruition.

ETRI's efforts toward people-based values beyond technological growth do not stop here.

Putting
Growth-driven
Values

by Putting People
at the Center of
Our Values

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President's Message

Today, we are undergoing a great transformation called the "Fourth Industrial Revolution." This transformation is also referred to as "digital transformation" or the "Secondary Information Age." Accordingly, the core technology is information and communication technology (ICT), comprised of ABCI represented by Artificial intelligence (A), Big data (B), Cloud (C), and Internet of Things (I).

For this reason, the expectations on our researchers, who are in charge of national ICT R&D, are greater than ever. ICT is not only creating the industrial roadmap geared for innovative AI tools across the sectors of society, such as manufacturing, national defense, health care, arts & culture, education, farming, and fisheries, but also working to benefit everyday lives of the people by addressing population decline, climate change, and the COVID-19 pandemic. To rise up to this national calling, over 2,600 ETRI employees are committed to research with a strong sense of research ethics and passion as a member of the 'National AI Research Institute'.

ETRI will support in earnest innovative growth by securing world-class technological competitiveness by developing the underlying technology of the AI information society. We will also leverage to create a safe and secure social environment that people can trust in based on ICT. In addition, we hope to contribute to designing a nation that embraces the spirit of 'mutual caring' by developing 'compassionate' ICT for a people-centered digital society.

ETRI always undertakes R&D with the aim of a safe environment (E), a mature society (S), and a transparent and fair life (G). As researchers we are guided by our mission to be loved by the people, trusted by the state, and highly regarded by customers.

We ask for your support so that ETRI can expand globally beyond Korea. Based on the hopes of global citizens, our research team will work with local and overseas experts to serve the public at large by establishing ourselves as an international research institute at the forefront of our nation's and mankind's future. We will play the role of the 'Smart Partner' for people worldwide.

Thank you.

President of ETRI
Kim, Myung Joon

With the aim of positioning Korea as an AI powerhouse, ETRI will fully adopt the ESG management system and focus on ICT development through launching over 10 world-class research groups within 10 years.

History of ETRI

1976.12.30.

KERTI established
Established for
electric research and testing

KIET established
Established for
semi-conductors and computers

1976.12.31.

**KECRI was founded
as an affiliate of KIST**
Established for R&D in
telecommunications technology

*Established KERTI, KIET and KECRI,
the origins of ETRI*

1976.12.30.
KIET(Korea Institute of Electronics
Technology) was established

1976.12.30.
KERTI(Korea Electric Research and
Testing Institute) was established

1976.12.31.
KECRI(Korea Electronics &
Communications Research Institute)
was founded as an affiliate of KIST

1977.12.10.

KTRI established
KECRI became independent from KIST
and KTRI was established on Dec 31,
1976 as a research institute specialized
in telecommunications

1977.12.10.
Independent from KIST and
renamed itself as KTRI

1981.01.20.

KETRI established
(consolidation of KTRI and KERTI)

Established KETRI

1981.01.20.
KETRI(Korea Electrotechnology
and Telecommunications Research
Institute) was established in
consolidation of KTRI and KERTI

1985.03.26.

ETRI established
ETRI Institute specialized in
information and telecommunications
(consolidation of KIET and KETRI)

Established ETRI

1985.03.26.
ETRI, institute specialized in
Information and Telecommunications
was established(consolidation of
KIET and KETRI) to meet with the
emphasize on electronics field

1996.01.01.

SERI transferred to ETRI
SERI, data process department of KIST,
transferred to ETRI as an affiliate

*Data process department of KIST
transferred to ETRI as an affiliate*

1996.01.01.
SERI(Systems Engineering Research
Institute) was opened as data process
department of KIST. In accordance
with government restructuring of the
Ministry of Science and Technology
to the Ministry of Information and
Communication, SERI became
affiliate of ETRI on January 1, 1996

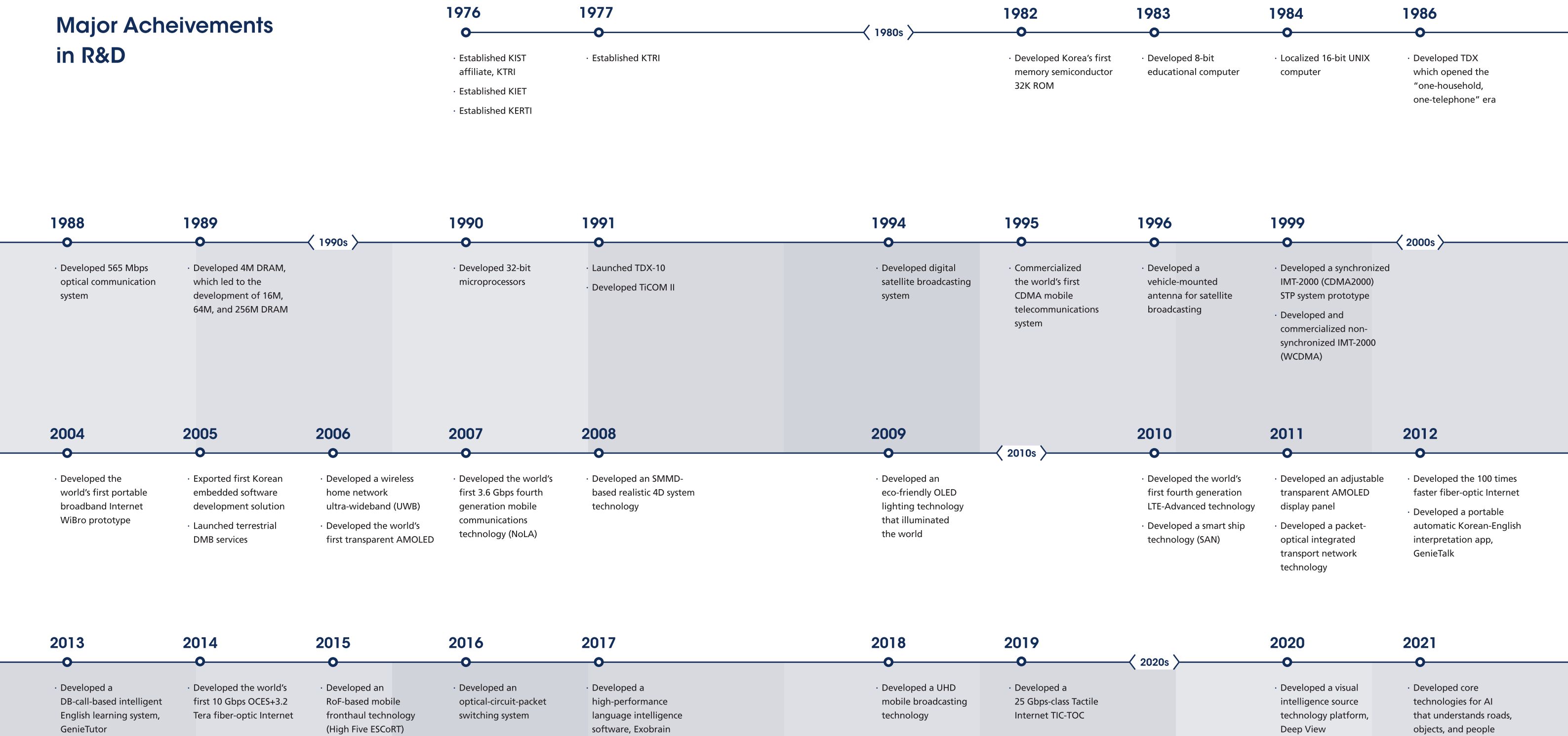**1998.05.25.**
Incorporated into ETRI

1997.01.31.

ETRI
Korean name of ETRI officiallchanged

*Korean name of ETRI officially
changed*

1997.01.31.
Based on regulations for electronics
and telecommunications

Major Acheivements in R&D

1976
· Established KIST affiliate, KTRI
· Established KIET
· Established KERTI

1977
· Established KTRI

1980s

1982
· Developed Korea's first memory semiconductor 32K ROM

1983
· Developed 8-bit educational computer

1984
· Localized 16-bit UNIX computer

1986
· Developed TDX which opened the "one-household, one-telephone" era

1988
· Developed 565 Mbps optical communication system

1989
· Developed 4M DRAM, which led to the development of 16M, 64M, and 256M DRAM

1990s

1990
· Developed 32-bit microprocessors

1991
· Launched TDX-10
· Developed TiCOM II

1994
· Developed digital satellite broadcasting system

1995
· Commercialized the world's first CDMA mobile telecommunications system

1996
· Developed a vehicle-mounted antenna for satellite broadcasting

1999
· Developed a synchronized IMT-2000 (CDMA2000) STP system prototype
· Developed and commercialized non-synchronized IMT-2000 (WCDMA)

2000s

2004
· Developed the world's first portable broadband Internet WiBro prototype

2005
· Exported first Korean embedded software development solution
· Launched terrestrial DMB services

2006
· Developed a wireless home network ultra-wideband (UWB)
· Developed the world's first transparent AMOLED

2007
· Developed the world's first 3.6 Gbps fourth generation mobile communications technology (NoLA)

2008
· Developed an SMMD-based realistic 4D system technology

2009
· Developed an eco-friendly OLED lighting technology that illuminated the world

2010s

2010
· Developed the world's first fourth generation LTE-Advanced technology
· Developed a smart ship technology (SAN)

2011
· Developed an adjustable transparent AMOLED display panel
· Developed a packet-optical integrated transport network technology

2012
· Developed the 100 times faster fiber-optic Internet
· Developed a portable automatic Korean-English interpretation app, GenieTalk

2013
· Developed a DB-call-based intelligent English learning system, GenieTutor

2014
· Developed the world's first 10 Gbps OCES+3.2 Tera fiber-optic Internet

2015
· Developed an RoF-based mobile fronthaul technology (High Five ESCoRT)

2016
· Developed an optical-circuit-packet switching system

2017
· Developed a high-performance language intelligence software, Exobrain

2018
· Developed a UHD mobile broadcasting technology

2019
· Developed a 25 Gbps-class Tactile Internet TIC-TOC

2020s

2020
· Developed a visual intelligence source technology platform, Deep View

2021
· Developed core technologies for AI that understands roads, objects, and people

Vision & Management Principle

Prepare for the future growth by vitalizing creative and challenging research

Generate world-class top-tier R&D performance

Vision

National AI Research Institute
Making a Better Tomorrow

Your Trusted Partner, Leading ICT, Creating a Better Future

Management Principle

Establish a research culture that is rooted in openness, sharing and cooperation

Resolve the living issues of the public and expand support for SMEs

Organization Chart

President

Audit & Inspection Dept.

Public Relations Dept.

National Security Research Institute

KSB Convergence Research Dept.

SDF Convergence Research Dept.

DMC Convergence Research Dept.

Daegu-Gyeongbuk Research Center

Honam Research Center

Seoul SW-SoC Convergence R&BD Center

Artificial Intelligence Research Laboratory

Telecommunications & Media Research Laboratory

Intelligent Convergence Research Laboratory

ICT Creative Research Laboratory

Planning Division

Administration Division

SMEs and Commercialization Division

Executive V. President

I

The Main R&D Field

2021 ETRI
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Artificial Intelligence
Research Laboratory

Autonomous Driving Vehicle without a Driver's Seat, Discovering a New Value for Transportation

Interview clip ▶

Intelligent Robotics Technology

ETRI Researchers succeeded in developing an autonomous driving vehicle without a steering wheel by mounting a high-performance AI SW onto an electric vehicle model made by an SME. The significance of this vehicle is that ETRI, as a leading government-funded research institute for AI, opened the doors to the public service market for personalized transportation services and the mobility handicapped. Services guaranteeing the autonomy of personal mobility through public R&D will create new values for means of transportation.

According to the autonomous driving standards of the Society of Automotive Engineers (SAE), autonomous driving vehicles are divided into six levels, ranging from level 0 to level 5. They include the level in which the driver drives and controls the vehicle (level 0), the level that has at least one automatic control function (level 1), the level that has at least two automatic control functions (level 2), level where most driving functions are automatically performed while the driver can intervene if necessary (level 3), and the level where the vehicle is driven 100% autonomously at any given time and place and the driver only needs to enter the destination (level 4).

Commercial autonomous driving technologies available now are at level 2 or 3, which still have the driver's seat and drivers need to intervene as necessary. On the contrary, ETRI developed a technology that make vehicles without the driver's seat, fully prepared for the era of level 4 autonomous driving. The name of the autonomous driving vehicle developed by researchers at ETRI is AutoVe. AutoVe is a compound word of "autonomous driving" and "vehicle," symbolizing a truly autonomous driving technology without a driver.

For user convenience, ETRI also mounted its world-class AI-based voice command interface. The shuttle service begins when someone calls AutoVe while it is parked in one of ETRI's building using a mobile device. If the user gets onto AutoVe and says, "Hi AutoVe, let's go to Research Building 7," AutoVe would recognize the voice and head to the destination. The passenger can engage in any activities inside the vehicle since there is no need to drive. The rider can control the vehicle by giving orders like "Stop" and "Dodge."

Inside the research center, AutoVe moves within a limited speed of 25 kmh according to the safety regulations. Booking for a ride can be made via a kiosk at the customer building where customers visit and can check the location of AutoVe in real-time through a QR code. AutoVe runs the route that passes by the main research buildings of the institute from 10 AM to 5 PM. AutoVe drives safely and smartly in different situations like crossroads without traffic signals, pedestrian crosswalks, or parked vehicles.

The high-performance AI algorithm applied in AutoVe processes the information obtained from the camera and lidar sensor in real-time to recognize surrounding traffic environment and objects and create a driving route. It is more efficient than processing the sensor information by communicating it to the remote base. AutoVe constantly communicates with the surroundings to move forward. The researchers installed various sensors around the institute using the data-centric between vehicle to infra communication infrastructure technology which remotely and safely transmit information on blind spots and areas that are under construction to AutoVe in real-time. Information observed by the vehicle and the expanded recognition of driving environment can ensure safer autonomous driving.

The transparent OLED display inside the AutoVe window has a realistic AR guide technology developed by ETRI and offers a device that streams 8K VR broadcasting contents in real-time. Accordingly, the passenger can enjoy the content linked to the vehicle information and 3D space or watch 360-degree 8K VR broadcasting in real-time.

This technology is a platform service that provides hyper-realistic content in real-time when a person does not have a car or cannot drive, taking them safely to their destination. It can be used in various areas such as transportation and logistics.

1. Demonstrating AR realistic guide technology with a transparent OLED display installed on the self-driving shuttle bus 'AutoVe' developed by ETRI researchers.
2. 'AutoVe' recognizes road traffic situational information in real time.

Improving Elderly People's Quality of Life through ICT

Walking Assistance Technology for the Elderly

Within ten years, Korea will be a country with more than 20% of its population aged 65 years or older. Aging leads to reduced economic growth potential, changes in the industrial structure, increased financial burden, and conflicts in political priorities. In accordance with such social changes, ETRI has developed a technology to increase the activeness of the elderly and aid them in enjoying a healthy lifestyle. This will be applicable not only to walking, climbing stairs, and other specific actions but all physical activities, likely proving to be a huge aid regarding muscle atrophy, rehabilitation, and improvement of walking disabilities.

Research that focuses on improving the quality of life with human-centered ICT is proving to be a hot topic. This is because R&D benefits should be shared equally among all members of society. According to such trend, ETRI has expanded citizen-centered research and increased efforts to develop technologies that resolve social issues.

ETRI has recently developed a walking assistance technology that allows users to move their joints through functional electrical stimulation (FES) technology. Electrodes consisted patches are attached to the desired muscle points and the system will figure out the users' intentions that how much they want to move their joints. It will then naturally and electrically help their muscles in order to generate comfortable assistance as they desired.

The FES, which is utilized in various fileds, is a technology that utilizes the principle of generating artificial contractions when the small amount of electric current is applied to the muscles. Low frequency electric stimulator devices for physical therapy and electrical muscle stimulation equipment for physical training utilize this principle.

