TECHNOLOGIES TO WATCH IN 2024 (2)

3D SENSING EXPANDING AS A FOUNDATION FOR DIVERSE APPLICATIONS

— ADVANCE THROUGH INTEGRATION WITH AI AND PROGRESS IN ENTERTAINMENT AND AUTONOMOUS DRIVING —

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ABOUT 3D SENSING

3D sensing is a technology that uses sensors and information processing technology to perceive objects and spaces in three dimensions such as length, width, and depth almost as humans do. This technology was developed for military use in the past, but it has recently become more accessible, with improved accuracy, lower prices, and simplified equipment as a result of investment in anticipation of its use in autonomous driving and extended reality (XR), and its integration with AI technology. This report explains 3D sensing technology, for which further expansion of applications is expected in the future.

(1) THE MECHANISMS OF LIDAR AND PHOTOGRAMMETRY

Sensing methods can be broadly classified into contact and non-contact types. Non-contact types do not require direct contact with the object being sensed. It includes sonar using sound waves, radar using radio waves LiDAR using laser, and photogrammetry using light. This paper focuses on LiDAR and photogrammetry, which have become more common due to cost reductions in recent years (Figure 1).

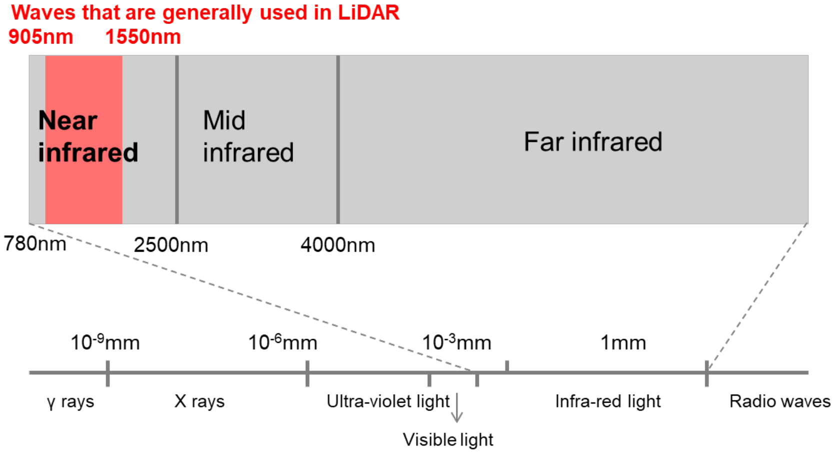
Figure 1: Sensing methods (non-contact)

	Sonar	Radar	LiDAR	Photogrammetry
Medium	Sound waves	Radio waves	Visible, near-infrared, and ultraviolet light, etc.	Light (cameras)
Range	Meters to thousands of kilometers	Hundreds of kilometers	Meters to hundreds of meters	Photographable range
Accuracy	From a few centimeters	From a few millimeters	Nanometers to a few centimeters	A few millimeters if close to the object
Cost	—	—	Tens of thousands to tens of millions of yen	Cost of the camera and the processing software ranges from free to several hundred thousand yen
Remarks	Mainly used underwater	It is difficult to use in rain because of rain attenuation	Affected by fog and other fine particles	Number of cameras and angle of view affect accuracy Difficult to use in the dark

Source: Prepared by Mitsui & Co. Global Strategic Studies Institute from various sources