Existing products, however, only apply the pre-programmed patterns of electrical and thus the users had no choice but to adapt to the system. This is because, when the FES generates artificial contractions, there is no technology that can distinguish whether the contraction is FES-induced or voluntarily user-induced. Therefore, only repeated electrical stimulation without the reflection of user's motion intention was possible, and there were limits to its effectiveness.

To breakthrough these limitations, researchers developed a technology to figure out the user's motion intention in real time using electromyography (EMG) sensor regardless of whether electrical stimulation was applied; and appropriate electrical stimulation suitable for each motion intention are generated to assist their movement. The researchers said that the technology to detect the muscle activity due to voluntary contraction from the EMG signals contaminated by electrical stimulation was the key to develop the product. As a result, the system can naturally adapt to the users with this technology.

In order to verify the effects of this system, it was applied to eight muscles on the lower extremity of elderly individuals. Commissioned research was performed with Sahmyook University for exploratory clinical testing. The clinical tests showed that the system is effective in natural walking assistance, and various clinical results support this effectiveness; short physical performance battery (SPPB) scores increased when walking or climbing stairs, the energy required to move in addition to muscle usage had been reduced, walking speed increased as did the muscle volume, and ground reaction force while walking was enhanced.

Currently the attachable electrodes are connected by wires, but wireless functionality will be made possible during commercialization. The weight (for assisting eight muscles) is around 950 g or so including the battery, making it very light. The patches are thin and can be hidden under flexible suit, making them easy to wear. As a result, this will help the elderly be more active and lead healthier lifestyles in addition to seeing increased utilization in rehabilitation, training or home training for muscle strengthening and other various fields.
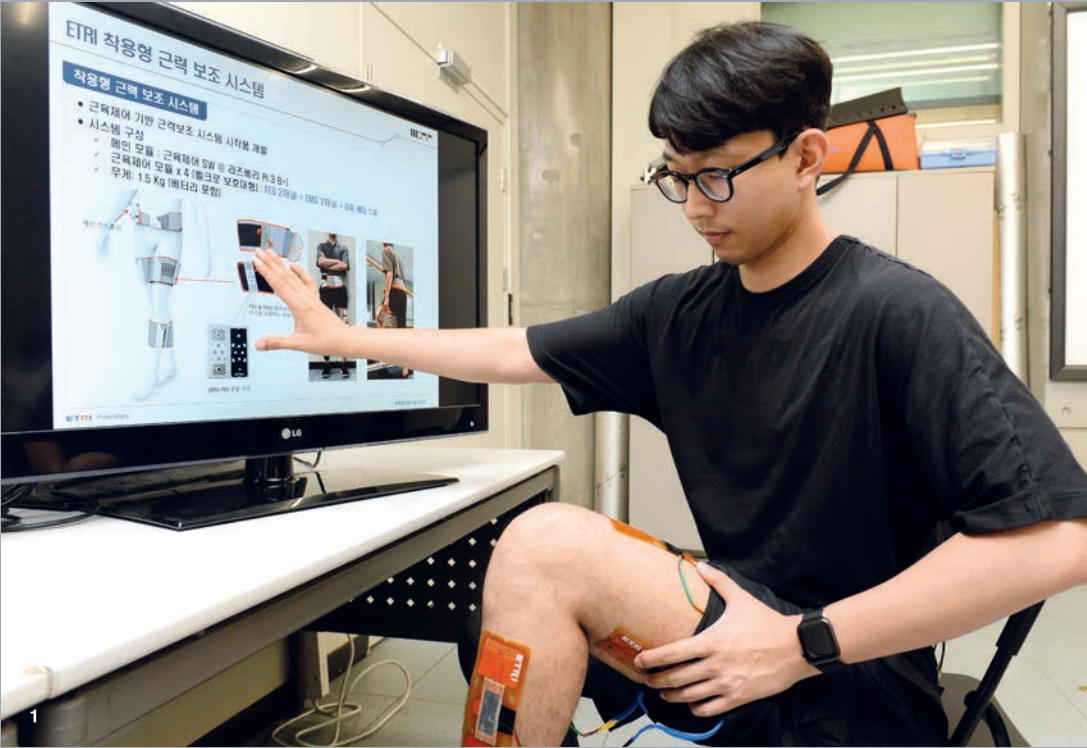
1. An ETRI researcher inspecting a walking-assist system that he's wearing.

2. Real-time muscle activity-based muscle control algorithm of the ETRI wearable walking-assist system.

3. Components of the ETRI wearable walking-assist system.
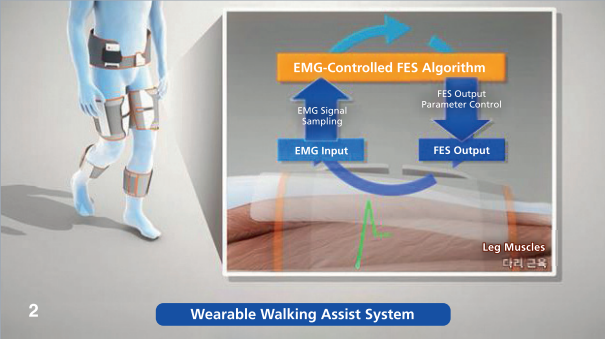
Actualizing Home Service Robots with Dataset Specialized for the Elderly

Interview clip ▶

Technologies and Dataset Specialized for Robots That Help the Elderly

In 2026, Seoul will become a "super-aged society" where over one-fifth of all citizens are elders. With this societal change, ETRI disclosed a 3D image dataset for studying the everyday behavior of elders in the robot environment. As a result, the development of home service robots for the elderly has gained momentum with data specialized for the elderly.

An image of a VR data sample of the daily life of the elderly in 2021.
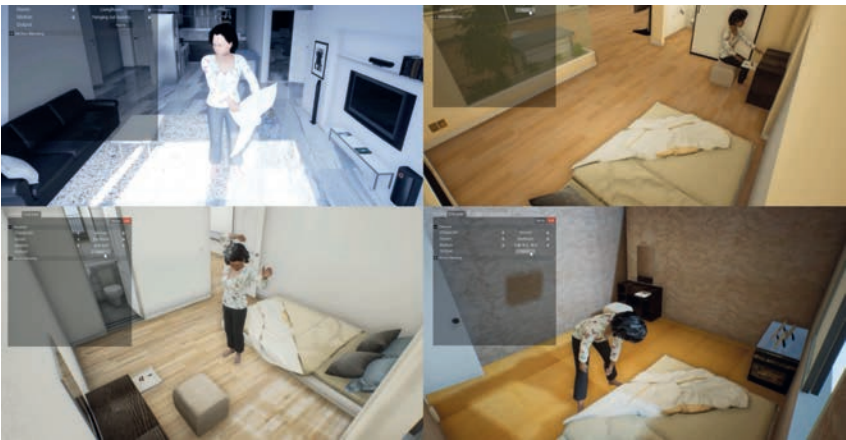
The UN classifies societies into aging societies if the ratio of persons who are 65 years old and older is over 7%, aged societies if the ratio is over 14%, and super-aged societies if the ratio is over 20%. Japan and the UK are already considered as super-aged societies, and Korea and the United States are estimated to turn into super-aged societies in the mid to late 2020s. The ratio of the so-called silver generation is increasing in developed countries.

Countries are making various attempts to facilitate economic activities of the silver generation. More importantly, the ICT industry for the elderly population is garnering attention. According to this societal trend, government-funded research institutes are trying to overcome social issues.

In particular, research to overcome social issues of the aging era is conducted actively to keep pace with the Fourth Industrial Revolution. However, image data of elders taken from the robot's perspective must be secured to study silver-care robots. Although robotics research is being conducted, there is still a serious lack of data that perceive the everyday behavior of people. It was especially hard to study robots for elders because practically no data were available.

ETRI has been accumulating data in various environments while conducting research on behavioral recognition for silver-care robots since 2017. (In November 2019), ETRI collected data from 100 participants in an apartment testbed environment simulating residential environments. At the time, ETRI secured 112,620 3D images containing 55 everyday actions and disclosed the world's largest 3D image dataset (ETRI-Activity3D).

High-quality data obtained with great efforts by the researchers will be provided for research purposes to numerous companies, schools, and laboratories at home and abroad. In fact, data disclosed were used by about 50 companies and universities of Korea and about 30 overseas research centers and universities.

ETRI also provides open-source data and core technologies to train robots for human-robot interactions. Primary technologies developed by researchers so far include 13 AI robot technologies that ▲recognize the everyday behavior of elders, ▲their appearance (facial features and clothing styles) and ▲belongings, ▲robots that automatically create interactions with elders, ▲voice recognition specialized for elders, and so on.

The researchers plan to develop robotic technologies that would support the elderly and socially disadvantaged people's everyday activities, including organizing, cleaning, cooking, and running errands. It wouldn't be an understatement to say that robots may provide useful help to elders in the near future.

A Challenge in Making the Era of Communication between Humans and AI

AI Language Technology

Interview clip ▶

ETRI's first Korean AI 'Exobrain' made a debut at the end of 2016 and participated in an exciting quiz competition. Ever since then, the Exobrain team has accomplished 22 technical transfers and 17 commercialization projects in the past three years, contributing to the expanding application services and preventing foreign AI solutions from making inroads into the domestic market.

Current AI services are still at the level of finding documents on the web or responding with short answers. To overcome such technical limitations, ETRI successfully commercialized the cutting-edge AI language technology through the "Exobrain project".

In July 2020, ETRI revealed the colloquial language analysis technology on relevant websites. This technology can accurately understand human conversations and improve analytical errors by up to 41% by expanding the existing language analysis technology, which mainly understands literary styles such as Wikipedia and laws. ETRI's Exobrain is a commercialized technology being installed in Hancom Office 2020, and it includes language analysis technology, deep learning language model technology, and question answering technology.

For instance, it required a lot of preparation works for language processing technology to provide an AI service for "fashion search" but ETRI's Exobrain application programming interface (API) allows users to focus more on services.

ETRI's colloquial analysis technology is largely divided into morphological analysis technology and named entity recognition technology. The technology revealed by ETRI complies with the TTA Standard Guidelines and there are 47 morpheme tags and 146 named entity tags.

The morphological analysis technology analyzes the minimum unit of Korean meanings and is essentially used in processing the Korean language. In 2019, it was used as the basic input of the KorBERT deep learning language model and many companies are using the deep learning language model technology that is based on morphological analysis as suggested by ETRI.

The named entity recognition technology recognizes unique objects and their meanings. It is highly used in various language processing services such as AI speakers and chatbots. It recognizes that "Kookmin Bank" is a proper name of a bank instead of a combination of words "kookmin (people)" and "bank."

The researchers explained that the challenge of colloquial language analysis is the difficulty of the project itself and the lack of learning data. For instance, when expressing "it is Gyeongsang-do (경상도인데)" as "it's Gyeongsang-do (경상돈데)", the existing morphological analysis technology fails to recognize the abbreviated representation of "it's Gyeongsang-do (경상도+인데)" and analyzes it as "it+is Gyeongsang-do (경상돈+데)."

Exobrain technology developed by ETRI participated in the TV show 'EBS Janghak Quiz' (November, 2016)

In addition, it is difficult to secure data for the colloquial language field when machine learning and deep learning technologies require large learning data. ETRI researchers successfully overcame the lack of learning data by using transfer learning and data augmentation technique. As a result, the colloquial language analysis API has improved the morphological analysis and named entity recognition performance by 5.0% and 7.6%, respectively, and reduced the error rate by 41.74% and 39.38%, respectively, compared to the existing model. The morphological analyzer is evaluated to be 10.6% more superior than the MeCab open source library.

ETRI researchers introduced the literary language analysis API with improved performance in addition to the colloquial language analysis API. The newly revealed API showed high performance of the morphological analysis and named entity recognition technology with 96.80% and 89.40% accuracy, respectively. The Exobrain team will contribute to the advancement of AI technologies and the development of the platform by continuously revealing and improving the performances of deep learning language models.

Telecommunications &
Media Research
Laboratory

ICT as the Eyes and Ears for Persons with Visual or Hearing Impairment

Technology to Create Subtitles and Sign Language Avatar

Interview clip ▶

Even in 2020, there is still prejudice against people with disability (PWD). There is a widespread stereotype that all PWD need help based on the vague prediction that disabilities disable everything. However, ICT is gradually widening the world for PWD. It creates an environment that help people do what they can besides just simply giving a helping hand.

People nowadays can control objects in their houses using voice commands alone or order products by clicking a device a few times. Thanks to the advancement of technologies, both PWD and non-PWD are experiencing a breakthrough in their everyday lives. ETRI recently revealed sign language animations for the Korean government's COVID-19 quarantine guidelines based on voice and graphics edited by deep learning to assist persons with visual or hearing impairment. Those with visual or hearing impairment can receive emergency disaster announcements through this service, which would close the information gap.

The gist of this technology is to make videos where an animated character uses sign language to provide information for the hearing impaired and read text messages for the visually impaired.

The video made by the researchers show the social distancing rules for COVID-19 and five guidelines to be followed by individuals announced by the Central Disaster and Safety Countermeasures Headquarters using Korean sign language. The video also contains a voice that reads subtitles out loud.

Emergency disaster text messages are translated from the Korean language into a sign language script using the translation engine developed by the researchers, and the sign language script is turned into a sign language animation.

ETRI announced that it made this video as an intermediate outcome while researching ▲"Korean sign language broadcast" that automatically translates the Korean language into Korean sign language, ▲"descriptive video service" that reads subtitles out loud using a voice trained to express emotions, and ▲"subtitles with expression broadcast" that uses diverse expressions by recognizing emotions and sound effects.
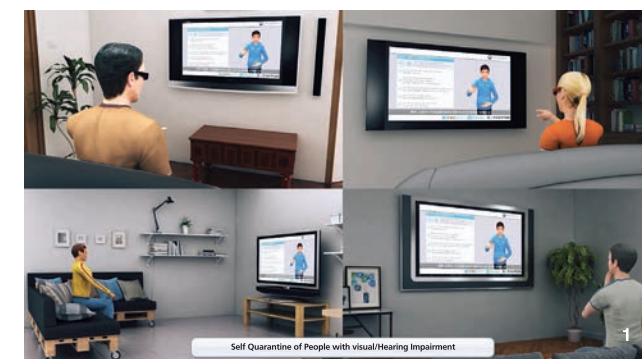
ETRI made the sign language animation jointly with EQ4ALL Co., Ltd. This animation will be supervised by the Korea Association of the Deaf and disclosed on the ETRI website before being distributed through other sources.

Besides, ETRI has been making efforts to develop various technologies and services that keep up with the changing media trends to increase media accessibility of the hearing and visually impaired. ETRI previously developed video on demand (VOD) services that are available for order and broadcast monitoring technologies for PWD.

The researchers aim to expand the scope of subtitle and sign language translations to cover other media content like VOD, CG, etc. In addition, ETRI will try to increase the service capability of the Korean government by improving the technology's performance level to the extent that would also enable informative announcements at public facilities, such as schools and hospitals, and online learning systems.

Even in 2020, there is still a big barrier in overcoming "disability." Nonetheless, the world is slowly turning into a place where PWD can live independently with efforts made by numerous people. ETRI looks forward to seeing ICT bring about a better tomorrow and hopeful future by creating new values.

1. Example of ETRI-developed CG demonstrating how visually impaired people can receive instructions through video.

2. Avatar sign language image translation workflow concept developed by ETRI researchers.

Self Quarantine of People with visual/Hearing Impairment

Avatar Sign Language Image Translation from Korean Sign Language Workflow Concept

Realistic Firefighting Training Realized Safely with VR

Interview clip ▶

Realistic VR Technology

VR has been used in gaming as well as training for medical operation, controlling tanks and plane, etc. Ever since the appearance of head-mounted display (HMD) type mobile devices for headwear, it became easy to enjoy realistic content, and its applications have increased in various ways. Recently, VR training systems using actual firefighting tools to provide firefighting training in environments identical to actual fires greatly helped firefighters protect the lives and property of many citizens.

VR allows people to feel as though they are interacting with a real environment that would be difficult to actually experience in their daily lives. VR is created using computers and artificial technology and refers to the virtual environments, situations, or the technology itself.