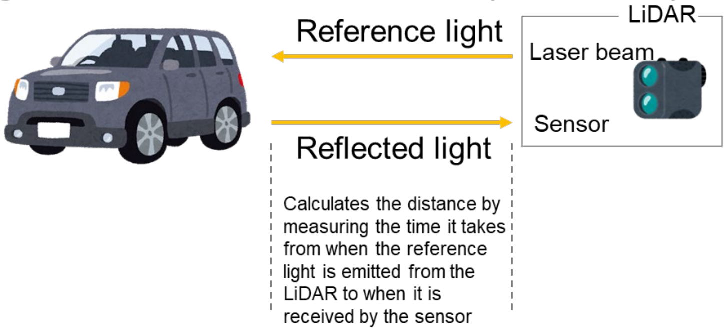
LiDAR (Light Detection And Ranging) is a technology that utilizes ultraviolet, infrared, and other frequency laser beams (mostly near-infrared rays between 905 and 1550 nm). (Figure 2). The typical time-of-flight (ToF) method involves shining a laser beam at an object and measuring the time it takes for the reflected light to return. Then, the distance to the object, the shape of the object, etc. are calculated and the object is reproduced usually via point cloud data. (Figure 3). LiDAR uses laser beams with higher optical flux density and shorter wavelengths than radio waves, which means it can detect positions and shapes with higher accuracy than radar. Since the technology was proposed in the 1960s, LiDAR has been used in a wide range of fields, including aerial surveying, where sensing device is mounted on airplanes to survey terrain, and visual inspection of turbines, which requires accuracy of several tens of microns. In recent years, its high accuracy has led to potential applications in autonomous driving, and research and development is accelerating.

Figure 2: Wavelengths used in LiDAR



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute from various sources

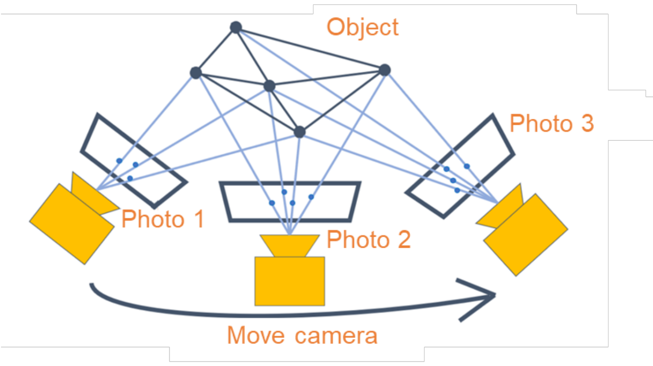
Figure 3: The mechanism of LiDAR (ToF method)



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute from various sources

Photogrammetry, on the other hand, is a technology that generates a 3D model by analyzing multiple photographs. With this technique, an object is photographed from a number of different distances and angles, the feature points of the object are then calculated from the photographs taken. The differences of those feature points in different distances, and angles are calculated and mapped onto spatial coordinates to create 3D point cloud data. Finally, the photographic image is fitted to the surface to generate a 3D model's texture (Figure 4). Although the process requires complex mathematical calculation, specialist software is commercially available, such as RealityCapture by Epic Games (US) and Metashape by Agisoft (Russia). That allows even ordinary users to get started relatively easily by simply preparing a camera and the software. Photogrammetry is also used for reproduction in surveying and topographical research, data for restoration of buildings and cultural heritage, as well as generation of 3D models using VR and game production.

Figure 4: Illustration of photogrammetric imaging and calculation

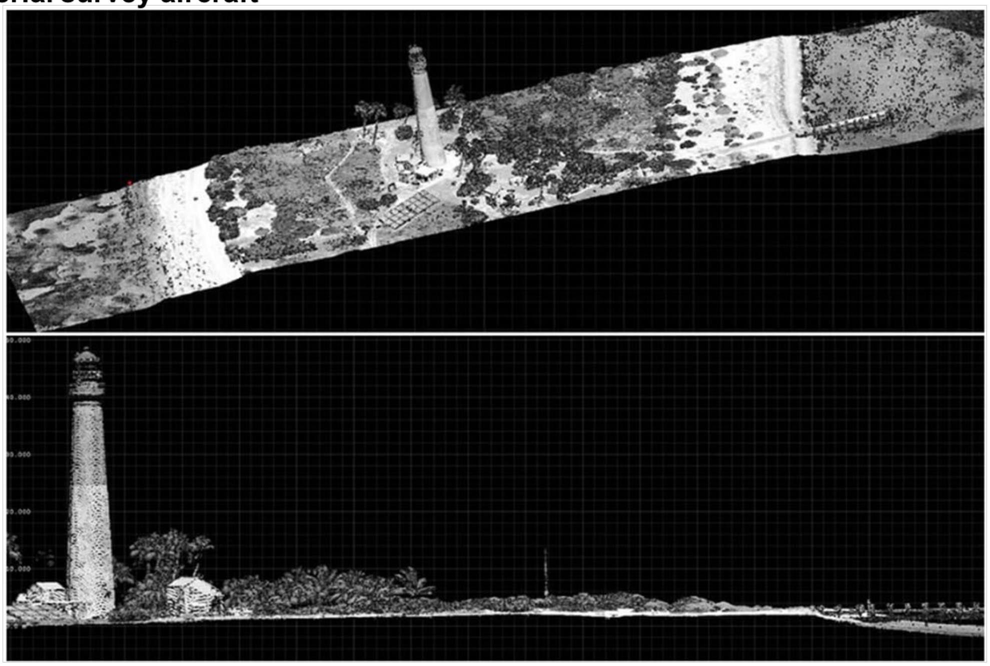


Source: 3D+ONE https://3dplusone.jp/photogrammetry/about-2/ (accessed January 9, 2024)

(2) SUITABILITY AND CHALLENGES OF LiDAR TECHNOLOGY

The advantage of LiDAR is that it can create 3D models of a wide range in a short time (Figure 5). Its disadvantages are that the equipment tends to be expensive due to the large number of components and that it is difficult to downsize. In fact, LiDAR for industrial applications that require nano-order accuracy costs tens of millions of yen per unit. However, for consumer and autonomous driving applications, replacing the mechanical part of the LiDAR (the mechanism that moves the laser beam and irradiates the object) with an image sensor can ensure the necessary accuracy, resulting in lower prices ranging from several tens of thousands to several hundred thousand yen and smaller sizes ranging from millimeters to centimeters (Figure 6). Both existing LiDAR manufacturers and also semiconductor manufacturers that specialize in cost reduction through mass production are contributing to this situation. Other drawbacks include the difficulty of reproducing textures that represent the qualities of materials, the fact that it is not suitable for scanning extremely small objects, and the fact that it is easily affected by weather conditions such as rain and fog.

Figure 5: Data for the vicinity of a lighthouse in Florida acquired by LiDAR-equipped aerial survey aircraft



Source: What is lidar?, National Ocean Service, https://oceanservice.noaa.gov/facts/lidar.html (accessed January 9, 2024)

Figure 6: Ouster's LiDAR product (OS2)

Source: DATASPEED,
https://www.dataspeedinc.com/product/ouster-os2-lidar/
(accessed January 9, 2024)

Future issues include improving depth accuracy by improving image sensor speed and further cost reductions. Measures under consideration to address these include the use of a phased array, by which the direction and shape of the beam can be freely changed by controlling the phase of the radar.

(3) SUITABILITY AND CHALLENGES OF PHOTOGRAMMETRIC TECHNOLOGY

The advantage of photogrammetry is its simplicity. As above, with just a camera and software, it offers flexibility in creating 3D models. Since photographic images are fitted to the surface of the 3D model, photogrammetry is also good at accurately reproducing the texture of the object's surface, something LiDAR finds difficult.

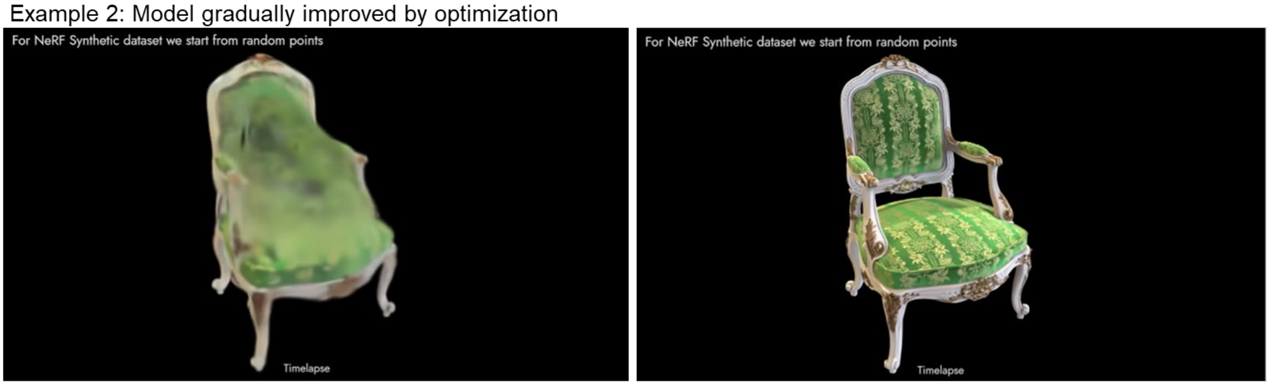
It is important to note that accuracy is dependent on the photographs. In order to generate a highly accurate 3D model, a large number of photographs must be prepared in high resolution and from a variety of angles. Therefore, it takes time to take the photographs and it is not suitable for objects that change in real time. Other important points to note are that photogrammetry cannot accurately reproduce parts of the object that are not in the photo, and that it is not good at processing glass or mirrored surfaces.