ETRI has recently created a realistic simulator using VR that allows firefighting training that utilizes actual firefighting tools in virtual reality. It was revealed that the training would undergo substantiation for actual use. The "Realistic Firefighting Training Simulator" developed recently is a composition of state-of-the-art VR technology featuring things such as: motion simulator technology that allows safe immersion experiences, multi-sensory interface technology that supports realistic fire situations, and training content developed with the help of firefighters.

This simulator is based on a changing motion experience platform that allows users to climb up and down inclines and achieve vertical movement. A head-mounted display with a wearable cable allows users to immerse themselves and perform various actions without fear of accidents. The realistic interface technology allows users to feel what it is like to actually use the firefighting hose as well.

Researchers provide large-scale virtual meeting training for firefighters who cannot gather because of restrictions imposed by the spread of COVID-19. They will undergo on-site substantiation with the simulator technology to reach completion of the product.

In addition, technologies that easily create VR training spaces and scenarios using 2D plans, engine-connected fire dynamics simulation visualization technology, hybrid multi-sensor information and AI learning model-based fire sensing technology are being developed and enhanced.

Researchers are also considering the fact that the use of radio and announcements are not enough to provide effective evacuation and rescue, and so they are developing IoT-based fire digital twin technology. This technology will enable remote real-time fire monitoring. The initial accuracy is about 86%, but through continued AI learning the goal is to bring this number up to 96%. Researchers will implement heat and cooling sensation devices on firefighters' breathing devices and uniforms as well as enhance the technology to monitor the trainees' vital signs to create a more realistic and effective training environment.

In addition, software that allows administrators of the training system to easily change the virtual environment will be developed and the simulator made lighter. This is expected to allow ordinary citizens to also have better access to virtual environments.

1. Image of a VR fire drill through an ETRI simulator developed by ETRI researchers.

2. The ETRI research team developed this realistic fire drill simulator.

Realizing Smart & Future Factories with 5G and Ultra-Low Latency Network Technology

Low-Latency Network / Cellular IoT Technology

With the world's first commercialization of 5G mobile communication services, the Ministry of Science and ICT has announced the "5G+ Strategy" in April, 2019. Afterward, the Ministry has made various efforts for the sophistication and expansion of smart factories using 5G. In particular, the Korean government will provide "5G-based smart factory solutions" to 1,000 factories of SMEs until 2022. Following this trend, ETRI drives innovation of the smart manufacturing industry using its core 5G and ultra-low latency network core technologies.

Mobile robots work in place of people at smart factories with automated systems. In order to make products that meet the various requirements of customers in real time, the workers in smart factories can change the production processes flexibly using panels and controllers. Then, the mobile robots link production facilities to make products based on the changed processes. Therefore, these factories are required to have the flexible production capability, which can be enabled by 5G cellular technology.

In other words, unlike ordinary factories that are appropriate for supplier-centered mass production, smart factories aim to provide diverse customized products in real-time. For this goal, factories need to reconfigure or recombine the existing production lines during the manufacturing processes, instead of producing each specific product in a dedicated production lines. Thus, the workers should be able to change process sequences and functions using panels and controllers, and the mobile robots must be able to link production facilities or make a product according to the changed processes.

Various technologies are needed to accomplish these tasks. All facilities must be connected wirelessly in a stable communication environment with minimal latency and errors, but existing wireless communication technologies like 4G LTE and Wi-Fi do not guarantee the quality of service.

To resolve this problem, ETRI developed technologies and testbeds for Industrial IoT based on the 5G standard (Rel-15) in 2020. ETRI successfully demonstrated smart manufacturing services in a smart factory (model factory) established by Korea Institute of Industrial Technology in Hayang-eup, Gyeongsan-si, Gyeongsangbuk-do, Korea. Services demonstrated by the researchers include ▲real-time control of mobile robots, ▲monitoring and control of production facilities using a portable control panel, ▲monitoring of processes using portable VR devices like HMD, and ▲wireless communication among PLCs required for the flexible change of production lines. ETRI contributed to opening up the era of 5G smart factories by converging and applying 5G cellular technologies in diverse manufacturing industries. There have been previous cases of using 5G to demonstrate smart factories at other research institutes, but this demonstration has significance in that the testbed was based on the technologies developed by ETRI, which can provide the best performance required to 5G systems.

Meanwhile, ETRI developed the world's first time-deterministic networking technology in 2020. This technology expeditiously delivers information between endpoints of the network without any loss of information within the bounded time delay. ETRI has succeeded in demonstrating the 10Gbps transport between Seoul and Daejeon using the technology. Through this, it is expected that this will contribute to the broadening and popularization of various ultra-low latency and high-precision vertical services including real-time remote control services of smart factories.

ETRI plans to improve the 5G Industrial IoT system until late 2021 to observe the next 5G standard (Rel-16). ETRI also plans to demonstrate a real-time control and management service of facilities from a remote site, by interconnecting the ETRI laboratory in Daejeon and Smart Factory in Gyeongsan about 250km away, through the 5G wired and wireless networks that can guarantee low latency of within 1/100 seconds(one-way) and high reliability. Furthermore, in early 2022, ETRI will connect the University of Oulu in Finland to the Gyeongsan Smart Factory to prove the possibility of remote overseas management and control through the intercontinental connection of a high-performance network.

In the near future, Korea and foreign countries will be able to build smart factories using 5G to manage and control production facilities in real-time.

ETRI researchers wrapping up the '5G-based industrial IoT technology and service demonstration' at a smart factory in Gyeongsan, Gyeongsangbuk-do province.

Overcoming the Limits of Communication with Satellites

Interview clip ▶

Satellite Communication Technology

Even in present times with the commercialization of 5G and discussion of 6G, there are still limits where communication is not smooth or impossible at all in remote mountain areas where it is difficult to install communication-related infrastructure due to a small population. Due to such limitations, there are many cases when disasters become even more problematic. If communication infrastructure becomes unavailable due to fire, flooding, or earthquake, communication is cut off. ETRI researchers for satellite communication technologies are overcoming these limitations one by one.
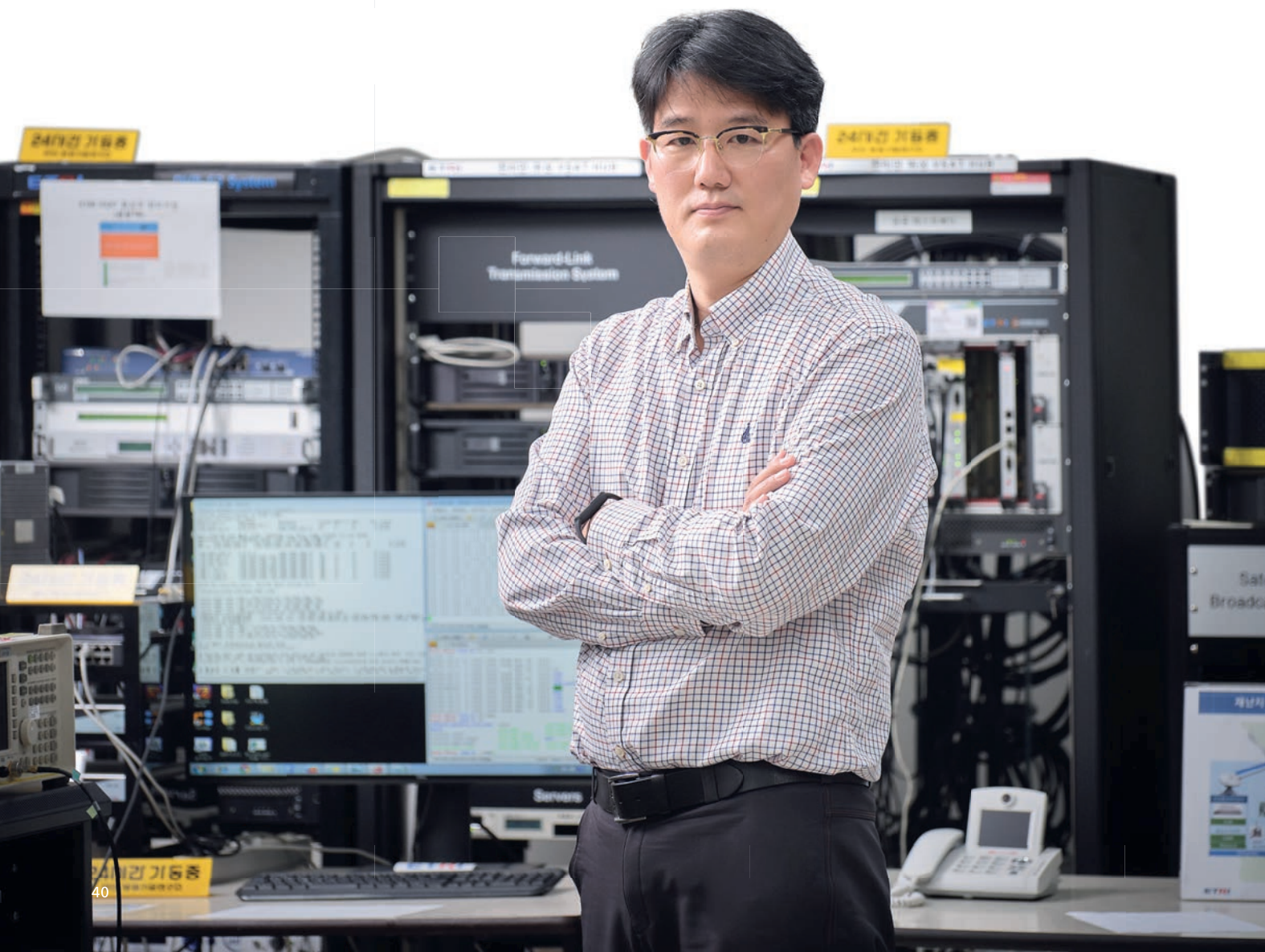
Checking the antenna for small satellite broadcasting equipment.

Satellite communication semiconductor ASIC developed by ETRI.

According to a 2019 survey by the International Telecommunication Union (ITU), the global Internet penetration rate was 58.8%. Considering that the criterion for judging the supply of the Internet is when someone has "accessed the Internet with any device within a year," in actuality, nearly half of the human population still has not accessed the Internet. One of the biggest obstacles to expanding the range of various telecommunication services such as the telephone as well as the Internet is geographical limitations. However, these limitations can be overcome by using satellite communication. This is because satellite communication can be used as long as there is an antenna that receive radio waves without the need to install separate infrastructures. In particular, if satellite communication is used in disasters areas, it can provide significant when responding to emergencies.

Recently, ETRI has greatly improved its satellite communication technology by succeeding in developing the world's best satellite communication semiconductor ASIC. This technology can communicate throughout Korea as well as in remote mountainous areas, where existing mobile communication does not work because of fires, earthquakes, or telecommunication disasters due to the fire accidents of a telephone company, etc.

In order to use the network satellite communication, it must support the radio wave transmission and the reception function in the terminal equipment, which has the disadvantages of high costs and bigger equipment size. However, ETRI researchers reduced the size and significantly reduced the cost of manufacturing the device by combining these two functions into one. The communication speed and the number of channels provided by ASICs exceed those of the world's best products which are currently commercialized. It resulted in improving not only the satellite communication technology but also its usability.

ETRI expects that its ASIC technology will be used for emergency responses at domestic disasters sites. The existing satellite communication equipment is heavy and complicated, requiring a mobile satellite news gathering (SNG) vehicle. However, the terminal equipment implemented with ASIC chip is light and has been developed so that not only firefighters but also ordinary people can use it easily.

Currently, the US and Israel dominate more than 68% of the global satellite communications market. ETRI expects to achieve independence with the developed ASIC modem chip technology and create a new direction in the global satellite communication market. By taking advantage of the strengths of this technology which significantly reduces the cost of building equipment and does not require a separate infrastructure, it is expected that it will significantly help in establishing communication infrastructure in countries where establishing communication facilities is a challenge. ETRI looks forward to a future where ETRI's technology actively drives the global market and improves the quality of human life.
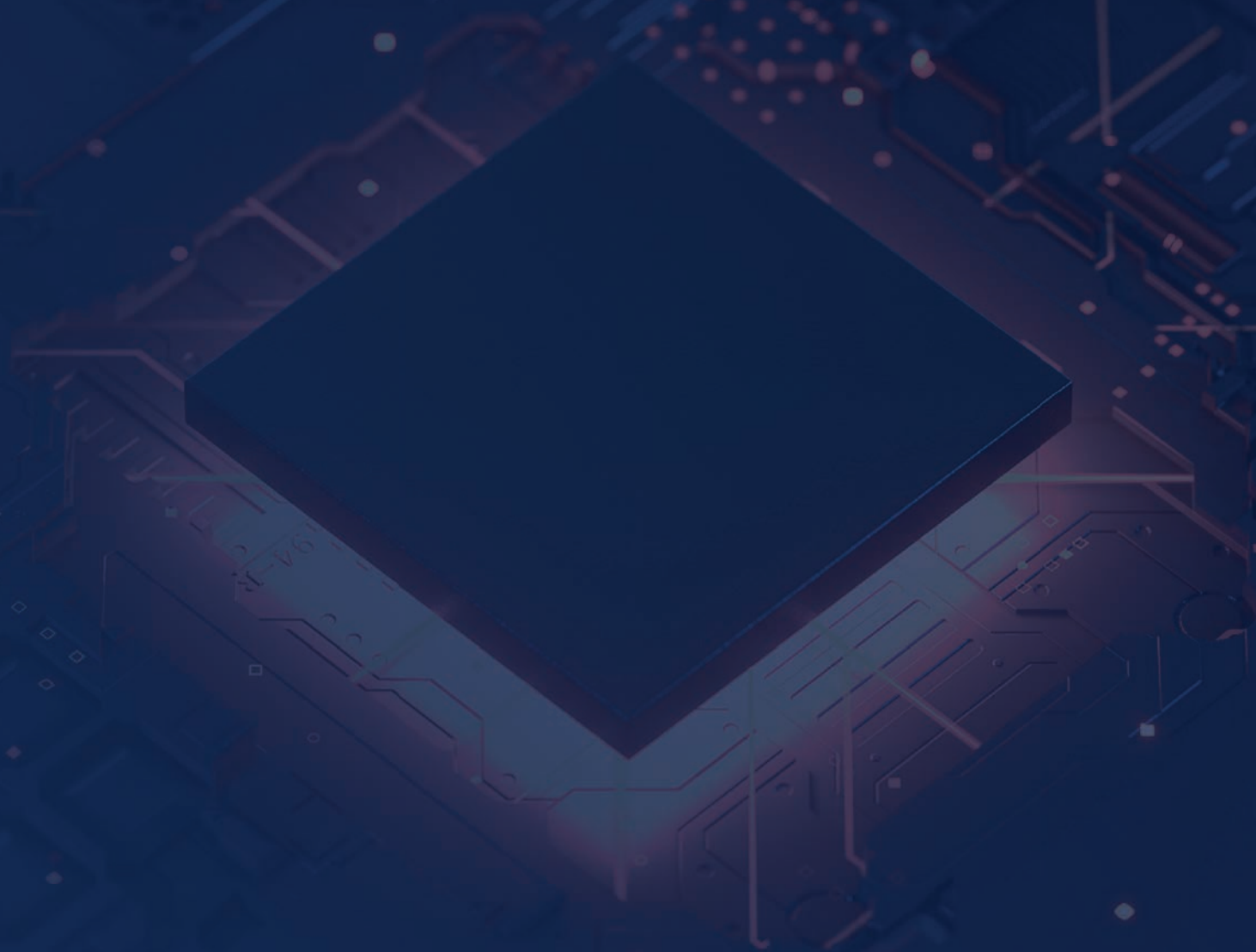
Emerging Power of the Touchless Market with Non-Contact Sensors