However, photogrammetry techniques combined with AI have been proposed in recent years, indicating there is potential for improvement of this point. These are called NeRF or 3D Gaussian splatting. NeRF is a method proposed in 2020 that uses AI to calculate the coordinate information, camera angle, and light intensity of each point from a large number of photos to create a model. Once the processing is complete, it can give a good quality 3D model from different camera angles. The announcement of a faster Instant NeRF by NVIDIA (US) in 2022 attracted a lot of attention. However, NeRF has the disadvantage of being computationally intensive and time-consuming to process because data must be calculated and displayed for all points. 3D Gaussian splatting (Figures 7 and 8) arrived in 2023 and is characterized by the use of elliptical Gaussian functions instead of the triangles (polygons) conventionally used in 3D computer graphics. The model is not as rigorous as NeRF, however, it can display three-dimensional objects with a high degree of reproducibility and is characterized by its fast processing. Although this method has attracted a great deal of attention, it is expected to take time to replace the polygon-based tools widely used in practice, because it is difficult to change the data type to Gaussian data from polygon data.

Figure 7: Model generation by 3D Gaussian splatting

Example 1: Final model on the left, Gaussian visualization on the right

Example 2: Model gradually improved by optimization



Source: 3D Gaussian Splatting for Real-Time Radiance Field Rendering, Inria/GraphDeco GraphDeco Inria Research Group YouTube, https://www.youtube.com/ watch?v=T_kXY43VZnk (accessed January 9, 2024)

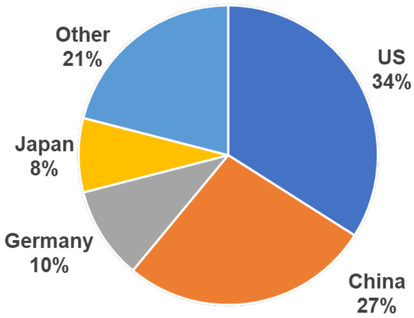
Other photograph-based 3D sensing technologies include photometric stereo, which analyzes photographs taken with different angles of light projection. The accuracy of this technology has also improved significantly in recent years, enabling the construction of 3D models with a high degree of reproducibility using only ten or so photographs.

PROMISING FIELDS OF APPLICATION

(1) MARKETS AND PLAYERS

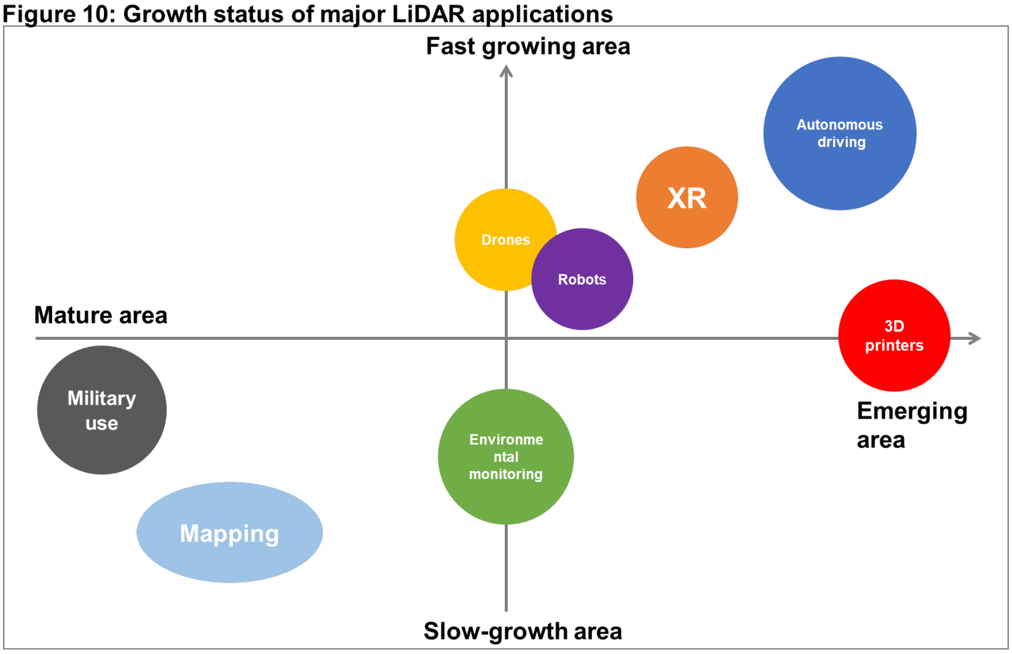
Due in part to its use in the field of autonomous driving, the LiDAR market is expected to reach $7.94 billion by 2030, up from $1.9 billion in 2022. Although there are a great many players, industry restructuring is also underway. Velodyne Lidar (US) originated from Velodyne Acoustics, an audio development and manufacturing company founded in 1983. Having commercialized a mass-market model in 2007, Velodyne Lidar is a pioneer in this field, and became the first company specializing in LiDAR development to go public on the NASDAQ exchange in July 2020. However, it announced a merger with Ouster (US) in February 2023. The company expects this to accelerate market penetration by expanding sales channels and to reduce operating costs, which stand at more than $75 million per year. Other companies to watch include Luminar Technologies (US) and Hesai Technology (China), which supplies LiDAR for electric vehicles manufactured by Li Auto (China) and other vehicles in China, where momentum is building in recent years. In Japan, leading players include Toshiba, Panasonic, and Denso (Figure 9). Figure 10 shows an illustration of the growth of major LiDAR applications.

Figure 9: Percentages of LiDAR players by country



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute from Lidar 2023-2033: Technologies, Players, Markets & Forecasts (IDTechEx)

Figure 10: Growth status of major LiDAR applications



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute from Lidar 2023-2033: Technologies, Players, Markets & Forecasts (IDTechEx)

The photogrammetry software market is projected to grow from $430 million in 2020 at an average annual growth rate of 14.7% until 2027. The two main players in game development and other general applications are Epic Games and Agisoft mentioned above. Some software are specializing in a certain domain, for example, Autodesk (US), Hexagon (Sweden), and Pix4D (Switzerland) are aim to be used in photogrammetry. In Japan, Pix4D's products are registered in the database system maintained by the Ministry of Land, Infrastructure, Transport and Tourism for the use of new technology in public works projects. These 3D modeling tools have become widespread, with their use by contractors being evaluated in project bidding.

(2) AREAS OF POTENTIAL FUTURE USE

As above, 3D sensing is a technology that has conventionally been used in topography surveys, product visual inspections, and the preservation of cultural heritage. Recently, however, its use is expanding to include the fields of autonomous driving, picking robots used in distribution warehouses, gaming/AR (augmented reality), and entertainment. In autonomous driving, the installation of LiDAR is said to be almost indispensable to meet the criteria for Level 3 (conditionally autonomous driving) or above. In entertainment, it is expected to be used in video production. Virtual production is a technique in which real-life subjects and virtual backgrounds projected on a screen are photographed together. Studios specializing in this type of production are increasing worldwide, and are mainly using LiDAR and photogrammetry technologies to create these backgrounds. Although real buildings have issues such as the site being too small to accommodate filming equipment, or walls interfering with the desired composition, the use of computer graphics eliminates these restrictions, allowing for freer production of video. In addition, 3D computer graphic backgrounds are beginning to be used for live broadcasts at events, taking advantage of the ability to depict and change background images in real time.