Non-Contact Sensors with 660 Times High Sensitivity

Sensors are used commonly in many electronic products nowadays, and the scope of sensors continues to expand with the development of technologies. The demand for thermal imaging cameras that measure the body temperature in real-time increased rapidly after the outbreak of COVID-19 last year, and the demand for non-contact sensors also increased with the increasing trend of being cautious about human contact. Recently, a non-contact humidity sensor with 660 times higher sensitivity was developed in Korea, and this sensor is expected to receive the spotlight in the touchless era.
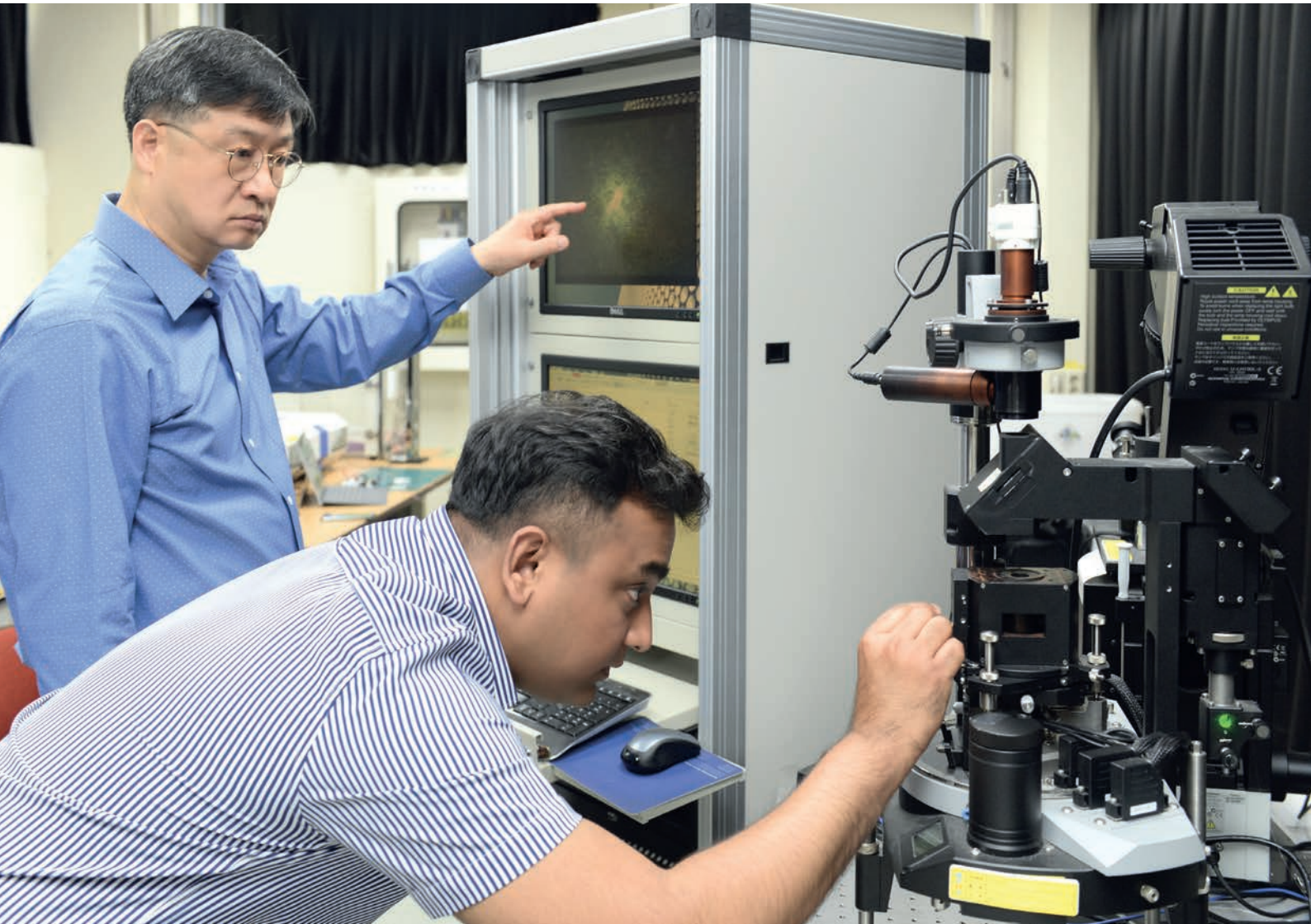
Non-contact or touchless sensors are sensors that detect position, speed, temperature, air quality, or distance using non-contact measurement method. Merits of these sensors include high reliability, fast operating speed, and long service life because it does not require any physical contact during its operation. This type of touchless sensors have recently been drawing attention due to COVID-19.

Meanwhile, researchers at ETRI developed a non-contact sensor that can detect humidity at a distance of about 1 cm without direct contact. This sensor's sensitivity is 660 times higher than existing sensors and can greatly help prevent contagious diseases in the COVID-19 era.

Humidity sensors are based on the principle that resistance and electric signal output change according to humidity. These sensors are utilized to make products that necessitate contact like automated teller machines (ATM), screen monitors or waterproof functions for electronic devices. Recently, they have been widely applied to IoT and smart farm management.

Non-contact sensors that respond without contact is made by increasing the sensitivity of humidity sensors. Besides home appliances and industrial electronic devices, they can be used as radiation-resistant sensors for nuclear power systems. It is expected to be widely applied to prevent infections with the spread of COVID-19.

The humidity sensor developed by ETRI has a sensitivity of over 66,000%, meaning that it is 660 times higher than existing sensors. This sensor has a detection time of 0.5 seconds, which is up to 12 times faster than existing commercial sensors that take five to six seconds.

This new sensor uses a new material called molybdenum disulfide (MoS_2) manufactured by researchers at ETRI and can detect moisture like sweat on the skin and breathing at high sensitivity. The researchers could drastically improve the sensitivity of this sensor by creating a honeycomb structure and coating it with molybdenum disulfide. This is because the honeycomb structure of sensor materials can improve the sensitivity by broadening the specific surface area for detecting moisture and vapor.

This sensor can sense differences in the amount of skin moisture or sweat before and after exercising, as well as breathing capacity. The sensor detects tiny amounts of moisture on hands without

Honeycomb shaped MoS₂ Structure
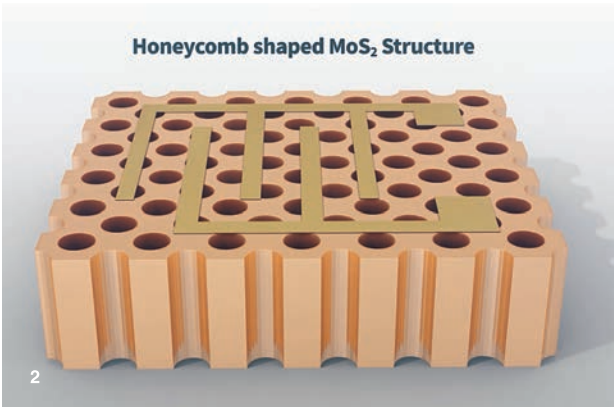
1. Demonstration in which skin humidity is checked with a smartphone by applying the ETRI research team-developed sensor on the skin.

2. CG showing the structure of the sensor developed by ETRI researchers in 2021.

actually touching the hands. The sensor can be made into an attachable patch, measuring changes in the amount of sweat before and after exercising and the amount of breathing based on exercise intensity. Moisture on different body parts can be sensed easily using this principle, and the sensor can be applied to products related to skin humidity such as digital healthcare products, moisturizing beauty products, and air purifiers.

The global economy has encountered a long-term stagnation with the sudden spread of a contagious disease, and it is difficult to predict when the disease will subside. Regardless, ETRI expects to see sensor technologies that can sense external information in real-time to improve public health and sanitation while adding convenience to everyday life.

Enjoying High-Quality Content with Micro LED Display

Simultaneous Transfer and Bonding (SITRAB) technology

Interview clip ▶

There are diverse display technologies that are in 4K and 8K resolutions, such as mini LED, OLED, and micro LED. Micro LED has the best definition, color reproduction, and dynamic range among them, but it is too expensive to be commercialized. ETRI developed new materials and processes for the first time, preparing a stepping stone to overcome the limitation of the conventional technologies.
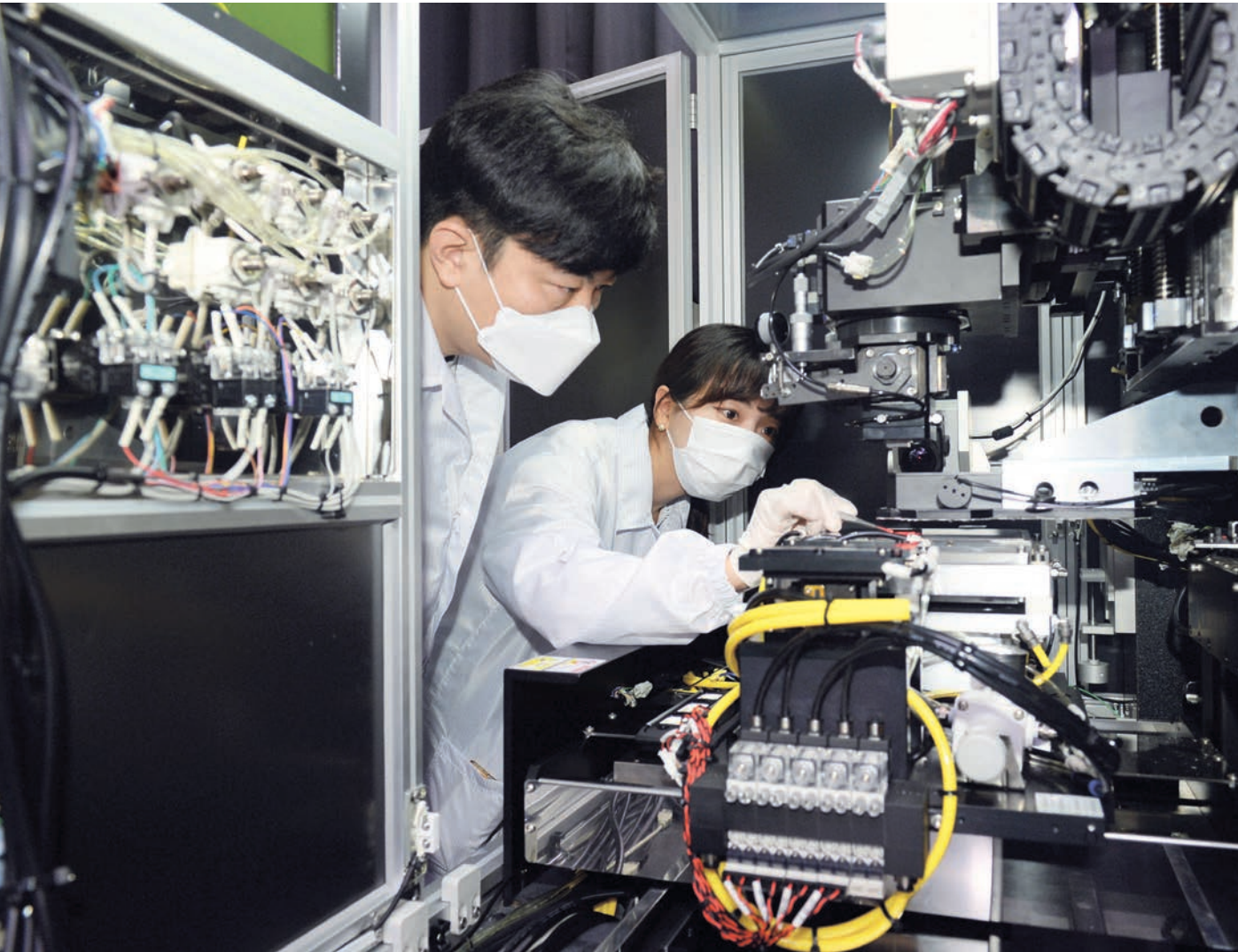

Counterpoint Research, a market research company, estimated that the smartphone market would grow in size by 11% in 2021 compared to 2020 and the wearable device market for smart watches and so on would grow by 19%. In particular, with the appearance of foldable display and 5G telecommunication technology in the smartphone market, the demand for new products will increase further with increasing high-definition content services. The definition of visual content like videos and photos is one of the objective criteria for determining the quality of content. The definition of content, including the dynamic range, resolutions, sharpness, and color reproduction, is an important indicator used by consumers to determine the quality of visual content. At the same time, it adds the availability for content makers to process content according to their intent. However, no matter how good the definition of the content may be, there is no meaning if the display device cannot express the definition. This is the very reason why OLED and mini LED are constantly evolving.

Under this circumstance, a Korean research group made a breakthrough in micro LED display by developing source technologies and new materials for next-generation micro LED. Micro LED display is a next-generation display technology that uses extremely small LED of about 10–100 micrometer (μm) as the pixel light source. Micro LED display can attain clearer colors with higher efficiencies compared to LCD and OLED. It is expected to be applicable to various devices such as TV, smart watches, and AR/VR displays.

Micro LED is made in a semiconductor device fabrication and moved to a display panel. Latest 8K TV requires 100 million micro LEDs, which are extremely small in size and take a long time. The LED bonding process followed after the LED transfer process was used until now, and there was difficulty in commercializing micro LED because of the expensive transfer and bonding machines and lengthy processing time. ETRI has developed a new technology that realizes the transfer and bonding process, which were sequential processes, into one process. Comparing with the conventional technologies, the new technology developed by ETRI can reduce the processing time and investment cost for transfer and bonding equipment to 1/10, and the time and cost of the process to repair defective pixels can be reduced to 1/100. The cost of new materials is also reduced to 1/100.

With the increasing demand for content, companies making electronic products attempt to increase the quality of their products and fiercely compete for technologies. ETRI hopes to see source technologies and new materials of ETRI help Korean companies dominate the market for next-generation display technologies so people are able to enjoy high-quality content.
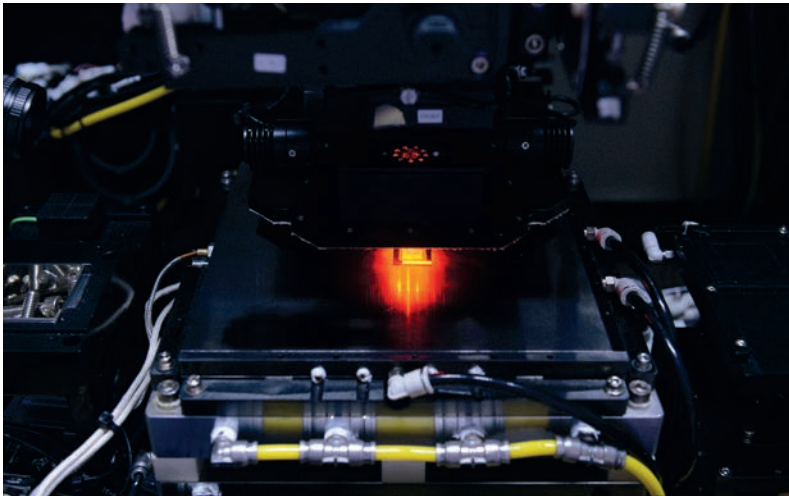

The world's first simultaneous transfer bonding process for micro LED developed by ETRI researchers.

Using Small but Powerful Semiconductors to Quickly Charge Electric Cars

Vertical GaN Power Semiconductor Technology

Is there a faster way to charge electric cars? GaN semi-conductors were considered a core element of next-generation semiconductors in order to increase the power conversion efficiency of electric cars. Among such things, ETRI developed the core power semiconductor technology that uses vertical GaN to minimize electric loss while performing well at high voltage. The development is expected to significantly help in increasing energy efficiency and the localization of materials, parts, and equipment.
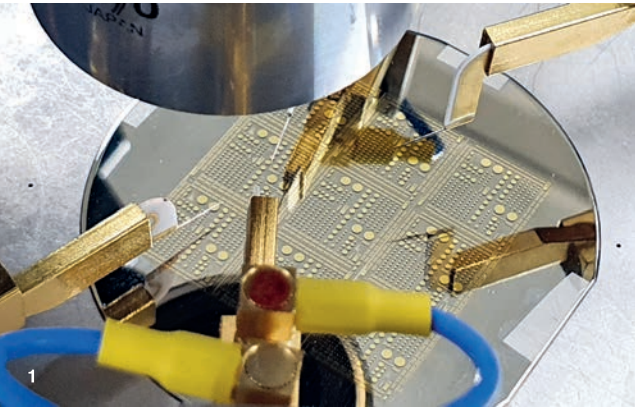
The demand for more efficient energy management and achieving higher power density in smaller spaces is continually increasing. Over the past 60 years, the semiconductor industry has utilized silicone to convert AC to DC and the DC voltage required for various devices ranging from phones to industrial robots. This formed the basis for all electrical parts that converted electricity in this way.