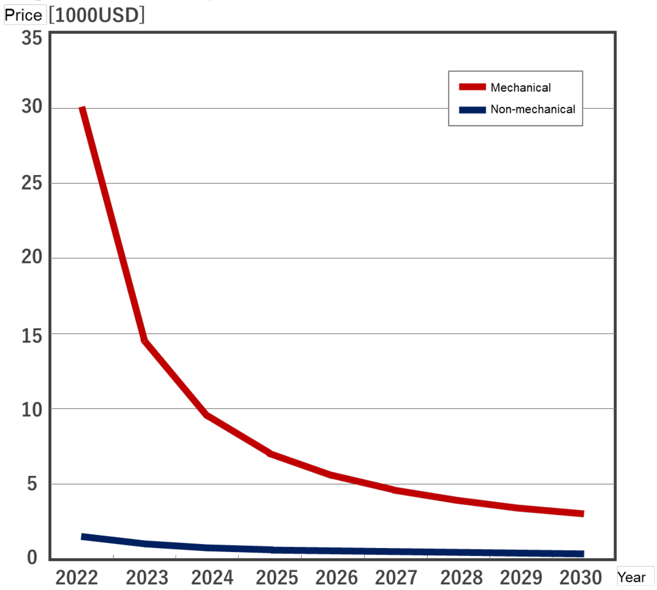
In consumer applications, LiDAR is beginning to be used in head-mounted mixed-reality/augmented-reality (MR/AR) displays and smartphones, although this is limited to a few high-end devices. With MR/AR head mounts, LiDAR is used to obtain information about the surrounding environment, and with smartphones, it is being used for applications such as saving the scenery of a travel destination in 3D and measuring distances in golf.

FUTURE PROSPECTS

Currently, the manufacturing cost alone for a LiDAR that can be used in autonomous driving is several hundred dollars per unit, and this is even higher at the full product level. However, according to forecasts, the cost expected to drop to the $100 level in the next few years (Figure 11), and more automated vehicles are expected to use this technology.

In fact, the above-mentioned Luminar Technologies has already signed contracts to provide sensors to six passenger vehicle and truck manufacturers, and several millions of vehicles are expected to be equipped with its technology in the next few years. If the expansion of the automated vehicle market leads to mass production and the price of the product falls to $100 or less, LiDAR is expected to spread to other fields.

Figure 11: LiDAR price forecast



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute from Lidar 2023-2033: Technologies, Players, Markets & Forecasts (IDTechEx)

In the consumer field, for example, although LiDAR is currently only available in a few smartphones, it may come to be increasingly used in lower-priced smartphones. It is not a stretch to think that this technology is approaching the point where anyone will be able to create and utilize 3D models, thereby replacing photography. The future where 3D sensing is used as a general-purpose technology in a variety of situations is just around the corner.

TECHNOLOGIES TO WATCH IN 2024 — INTELLECTUAL PROPERTY REPORT —

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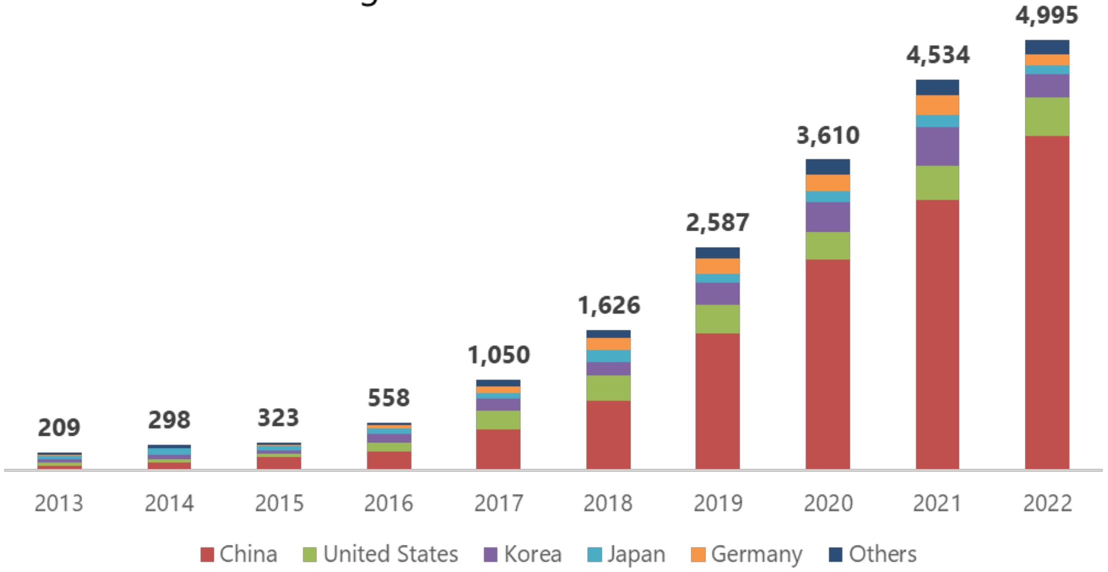
This paper examines, analyzes, and reports on international trends in patent applications related to 3D sensing, which were featured in Technologies to Watch in 2024. This investigation and analysis were conducted using PatSnap Analytics, a global patent search and analysis tool, and PatSnap Discovery, a search tool for various kinds of technical information, provided by PatSnap. All data was obtained on December 1, 2023.

3D SENSING

Figure: Trend in the Number of Patent Applications Related to 3D Sensing



Source: Prepared by Mitsui & Co. Global Strategic Studies Institute based on PatSnap Analytics data

ANNUAL TRENDS IN PATENT APPLICATIONS

The number of patent applications related to 3D sensing is on the rise, with a remarkable growth of 73% and 88% year-on-year in 2016 and 2017, respectively. With a compound annual growth rate (CAGR) of 42% from 2013 to 2022, 3D sensing is a technology area with a high growth rate.

By region, patent applications from China account for 66% of the total. This has a significant impact on the growth of this technology sector, with a CAGR of 60%. However, with only 9% of patent applications in China also being filed in other countries, most of these applicants seek protection in China alone. For reference, 62% of patent applications in the US are also filed overseas. This ratio is an indicator of how much a country’s technology requires protection outside the country and reflects how influential the country’s innovation is in the international marketplace.

Looking at the attributes of applicants, the ratio of patent applications filed by companies to those filed by academic institutions in China is 3:2, suggesting that R&D at academic institutions is linked to patent applications. A similar trend is seen in Korea. In the US, the overwhelming majority of patent applications are filed by companies, with the ratio of patent applications filed by companies to those filed by academic institutions being 18:1. Similar trends are seen in Japan and Germany.

TECHNICAL FOCUS

The data on patent applications for 2019 and beyond were analyzed for technical focus.

Patent applications related to LiDAR accounted for 49% of all applications related to 3D sensing, indicating that LiDAR is in an important position. The wide range of potential applications of 3D sensing can be seen in a variety of fields, including autonomous vehicles, security, healthcare, entertainment, robotics, smart cities, etc.

Autonomous vehicles: Include advanced sensor systems for 3D mapping of the environment, obstacle detection, and safe navigation of the vehicle. Patents for new methods and devices have been filed to improve these systems.

Security: Includes motion detection, facial recognition, and identification of abnormal behavior. These play an important role in security and surveillance systems, contributing to public safety and personal privacy protection.

Healthcare: Used for analysis of patient movement patterns, surgical support, and monitoring systems for rehabilitation, enabling more effective diagnosis and treatment.

Entertainment: Used for immersive gaming and interactive entertainment, enabling real-time user interaction, and augmented reality (AR) and virtual reality (VR) experiences.

Robotics: Used for object detection, navigation, and execution of precision tasks, 3D sensing is expected to improve the efficiency and safety of manufacturing processes.

Smart Cities: Used in applications such as urban planning, traffic management, and infrastructure maintenance, with the aim of improving the efficiency, sustainability, and safety of cities.

REPRESENTATIVE PATENT APPLICANTS

1. Robert Bosch (Germany): Focusing on autonomous driving technology and improving sensor performance in different environments.

2. Waymo (US): Focusing on autonomous driving technology, machine learning and algorithms.

3. Hyundai Mobis (Korea): Related to autonomous driving technology and advanced driver assistance systems (ADAS).