The parts were continuously being improved and optimized, but the physical nature of silicone had reached its limit. This meant that the industry needed something other than silicone to base their electrical semiconductors on.

According to such societal demand, ETRI has recently developed the "1kV vertical power semiconductor technology that uses GaN single-crystal substrate." Power semiconductors are conductors that convert, control, and process electricity into a format required by the relevant system. The vertical power semiconductor developed by researchers has a very high breakdown voltage compared to existing vertical types since GaN single-crystal substrate was used.

ETRI researchers, based on many years of GaN semiconductor know-how, used a process to increase the thickness of the epitaxial layer to increase voltage and suppress resistance. As a result, a higher breakdown voltage was realized compared to existing vertical types, and a 1kV vertical GaN diode power semiconductor was developed.

Vertical power semiconductors are made by growing an homo-epitaxial layer on a single-crystal substrate. Then it is pro-duced after the designing, processing, and packaging stages. In Korea, more than 90% of epitaxial wafers were imported for semiconductor device processing. The GaN epitaxial growth and power device technology developed by ETRI are expected to reduce the dependence on imports of power semicondcutors as well as the gap in core technology.

GaN is strong against heat and the switching is speed fast enough to reach tens of MHz. The separate energy storage space required is minimized, allowing for systems that are 1/3 the size of existing silicone-based systems. The energy difference (band gap) of 3.4Eg (eV) is also more than three times better than silicone. It is suitable with high voltages and is considered as a next-generation power semiconductor material.

This technology in particular is essential for electric car batteries, which require high voltages in small, compact size. With reduced electric loss comes enhanced power conversion efficiency, and miniaturization can help reduce the volume of electric cars. Researchers will work with semiconductor technology localization and enhancement as the goal and continue research to further expand the high voltage and large area output of vertical GaN power semiconductors.

1. A 2-inch vertical gallium nitride (GaN) power semiconductor developed by ETRI researchers.

2. Diagram of the vertical gallium nitride (GaN) power semiconductor device process.

Opening the Path of Communication through Touch
The Dream Technology to Feel Touch from Afar

Telehaptics

Haptics refers to a field of technology that allows users to feel touch by generating a vibration, force, or shock on various digital instruments. What if users can feel the texture of clothes while shopping on the Internet? It seems like a very distant future, but ETRI took a step closer to this dreamlike future by developing a technology that allows users to feel the texture of metals, plastics, and rubbers 15 m away.

Haptics became widely known to the public in the mid-2000s when it was applied to smartphone touch screens. Haptics is currently adding vitality to digital devices in combination with different fields, like gaming consoles, touch screens, automobiles, robots, and medical services.

ETRI recently developed a touch technology to remotely touch and feel objects. The time has come where people can touch objects from afar. The researchers also succeeded developing core materials, which used to rely on foreign technologies, to become a global leader of next-generation haptics.

ETRI's next-generation telehaptics uses a sensor and actuator based on piezoelectric materials to maximize immersion in virtual and augmented realities and communicate the sense of touch from remote distances. People can now feel whether materials are firm, rough, or soft from afar. The researchers announced that it would try to develop this technology so people in the United States can feel the softness of fur while stroking a pet in Korea.

A sensor, actuator, communications device, and driver are necessary to feel the sense of touch of objects from afar. The researchers explained that bluetooth communication used in the laboratory setting attained a 97% match of signals acquired and reproduced. Users can feel the touch in real-time because there is almost no delay in the data signal transfer process.

ETRI researchers materialized a touch communication that gathers touch information using a sensor and copies and reproduces gathered information using the actuator. More importantly, this technology can deliver the sense of touch, texture, and sound to a remote place.

Researchers demonstrated the technology by sending the letters E, T, R, I to a remote distance using Morse code. Piezoelectric materials can respond faster than human recognition using low power, and they can produce instantaneous voltage of 100V or greater without power by bending or pressing.

Researchers announced that the core parts of this technology include ▲flexible piezoelectric composite sensor, ▲high-power multimorph piezoelectric actuator, ▲signaling and operation of piezoelectric sensor and actuator, ▲composite texture data control and wireless communication.

The researchers plan to increase the accuracy of output and data collection through the sophistication of the structural design for the piezoelectric material mixing process, leading the efforts to gain a competitive edge in telehaptics. In the near future, it will be possible to touch and feel a puppy in Korea from a faraway land. ETRI's new technology will help propel society and technology to a bigger and broader world.

1. ETRI researchers are conducting tactile sensing experiments using sensors.

2. Sensors and actuators developed by ETRI.

1

2

Flexible piezoelectric nanocomposite-based pressure sensors

Multimorph-structured piezoelectric actuators

4-channel patterns

13-channel patterns

35×8mm

20×15mm

15×15mm

10×15mm

35×15mm

Miniaturized piezoelectric actuators
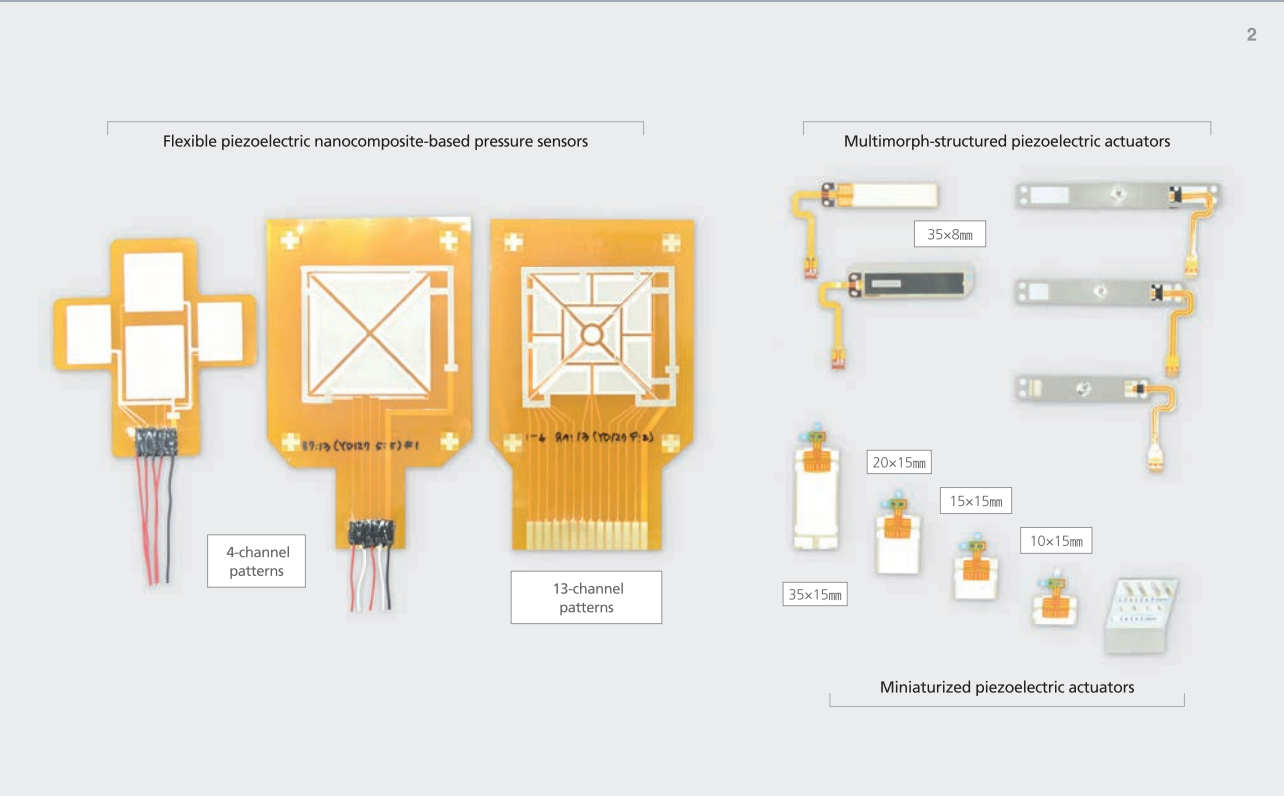
Intelligent Convergence Research Laboratory

AI Robots for the Safety of Underground Utility Tunnels

AI Robots Using Digital Twins

Disasters in underground utility tunnels, where lifelines are installed and managed for the convenience of services needed in urban living such as electricity, communications or waterworks, etc. result in loss of lives and severe economic damage due to the termination of basic social services. In order to suppress underground utility tunnel disasters and reduce the damage, ETRI is developing a disaster safety management technology that utilizes digital twin technology. The researchers have developed AI rail robots using digital twin technology and applied them into the field. They are expected to provide an effective disaster response.

Digital twin refers to a technology that creates virtual world which is simllar with the real world. Digital twin technology has a level of detail that is completely different from common 3D maps. Data collected from public institutions and IoT devices are used for weather changes, urban planning, various simulations, and R&D. Simulations can also be used to analyze and optimize the time needed for citizens to evacuate in the event of an emergency inside a building.

Korea has also started to accelerate its research and development for digital twin technology. In particular, digital twin technology has selected as one of the ten major projects included in the plan for the Korean New Deal. Related research is being actively conducted and cases of actual utilization and operation are also increasing.

As a part of this process, through the development project for a digital twin-based integrated platform for fire and disaster management in underground utility tunnel, ETRI and KI Co., Ltd. have installed two AI robots applied digital twin technology in April in all electrical utility sections in the underground utility tunnels in Oh-chang, Cheongju. As a result, the inspection and the unmanned patrol process of electrical cables have been automated to allow preventive ascertainment and effective management of signs of disaster. It is also expected that quicker responses will be possible in the event of an accident.

The robots monitor the entire environment of the underground utility tunnels including video, thermal imaging, temperature, humidity, oxygen, nitrogen dioxide, carbon monoxide, and carbon dioxide, and send this information in real time to the control towers. Before, The inspection/patrol for the facility required over two and a half hours by groups of two personnel to perform every day. (or Before, facility inspection and patrol tasks required more than two and a half hours by group of two personnel each day.) However, AI robots are capable of high-speed inspection and patrol depending on the circumstance and able to reduce the inspection time to 30 minutes maximum.

ICT based smart disaster management technology has been introduced in other underground utility tunnels before. However, the technology used only fixed IoT sensors to collect data, so utilization was limited. The underground utility tunnels in Ochang, Cheongju has greatly increased AI robot performance and also used digital twin technology to allow data analysis and quick responses, showcasing its great development.

The researchers revealed that they expected this test operation to be the beginning of discovering disaster and danger in advance and controlling them in order to quickly assess the situation and respond quickly on site (quick and accurate responses from relevant fire stations, military, and police forces).

This technology, developed by ETRI, can be also applied to private underground utility tunnels, subways, underground shopping areas, industrial complexes, and various other areas as well as public underground utility tunnels; it is expected to be widely used for safe and smart management of complex spaces. The researchers plan to utilize the data analysis results and on-site requirements to advance the digital twin technology and broaden the regional range for substantiation. ETRI looks forward to the future of digital twin technology that will provide society with safe lifestyle in the years to come.

1. Real-time unmanned patrol monitoring screen of AI rail robot.

2. Researchers are examining the video captured by the AI rail robot.
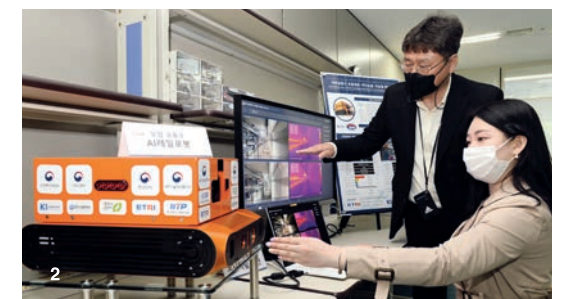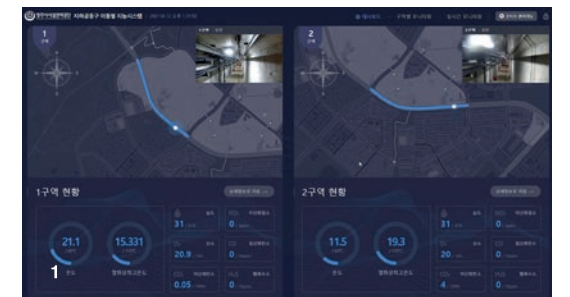
Creating a Way to Delivery to Remote Mountainous Areas Through Drone Technology

Delivery Service Technology with Drone Logistics

The popularity of drone technology is immense. Drones are rapidly being applied to various fields, from leisure activities that seek pleasure with flying and controlling drones in the sky, to aerial photography, observation & surveying, reconnaissance & surveillance, disaster prevention, and science and technology. In particular, drones are expected to bring about a new paradigm that can bring innovative changes in the fields of logistics and transportation. Drones can now reach islands as well as remote mountainous areas through the rapid development of drone technology where AI, communications, and sensor technologies have been combined with the relaxation of government-led flight-related regulations. If so, what is the ultimate goal for drone technology?

There are still many places in Korea where delivery of packages or parcels take a long time. There are places where a passenger ship may or may not go to an island, or if the weather is a little bad, the pick-up truck cannot go up in some remote mountain area. Drone research has being actively conducted to solve these problems. This is because flying a drone can solve these problems within ten to twenty minutes regardless of the surrounding conditions.

ETRI has been conducting research on drones logistics through Ministry of Trade, Industry, and Energy (MOTIE)'s "Drone Utilization Service Market Creation Support Project," "Multi-Department Public Innovation Procurement Linked Unmanned Mobile Vehicle and SW Platform Development Project," "Pilot Project of Local Governments Led by the Ministry of the Interior and Safety (MOIS)," etc.

The MOTIE's task is to develop drone delivery technology that can deliver goods quickly and safely anywhere in the country, targeting islands and remote mountainous areas. More specifically, the task is to build a universal platform that anyone can use, such as courier companies, logistics companies, postal service headquarters, and newspaper companies, to develop real-time control and safety control technology that enables safe flight, and then create and apply such technology to the drone.

The multi-department task is to build and operate drone delivery logistics network based on 5G communication by developing drone operation technology for the postal office's last mile business innovation. The pilot project for local governments through open calls led by MOIS as a research project for address-based drone delivery operation in Jeollanam-do and Chungnam, is the project for building drone delivery points and flight routes using road name addresses, as well as building infrastructure by presenting a plan to commercialize address-based drone delivery. It is expected that drone service will be finally possible only when all these tasks are intertwined.

Until now, drones only have the capability to fly within a distance of 5 km while carrying 5 kg of goods. However, the MOTIE's "Drone Utilization Service Market Creation Support Project" set the goal for developed drones to finally carry 10 kg of goods and fly as far as 10 km. Furthermore, safety control is of paramount importance because it cannot fly drones unless they are 100% safe. This technology includes evasive maneuvers, precision land-

ETRI aims to adapt the technologies developed this year to drones and to provide commercialized services by 2023 through 1,000 iterations of field demonstrations and verifications by next year.

ings, self-diagnosis, and failure prediction. In addition, this aims real-time control technology where multiple drones fly simultaneously through intelligent control, flight controller (FC), and localization of communication security module and parts.

The technologies that ETRI cares most about are evasive maneuvers and precision landings. This is because the drone must land accurately at the origin and destination. Image processing technology is also important for this operation. It should be able to land accurately at the destination by recognizing it as an image and be able to detect what objects are moving in front of it and avoid them.

In addition to this, many safety devices are attached to the drone. Currently, drones have the embedded communication security module hardware. This prevents hacking, and has the scenario in which the drone can respond immediately if there is a problem with the device while flying. Moreover, the drone may fall if there is a problem with major parts such as the battery, FC and motor. ETRI is also developing a prognostics and health management technology that tells when the component will fail as a preemptive measure, and plan to implement this technology perfectly to realize safe and reliable drones. ETRI aims to apply technologies that have been developed this year to drones and provide commercial service in 2023 by conducting a total of 1,000 field demonstrations and verification by next year. In addition, in order to lead the unmanned mobility industry, which is one of the largest markets in the future, ETRI will develop the goods delivery system that can carry 50 kg cargo flying in downtown areas, and expand it up to 100 kg. Finally, the ultimate goal is to implement drone taxis in downtown areas. It is expected that the efforts of the ETRI Postal and Logistics Technology Research Center will create results that realize these technology one by one.

Tracking a Criminal's Vehicle with AI and Taking Responsibilities for Citizens' Safety

Interview clip ▶

Technology that Tracks a Suspect's Vehicle by AI Recognition of a License Plate

The number of CCTVs installed in Korea is estimated to be over 10 million in public and private areas to the extent that it can be called the "Land of CCTV." However, it is different than developed countries that use CCTV information as big data. Because of this, the activation of intelligent CCTV is essential for social safety. ETRI is accelerating the R&D of intelligent CCTV that infuses AI into CCTV. This will upgrade the citizens' safety. It will serve as a basis for improving the citizens' quality of life.

The technology that analyzes images using artificial intelligence is continuously developing and evolving. ETRI automatically detects dangerous situations such as traffic accidents and crimes in real time and informs the police, and is grafting artificial intelligence technology onto CCTV for security so that it can automatically identify and track suspects and vehicles involved in the accident. Recently, ETRI has developed a technology that can clearly restore and identify the license plate number recorded on CCTV, which is typically difficult to distinguish.

In November 2019, ETRI proved the excellence of ETRI's AI technology at the "Artificial Intelligence (AI) vs People: Unclear License Plate Identification Challenge" held in Jeju Advanced Science and Technology's National Industrial Complex. An thrilling match, where thirty people, including public officials, students, and researchers, participated as human representatives competed against AI developed by ETRI to match the number of license plates that are difficult to identify with the human eye, was held in Jeju. The Korea National Police University and Public Science Institute presented 15 questions using license plates captured on actual CCTV during the match. To protect personal information, it was conducted in a way where it matched only the last four digits of the vehicle and covering the car's model and front seats. Each participant inferred the correct answer using the image tool installed on their laptop and submitted it. The match proceeded one question at a time, and when participants submitted all their answers, the AI began to solve the problems. Participants

watched the approximate process and results when AI inferred the correct answer in real time through the screen in front of the stage. When the solution was completed, the correct answer was immediately revealed, and the cumulative score for each individual was added up according to the number of correct answers. As a result, ETRI's NPDR solution scored 82 points out of 100, which was 21 points higher than a human's best score, and won the match by an overwhelming margin.

The technology developed by ETRI researchers was created through competitions between AI models. It is a method where a model that generates false data by learning the data and a model that discriminates it compete with each other and create data that are closer to reality through learning.

With this method, researchers derived clear numbers by learning the blurry or broken photos taken from various angles in advance. Thanks to this, AI can quickly analyze and inform high-probability numbers, even in photos that are difficult to see with the human eye.

In the future, ETRI researchers will supplement the current license plate recognition technology that fails to recognize the image if it is slightly dark, deformed, or stained, and plans on applying them to real environments by developing a software that automatically performs all the processes of detecting and identifying blurry license plates in regular CCTV images. This technology development is expected to greatly contribute to smart security and safety such as crime prevention and parking management.

Simple and Fast Cardiovascular Disease Test to Keep People Healthy

Automatic Biomarker Analysis Technology

It is important to discover and respond to cardiovascular diseases in its early stage. However, these diseases worsen in many cases because patients do not get diagnosed due to the cumbersome testing process and high cost. For this reason, there is an increasing demand for a system that allows people to manage their health at any time and place. As a solution to this problem, ETRI recently developed the 'automatic biomarker analysis technology,' which measures the possibility of cardiovascular diseases within 15 minutes.
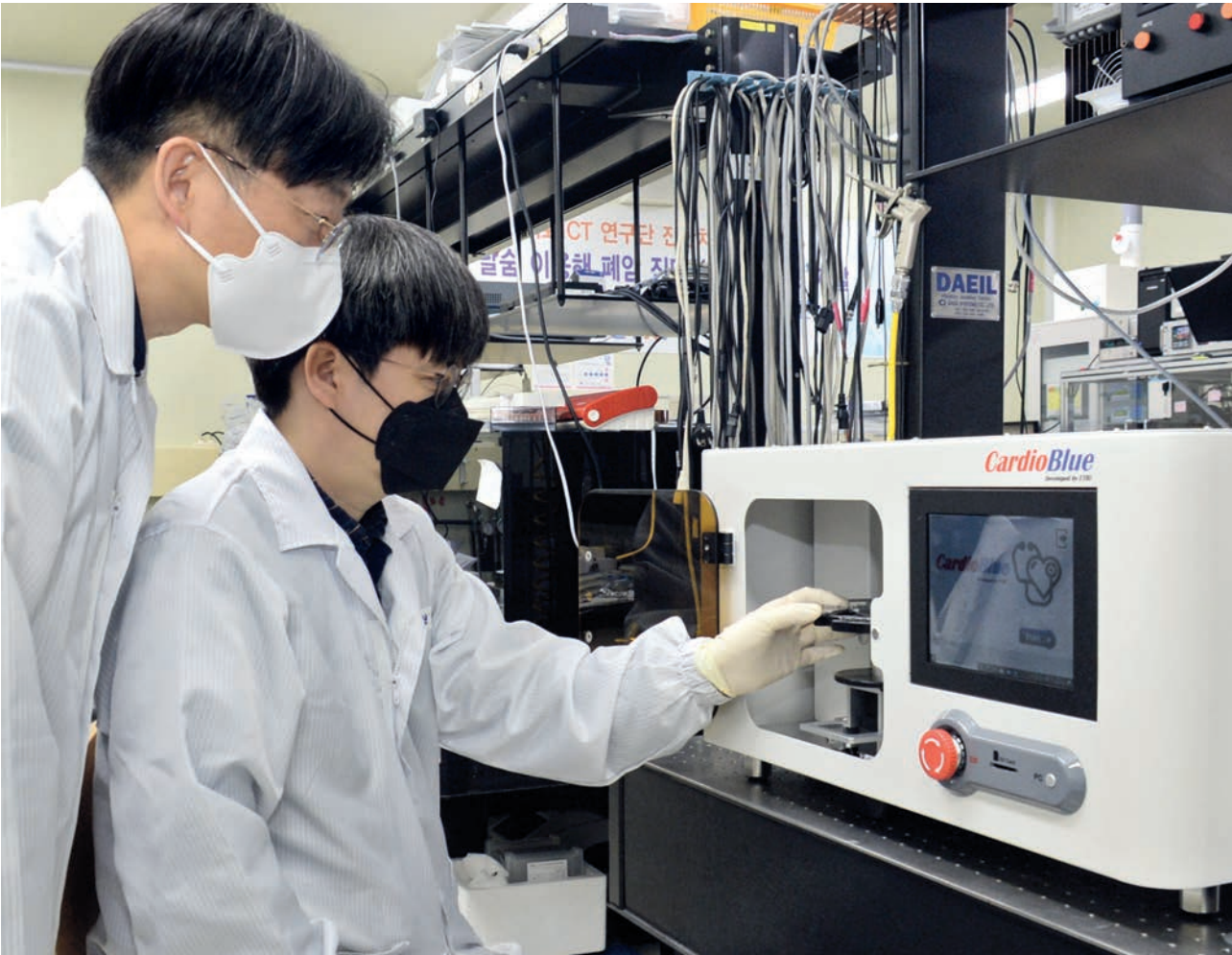
The demand for healthcare services to improve the quality of life is gradually increasing with the transition to aging society. More importantly, the latest trend is to take care of health by focusing on prevention. As the elderly population increases, the incidence rate of chronic diseases also inevitably increases. Healthcare in everyday life is vital because the incidence rate of cardiovascular diseases like arteriosclerosis, hyperlipidemia, and heart attack increases with age.

Accordingly, ETRI developed a technology that measures the possibility of cardiovascular diseases like arteriosclerosis and myocardial infarction within 15 minutes, called the "automatic biomarker analysis technology." Biomarkers are indicators that show abnormal symptoms in the body through DNA and proteins.

Cardiovascular diseases like myocardial infarction and angina pectoris develop from hyperlipidemia or arteriosclerosis. Among various biomarkers in the blood, the biomarker analysis method predicts diseases using five biomarkers known to increase when a disease develops, including cTnI, CRP, D-dimer, CK-MB, and NT-proBNP.

The automatic biomarker analysis technology developed by ETRI is a technology that measures five biomarkers that increase the concentration of corresponding proteins when there is a cardiovascular disease. It applies ▲signal amplification technology, ▲high-density antibody immobilization technology, and ▲automated technology based on rotary motion.

ETRI's automatic biomarker analyzer is almost the same size as a household microwave oven. This analyzer resolved the problems of commercial analytics systems, which are large in size, expensive, and has a lengthy analysis process. Urgent patients with pos-

sible cardiovascular disease can get tested easily and quickly at a local hospital without having to visit a large hospital, reducing the probability of developing into cardiovascular diseases.

The researchers also developed a centrifugation function within the automatic analysis system for the pretreatment of whole blood samples for blood testing. If this module is used, biomarkers can be measured easily and quickly by pretreating 1 mL of blood in 3 minutes.

The researchers explained that the automated technology based on rotary motion shortened the measurement time by minimizing the moving distance of samples and various modules. This technology also minimized deviations and errors caused by external factors. The reproducibility (CV: coefficient variation), which is the deviation in value measured during continuous measurement of the same samples, was 3.4%. This value is nearly the same as the world's best outcome.

The researchers will conduct a clinical experiment next year to verify the performance of the automatic analysis technology and optimize the structural design of the system to reduce the spatial burden. Additionally, by changing the capture and detection antibodies used for automatic analysis, the technology can be applied to cancers, viral infections, bacteria, and diseases related to food poisoning. This new technology will offer improved convenience for medical examinations.

1. The ETRI research team's automated analysis system performs specimen preparation.

2. Automated analysis device for diagnostic tests developed by ETRI researchers.
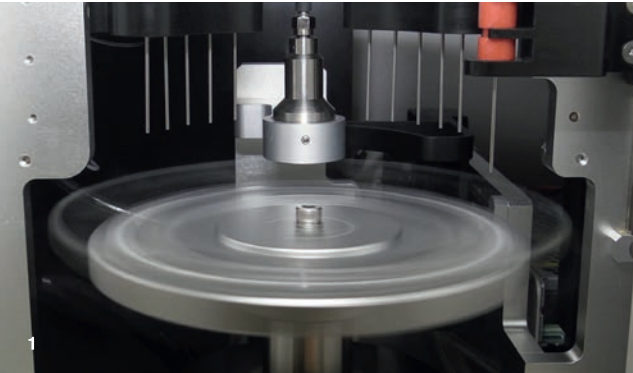
Convergence Research Dept. & Regional Research Center

Laying the Foundation for an Independent National Defense through AESA Radar Core Component Technology Development

Switch MMIC for Radar Transceiver

It is more necessary than ever to respond to rapidly changing external environment and secure localization technology for core defense materials and parts for the realization of independent defense. Therefore, the National

On battlefield of future, advanced weapon technology and the level of innovation determine victory or defeat. Therefore, it is essential to apply the core technologies of the Fourth Industrial Revolution to the weapon system in order to take the lead in the global arms industry. Since this is directly related to the success or failure of national economic growth as well as national defense, it is very important to localize advanced weapon systems and to have self-defense capabilities.

However, Korea still relies on imports for many core parts of advanced weapon systems. In particular, as technologically advanced countries are strengthening their export licenses in recent years, it is more necessary than ever to have the technology based on the independent development of core weapon systems and parts and their localization.

With this in mind, domestic industry, academia, and research institutes are working actively to localize defense semiconductor materials and parts and to acquire original technologies. It will be of great help in realizing independent defense and acquiring core semiconductor technology.

ETRI, which oversees the DMC Convergence Research Department, is developing a platform for military core components based on compound semiconductors and silicone. Major development targets include silicone-based high-voltage switches and uncooled infrared imaging sensors, the core parts of semiconductors for detonators of weapon systems.

Recently, ETRI announced that they have developed GaN monolithic microwave integrated circuits (MMICs) for radar transceivers which can be used in the C-band and X-band for the first time in Korea. This technology is a core part of radar semiconductors in surveillance weapon systems. The progress is meaningful in that the design and production of switch element and integrated circuits are all created with the technology of domestic researchers.

In order to detect and reconnaissance from a long distance, radar requires radio wave technology that produces high output power and minimizes signal loss in the information transfer process. The research team received great attention by developing a core semiconductor component technology for radar that can be used in the front end of active electronically scanned array (AESA) radar.

The technology developed by the research team utilizes gallium nitride, which is good for enduring high power output, to create switch integrated circuits. The result shows an isolation of 30 dB or more, and a C-band and X-band output power of 40 watts and 30 watts respectively. These results are comparable to commercial products in the US or Europe, which are leading research institutes. Utilizing this technology is expected to be highly effective in reducing the size of AESA radar transceiver module. In particular, as it can be applied to various fields such as military high power radar transceiver modules as well as the transceiver modules of civilian ship radar, weather radar, and etc.

It is becoming more urgent to secure advanced scientific and technological response capabilities in line with the changing battlefield and the expansion of the arms trade market. Even now, challenging and innovative R&D is being carried out in the field of defense R&D area. ETRI hopes that a safer and stronger national defense independence will be achieved under such strong efforts.
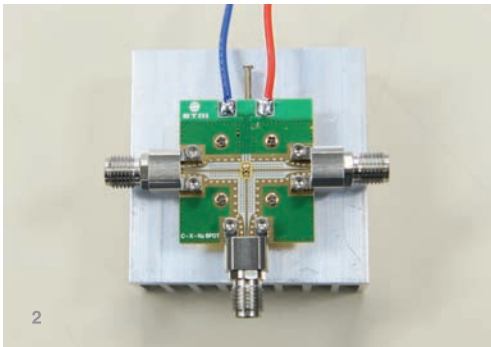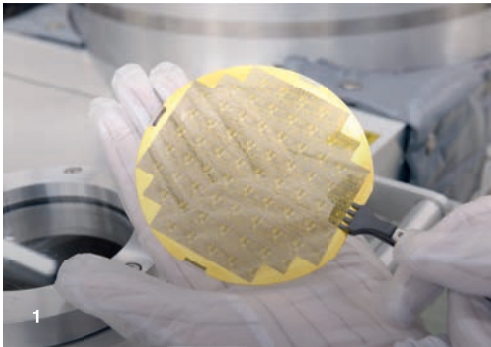
1. The GaN switch integrated circuit wafer used in radar semiconductor transceivers developed by ETRI researchers.

2. GaN switch integrated circuit for radar semiconductor transceivers developed by the ETRI research team.

Supporting Optical Communication SMEs in Korea for the Vitalization of 5G, and Becoming an Internationally Accredited Testing Body for Optical Communication

Support for the Vitalization of the 5G Industry

In June last year, ETRI supplemented the criteria for the accreditation of internationally accredited testing bodies and was recently reassigned as an internationally certified testing body of the American Association for Laboratory Accreditation (A2LA). ETRI performs testing of eight electrical and mechanical test items. A2LA's international accreditation test is the first prerequisite for companies to get through because it is essential for Korean optical communication companies to expand their businesses overseas. The ETRI Honam Research Center (HRC) is the central place for this test. Reassignment as an internationally accredited testing body of the A2LA can lead the advancement of the Korean optical communication industry.

Contributing to the nurturing of the optical communication components industry that would boost the commercialization of 5G telecommunication technologies, ETRI became an internationally accredited testing body both in name and reality. The ETRI HRC performed 3,608 international accreditation tests for 493 businesses from 2006 until present, increasing the sales volume of companies by KRW 828.8 billion and helping them get listed on the KOSDAQ.

The ETRI HRC had various difficulties in operation, such as old equipment and lack of human resources, which ETRI overcame by analyzing internal and external environments in October 2019 to come up with the "2025 Honam Research Center Development Plan" and "2030 Road Map for Mid- to long-tem Service Technology."

The researchers made efforts to resolve the issues of old equipment and corporate support by conducting projects of establishment of photonic-based process innovation platform and industrialization support and new projects of like 5G open test labs. In addition, ETRI will upgrade A2LA's ISO/IEC 17025 Quality Management System to concentrate on creating the framework for future development of the optical convergence industry.

Besides pump-priming overseas expansion of Korean optical communication companies through testing, the ETRI HRC also created significant effects, such as increased sales, shortened development period, and reduced testing expenses.

In 2000, Gwangju Metropolitan City selected the optical communication industry as the specialized industry that will lead the regional economy, preparing the groundwork for an integrated industrial complex. Accordingly, the ETRI HRC built optical communication components developing and testing infrastructures and supported technological development and commercialization by strengthening the technical competitiveness of SMEs and fostering optical communication components technologies, international accreditation testing, FTTH system, and service technologies.

The researchers conducted 3,608 tests so far, contributing to building an ecosystem and creating jobs for the optical communication components industry based on the wired communication network. Moreover, PPI supplied AWG optical modules used in 5G communication networks for telecommunication companies at home and abroad, generating a sales volume of KRW 70 billion in two years through the international accreditation test. Resultingly, PPI was listed on the KOSDAQ in December 2019.

The ETRI HRC upgraded the process and requirements of the ISO/IEC 17025 Quality Management System[1] through non-face-to-face video conferences to provide extensive support for Korean optical communication companies, and was reassigned as an internationally accredited testing body. Based on 66 test standards including Telcordia, IEEE, IEC, TIA/EIA, and MIL-STD, the center offers testing of four mechanical items like temperature, humidity, and high-temperature storage and four electrical test items like optical power, insertion loss, and reflection loss.

The ETRI HRC will revitalize the 5G industry, strengthen the competitiveness of businesses, and increase sales of companies based on accumulated technologies and experiences. ETRI looks forward to seeing it play the role of a government-funded research center and achieve a balanced regional development.

1. A2LA International Accredited Testing Agency Certificate (Reliability category).

2. A2LA International Accredited Testing Agency Certificate (Measurement characteristics category).

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1) American Association for Laboratory Accreditation (A2LA): An association for laboratory accreditation approved by the United States based on the ISO/IEC Guide 25 or equivalent national standards.

Development of a fully homomorphic encryption accelerator that is secure against cryptanalytic attack by the quantum computer

HW Acceleration Technology

The existing encryption technology is unable to operate on encrypted data directly. Since private keys are used to decrypt (re-identify) data, it is inevitable to expose private keys as well as the original information. ETRI recently announced that they are in the progress of developing a hardware accelerator technology for fully homomorphic encryption that breaks away from the existing encryption method. Accordingly, it is expected to open the way for data to be directly applied to various convergence services in an encrypted state in fields requiring security, such as medical care, finance, public service, and national defense.

A domestic research team is developing an advanced security "accelerator" technology that can safely receive and process encrypted information as it is without re-identification, breaking away from the conventional method.

ETRI said they are researching a fully homomorphic encryption accelerator technology that can be applied to machine learning while guaranteeing the privacy of encrypted data.

Fully homomorphic encryption technology is to process encrypted data as it is without additional decryption processes.

It is considered the fourth generation cryptographic technology and is attracting attention as quantum-safe next-generation cryptography.

ETRI's work on the fully homomorphic encryption accelerator technology aims at also developing an arithmetic logic unit (ALU), which can calculate large encrypted data in large arithmetic word sizes.

Moreover, it guarantees that data can be processed or combined with other services in an encrypted state without re-identification, which is the advantage of fully homomorphic encryption, and that the security of encryption is not broken even in quantum computing.

Homomorphic encryption has a problem that it takes a lot of time to process data that has grown due to encryption.

The research team intends to solve this problem by developing HW-based fully homomorphic encryption acceleration technology.

Researchers are making their way to developing this technology to reduce the time required by the CPU to process encrypted data by more than 10,000 times faster than the current technology.

ETRI said that this technology development results in HW accelerator chipsets, accelerators embedded in data servers, libraries for boards, and application SWs for artificial intelligence.

An accelerator board equipped with the chipset to be completed through this technological development can be used in servers such as cloud data centers.

This is possible due to source technologies previously developed by ETRI such as the "high-speed HW processing elemental technology of homomorphic encryption" and "encrypted question answering database technology."

ETRI's Seoul SW-SoC Convergence R&BD Center also has technologies and competencies needed for developing an accelerator, including application-specific integrated circuit (ASIC), system on chip (SoC), and device development.

The technology to be developed is planned to be transferred to cloud computing service companies, DBMS companies, fabless companies, and server-mounted homomorphic encryption accelerator developers.

We expect that the research team's HW acceleration technology will be developed to a world-class level, contributing to Korea leading the next generation of security technology.
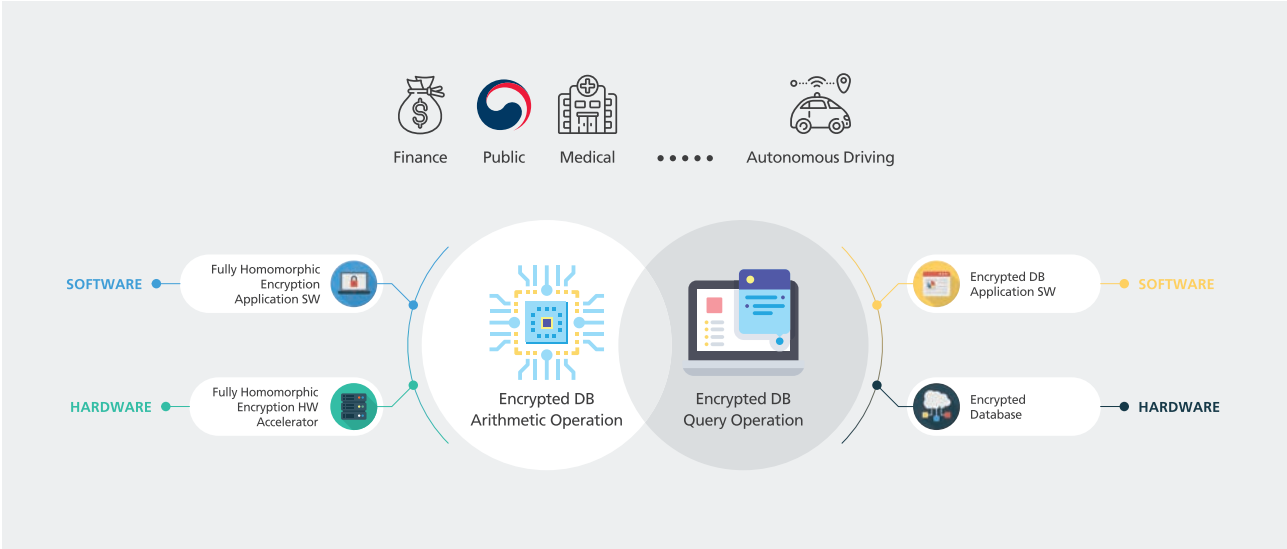
Conceptual diagram of fully homogeneous encryption technology.

Applied AI Technology for the Health and Safety of Citizens

Medical ICT Fusion Technology + Applied AI Technology

ETRI has developed computer technologies such as semiconductors in addition to 4G and 5G communication which have brought many positive changes to people's lives. It is also putting in efforts for developing technology that will increase the quality of life of citizens. With the start of the COVID-19 pandemic last year, the need for contactless vital signs monitoring technology is becoming more prominent. ETRI has acquired core technologies for vital signs monitoring so patients can be diagnosed in a contactless environment without going to the hospital. It is also developing an AI-based fire detection technology that detects forest fires in real time to ensure the health and safety of citizens.

Dimensions
5.4 x 6.9 x 1.3 (cm)

Functions
Authentication completed
Electrocardiogram, Respiratory rate, PPG, Blood pressure

To be verified
Blood oxygen saturation(SPO2), Body temperature

Network
WiFi, Bluetooth

Battery Capacity
(Continuously) 7hrs
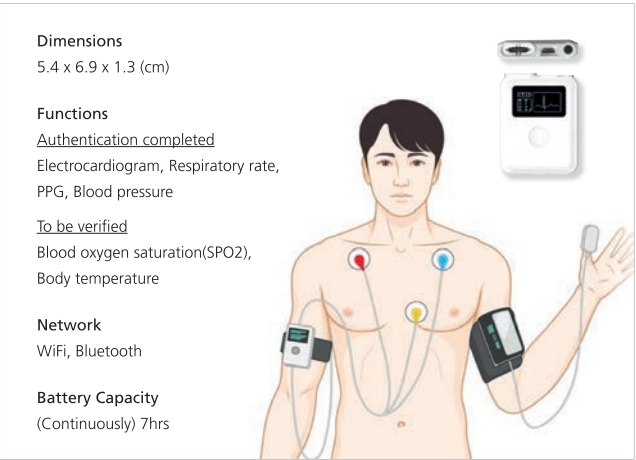
Biological signal measuring device function.

Mobile   PC

Central monitoring unit operation screen.

Although the COVID-19 pandemic that started in 2019 has slowly improved due to vaccinations, the spread of mutant viruses such as the highly contagious Delta variant and the highly lethal Lambda variant exacerbates the pandemic situation since the first half of 2021 both in Korea and worldwide. Additionally, medical staff, who are considered frontliners and top priority for vaccinations, is experiencing a breakthrough infection of the virus due to contact with COVID positive patients. This is a very dangerous situation that may even dismantle the medical system.

Using ICT know-how, ETRI has developed an contactless vital signs measurement technology that allows medical staff to measure patients' biological signals in real time without physical contact. This development is expected to be of great help in preventing and reducing secondary infections and breakthrough infections among medical staff and increasing the operational efficiency of medical staff operation. This technology has been developed jointly by ETRI, Daegu-Gyeongbuk Research Center and SMEs for medical devices, and is composed of devices for biological signals and central patient monitoring system.

The vital signs monitoring device measures the ECG, heartbeat, respiration, body temperature, blood pressure, blood oxygen saturation and delivers measurements to the central patient monitoring system, allowing medical staff to monitoring a patient's status in real time. The researchers have also developed vital signs analysis technology that works on the vital signs server system. In

addition, the researchers cooperated with the Daegu Gyeongbuk Medical Innovation Foundation to greatly speed up testing, inspection and licensing. The technology developed by ETRI has been certified as a class 2 medical device in July 2020 through the National Institute of Medical Device Safety Information's review, which is an institution under the Ministry of Food and Drug Safety.

The contactless vital signs monitoring system is not only applicable for efficient monitoring of rehab patients suffering from infectious diseases, this system is also being tested in general hospitals like Seoul National University Hospital and is already being distributed to a few select hospitals. In the future, ETRI plans to improve the system perfection by reflecting the on-site requirements from medical staff.

Recently, the ETRI researchers also developed an AI based fire detection system that monitors forest fires in real time. Forest fire monitoring is currently performed via direct surveillance utilizing surveillance towers and personnel in addition to CCTVs installed in high locations. However, monitoring an unchanging scenery with human eyes leads to excessive fatigue and lower efficiency in surveillance. Such problems have been solved using deep learning-based video analysis technology. In addition, deep learning video analysis technology shows the same scenery that is being watched by the CCTV on a digital twin, allowing for quick location tracking. Similarly, ETRI hopes that smart solutions it has provided will aid in efficiently protecting the safety and health of citizens.

II

General Status

Personnel

* As of Aug. 31. 2021

Type of Work
2,298

87.5%
7.3%
5.2%

- Research/Technical Staff 2,011
- Board Member/Administrative Staff 168
- Assistant Staff 119

Status of Degree Holding
2,298

48.6%
40.3%
11.1%

- Doctoral 1,117
- Master 925
- Bachelors 256
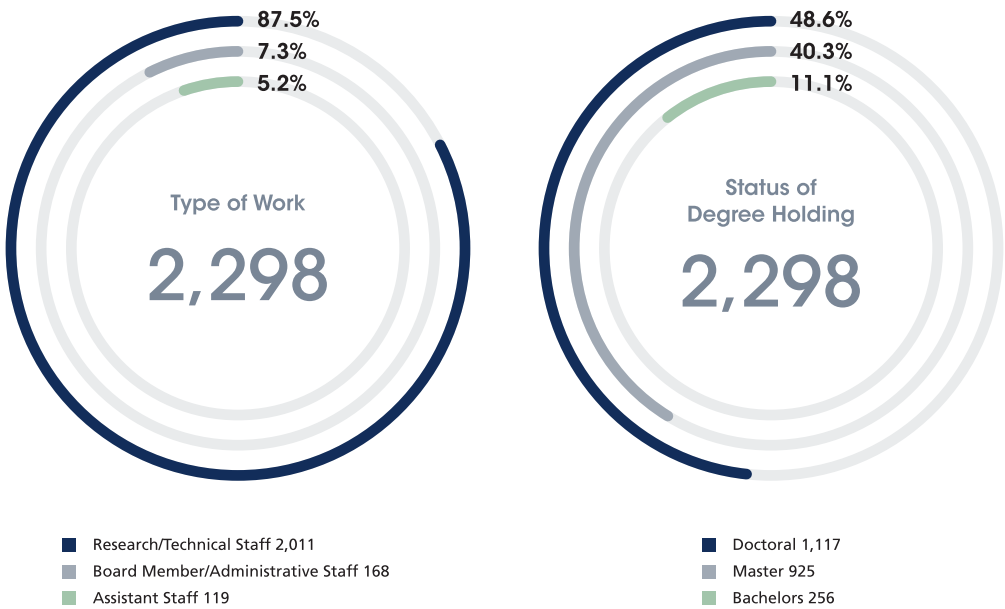
Proejct Status

* As of Dec. 31. 2020

No. of Projects
(unit: cases)

Budgets
(unit: million KRW)

No. of Projects
(Total of Past 5yrs)

2,961

Budgets
(Avg. of Past 5yrs)

612,435 M KRW

Year	No. of Projects	Budgets
2016	552	634,269
2017	574	599,164
2018	586	575,363
2019	599	604,756
2020	650	648,625
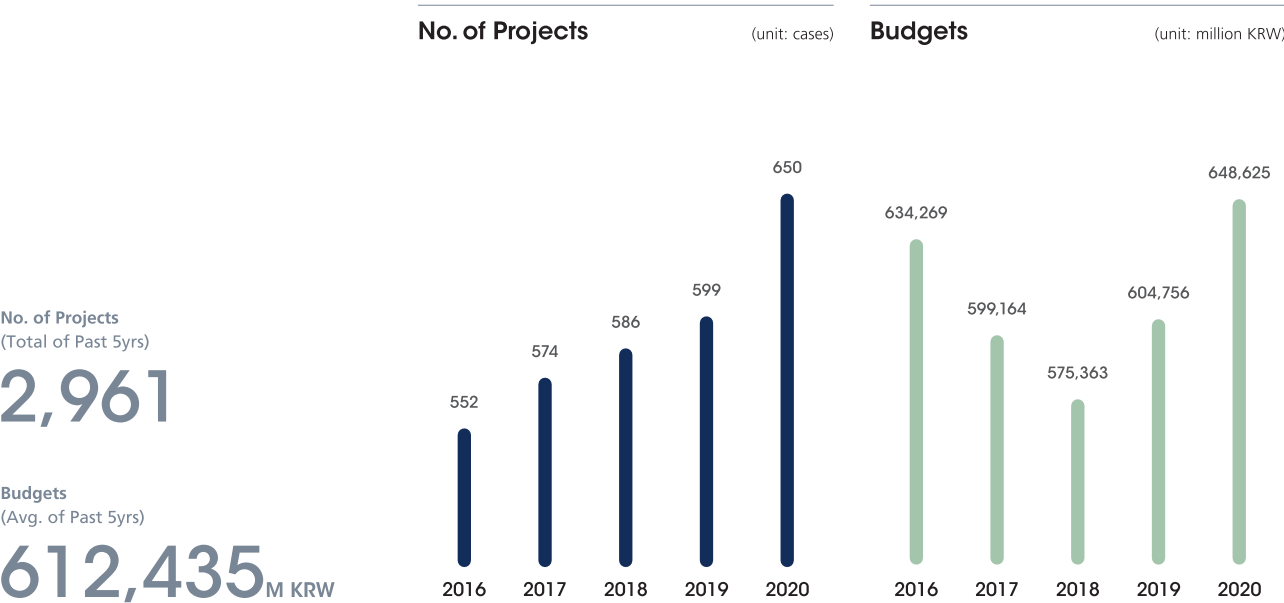
Patent Application

* As of Dec. 31. 2020
(unit: cases)

- Domestic
- International

Year	Domestic	International
2016	2,226	997
2017	2,005	895
2018	1,849	881
2019	1,863	769
2020	1,802	734

No. of Patent Applications
(Total of Past 5yrs)

14,021
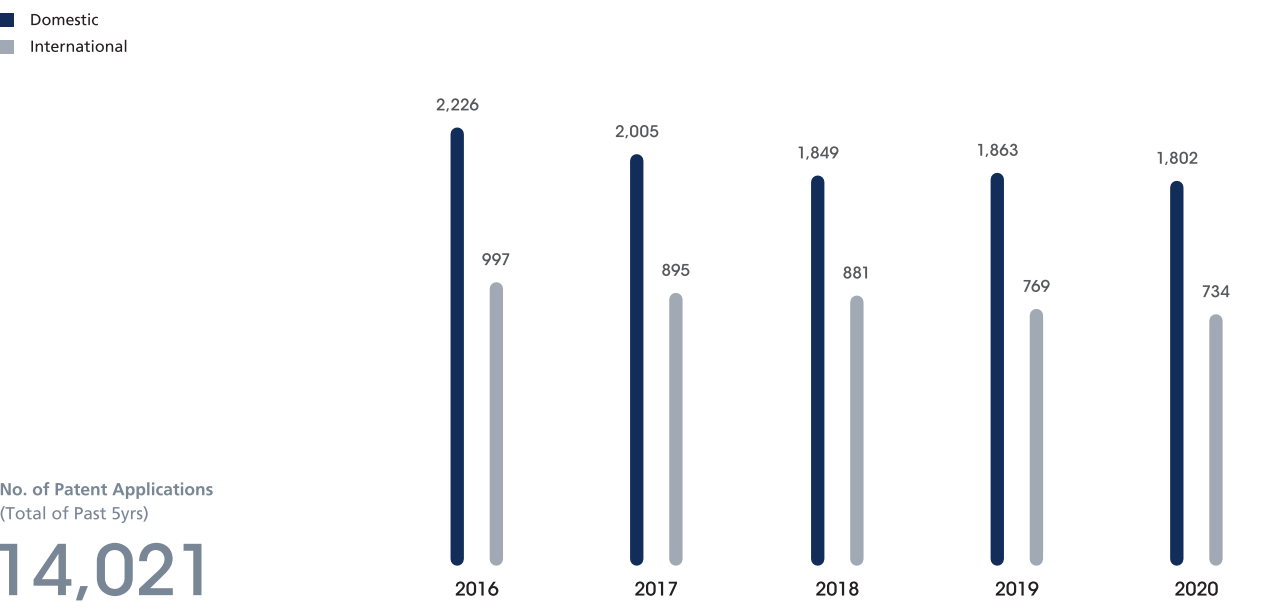
Technology Transfer

* As of Aug. 2021

No. of Technology
Transfer Companies
(Total of Past 5yrs)

1,917

No. of Technology
(Total of Past 5yrs)

1,954

Royalty Income
(Total of Past 5yrs)

229,549 M KRW

Royalty Income / No. of Technology
(unit: million KRW/cases)

- Royalty Income
- No. of Technology

Year	Royalty Income	No. of Technology
2016	37,337	599
2017	39,122	473
2018	39,001	321
2019	50,127	257
2020	63,962	304

No. of Technology Transfer Companies
(unit: cases)

- SME
- Others

Year	SME	Others
2016	580	12
2017	452	15
2018	315	2
2019	243	7
2020	288	3

Standardization

* As of Dec. 31. 2020

No. of Standards Contributions Adopted
(unit: cases)

■ Domestic ■ International

No. of Standards Contributions Adopted
(Total of Past 5yrs)

4,491

No. of Standard Leaders
(Avg. of Past 5yrs)

85.2

	2016	2017	2018	2019	2020
Domestic	293	149	126	100	115
International	1,262	731	695	583	437

No. of Standard Leaders
(unit: people)

2016	2017	2018	2019	2020
87	81	89	81	88

Papers

* As of Dec. 31. 2020

Domestic/International Papers
(unit: cases)
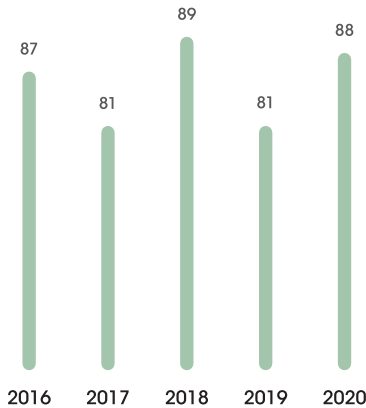
■ Domestic ■ International

No. of Papers
(Total of Past 5yrs)

7,765

No. of SCIE Papers
(Total of Past 5yrs)

1,337

Average IF
(Avg. of Past 5yrs)

2.88

	2016	2017	2018	2019	2020
Domestic	1,183	1,131	985	938	1,028
International	572	541	574	424	389
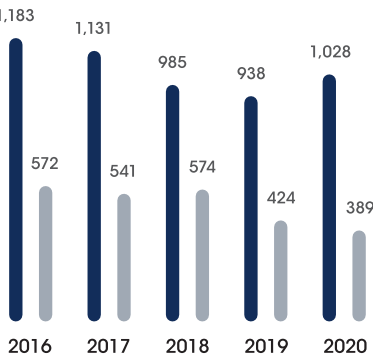
SCIE Papers
(unit: cases)

■ SCIE Papers —○— Average IF

	2016	2017	2018	2019	2020
SCIE Papers	297	257	275	223	285
Average IF	2.15	2.47	3.28	2.83	3.66
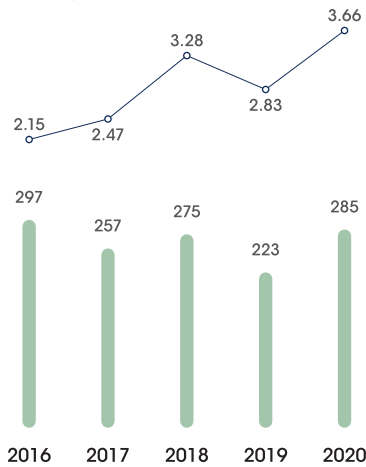
Status and Progress of Companies Established by Alumni

* As of Dec. 31. 2020

853
No. of Companies
After the establishment of Sambo(Trigem) Computer in 1980, approx. 835 companies have been established.

19
Initial Public Offering
19 of ETRI Alumni Companies are listed on the KOSPI [2], KOSDAQ [13], KONEX [4].

244 Billion KRW
Sales
As of end of 2020 Among 52 Companies Approx. 244 billion KRW.

Gachisoft(Co.)	RADOPOS(Co.)	Batoners(Co.)	SaltnLight(Co.)	Mforus(Co.)	Forsedu(Co.)	(Co.)Bigpicturelabs
GonggamSensor(Co.)	linewalks(Co.)	BWsystem(Co.)	PINES&S(Co.)	oprocessor(Co.)	Protos(Co.)	(Co.)ACROSSPACE
GuberNet(Co.)	Radar&Space(Co.)	BLUETILELAB(Co.)	RCN(Co.)	AllNewSystems(Co.)	Play46(Co.)	(Co.)Nspectra
NEWRATEK(Co.)	LUCENTBLOCK(Co.)	BIBIM PLANET(Co.)	RTst(Co.)	Optella(Co.)	HAJIYO(Co.)	AID Korea
Thenatech(Co.)	Looko(Co.)	BnTSoft(Co.)	Awesome Tech Inc.	CoXlab(Co.)	Hojeonable(Co.)	
THEPEACH(Co.)	Mafitner(Co.)	Solarinno(Co.)	Estudio(Co.)	QUI(Co.)	HURA(Co.)	
Developtainment(Co.)	Magenta robotics(Co.)	SMATCH(Co.)	EXOSYSTEMS(Co.)	CREADE(Co.)	Dri&B(Co.)	
Dicto(Co.)	MetaRPAS(Co.)	SPOTTER(Co.)	ELSSEN(Co.)	DDAKPET(Co.)	(Co.)VITEALTH	

ETRI Laboratory Enterprise Status

* As of Dec. 31. 2020

Registered Companies
ETRI has set up 63 ETRI Laboratory Enterprises through successful commercialization of research outcomes since 2007.

71

53

Companies in Operation
53 ETRI Laboratory Enterprises in Operation (As of 2020)

Gamdongbox(Co.)	Leadpointsystem Inc.	Sugentech(Co.)	icerti(Co.)	WiseThan(Co.)	Gene System(Co.)	(Co.)InnoRay
Gamma Spectra(Co.)	MINDs Lab	ShareChem(Co.)	EYEQ Lab Inc.	Y-tech(Co.)	curaum(Co.)	Eintelligence(Co.)
Gridaenergy(Co.)	MAG-SOLUTION inc	SNET(Co.)	RNSlab(Co.)	Wooksung Media(Co.)	Cruxell(Co.)	INTU Works
GreenZone security(Co.)	MINTROBO(Co.)	StandingTALL(Co.)	Antrorse(Co.)	Withmind(Co.)	To be smart(Co.)	TEXTORY(Co.)
Dark Horse Games(Co.)	Biosenstech(Co.)	Secuworks(Co.)	URBAN DATA LAB(Co.)	UGS(Co.)	PDXen(Co.)	FARMCONNECT
Devstack Inc.	Bird Letter(CO.)	Sogware(Co.)	ALtech(Co.)	E&D(Co.)	HarborMAX(Co.)	
DNI(Co.)	VODABi(Co.)	CH Solution(Co.)	NDOS(Co.)	EPhotonics(Co.)	HANCOMINTERFREE(Co.)	
DEEP INSPECTION(Co.)	BTWorks(Co.)	Aritel(Co.)	Optella(Co.)	JUNGSANGLIDAR(Co.)	Hojeonable(Co.)	

Nationwide Regional Research Center

The Main Office(Daejeon)

Tel. 042.860.6114
218 Gajeong-ro, Yuseong-gu, Daejeon, 34129, Korea

Seoul
Gyeongbuk Expressway
Honam Expressway
Busan
Gwangju
Yuseong IC

Buk-Daejeon IC Hoedeok IC

Mokwon Univ.
Daedeok Cultural Center

NRF UST KRISS

KT&G
Research Institute

ETRI
Daejeon

Expo
Science Park

Chungnam National Univ.

KAIST

Shinsegae
Art&Science

Seoul SW-SoC Convergence R&BD Center

Tel. +82.31.739.7200
22, Daewangpangyo-ro 712beon-gil, Bundang-gu, Seongnam-si, Gyeonggi-do, 13488, Korea

Daewang Pangyo IC
Pangyo JC
Korea Expressway Corporation
K-water Seongnam
Gyeongbu Expressway
ETRI Seoul SW-SoC R&BD Center
Institut Pasteur Korea
Nagwon Middle School
Pangyo IC

Honam Research Center

Tel. +82.62.970.6501
11, Cheomdangwagi-ro 176beon-gil, Buk-gu, Gwangju, 61012, Korea

Seoul
Hanam
Gwangju Institute of Science and Technology(GIST)
ETRI Honam Research Center
Daewoo 1st APT
Dongbu 1st APT
Ssangam Park
Wolgye Middle School
Gwangju Design Center
Gwangsan IC
Eungam Park
Cheomdan Hospital
Gwangju Mail Center
Line 1st APT
Empire Tourist Hotel
Dong-Gwangju IC
To Nambu Univ.

Daegu-Gyeongbuk Research Center

Tel. +82.53.670.8000
1, Techno sunhwan-ro 10-gil, Yuga-myeon, Dalseong-gun, Daegu, 42994, Korea

DGIST
Daegu Technopolis
Dalseong Policestation
Yuga Town Office
ETRI Daegu-Gyeongbuk Research Center
Daegu National Science Museum

Global R&D Cooperation Network

45 Countries
155 Organizations

NORWAY
FINLAND
RUSSIA
NETHERLANDS POLAND
BELGIUM GERMANY
FRANCE BULGARIA KAZAKHSTAN
SWISS UZBEKISTAN
SPAIN TURKEY
ITALY ISRAEL TAJIKISTAN
PALESTINE JORDAN PAKISTAN
IRAN INDIA
ETHIOPIA THAILAND MYANMAR
GHANA KENYA VIETNAM
GABON RWANDA MALAYSIA
BOTSWANA ZIMBABWE INDONESIA
REPUBLIC OF SOUTH AFRICA AUSTRALIA
ETRI KOREA JAPAN TAIWAN
CANADA USA
NICARAGUA
BRAZIL
CHILE

SWISS
ETH Zurich / AOneSat / Switzerland Innovation Park Biel
FRANCE
INRIA/CNRS/ETSI/Sigfox
GERMANY
Fraunhofer IAF / Universitat Zu Lubeck / Rohde&Schwarz / X-FAB / MERCK / BOSCH / Fraunhofer-HHI / BMW / Julich / ESCRYPT / BMBF
BELGIUM
IMEC
ISRAEL
ARO Volcani Center / Design Art Networks / FINLAND
KAZAKHSTAN
Transtelecom /
IGTIC(International Green Technologies & Investments Center)
ITALY
SIM2 BV Intermational / ENEA
PALESTINE
An-Najah National University
KENYA
Postal Corporate of Kenya / Baringo County Government
INDIA
CDAC / Sagacious Research Pvt Ltd / Saankhya Labs Private Limited
VIETNAM
Viettel / UET-VNU / Ton Duc Thang University
MALAYSIA
MYANMAR
Mytel / UCSY(University of Computer Studies, Yangon) / West Yangon Technological University / Ministry of Education
TAIWAN
INDONESIA
Researchwire Knowledge Solution Pvt. Ltd. / Ministry of Communication and Information Technology / NCCA(National Cyber & Crypto Agency of Indonesia)
RUSSIA
JSC 'Radiophyzika' / JSC Apex / ITAE RAS / Russian Academy of Science
SPAIN
UPV(Universitat Politècnica de València) / University of the Basque Country(UPV/EHU)
MONGOL
MUST / MTZ

JAPAN
RIKEN / Morita Tech / Zeon / Konica Minolta / NHK / DNPT & DNP / Heartwell / Novatech & Sharp
CANADA
IP Cube Partners / University of Saskachewan / CRC Canada / UHN / University of Waterloo
IRAN
ETHIOPIA
Ministry of Science and Technology / Adama Science and Technology University
BRAZIL
PAKISTAN
Information Technology University / Pakistan Post
CHILE
CHINA
Tongji University / TSMC / Beijing Jiaotong University
POLAND
Warsaw University of Technology / PUT
FINLAND
University of OULU
BULGARIA
IOMT-BAS
ZIMBABWE
GHANA
Council for Scientific and Industrial Research
NETHERLANDS
WLR
NORWAY
Sintef Ocean AS(MARINTEK)
AUSTRALIA
University of South Australia / University of Queensland / University of Wollongong
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University of Texas Austin / University of Washington / University of California Riverside / Texas A&M / MGH / Harvard University / Georgia Tech / CSUFF / SDSU / University of California Davis / University of California San Diego(UCSD) / Indiana University / Virginia Tech / Arizona State University / Columbia University / University of Colorado, Boulder / Massachuset Institute of Technology(MIT) / University of California, Los Angeles (UCLA) / Qualcomm / University of North Carolina at Charlotte / Houlihan Lokey / Avanci, LLC / IBM corp. /

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ETRI BEIJING R&D CENTER
Room 2011, Air China Plaza, 36 Xiaoyunlu, Chaoyang District, Beijing 100027, CHINA
Tel : +86-10-8447-5215
ETRI US R&D CENTER
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