LiDAR Technology: Usage, Trends, and Future Growth.

Introduction

LiDAR is a technology that has seen growing excitement among engineers. The laser-based technology that can map anything from mountains to singular molecules is now an essential component in many of the systems that we use.

It is one of the fastest-growing technologies thanks to increasing demand across a wide array of applications ranging from automobiles to construction and mining. Further advancements in LiDAR make it cheaper and more effective, opening doors to other industries that haven't applied before.

Market survey shows that LiDAR is projected to reach USD 5.82 billion, while many other projections show a similar figure. It is all thanks to advancements such as solid-state LiDAR, miniaturization, and spectrum scans with the support of new and more progressive laws and regulations by many governments worldwide.

LiDAR is a fast, accurate, and automated way to access the environment. This whitepaper takes a deeper look at the major factors pushing the future development of LiDAR, along with the current trends and its many applications.

What is LiDAR Technology?

LiDAR stands for Light Detection and Ranging. This sensor is used for finding ranges by measuring the time taken for a pulse of a targeted laser on an object or a surface to bounce back and calculating the distance.

A LiDAR sensor has three major components, which include:
- A source that throws laser pulses
- A scanner that deflects the light from the scene
- A photodetector that collects the reflected light

Other than that, there are several supportive components, such as optical lenses, to ensure the efficient collection of data.

Growth Drivers

LiDAR is among the fastest-growing fields of engineering. Using LiDAR, machines can gather information about distant objects and environments, such as mountains. At the same time, it can detect minuscule objects such as insects, thus giving a more detailed and comprehensive mapping of the area than traditional sensing using radar. Applications of LiDAR-based systems are coming up in all types of different industries.

With the ongoing research in LiDAR technology, we will likely see improvements in resolution, range, and accuracy. With that, its efficiency in detecting and navigating complex environments will increase, which is essential for existing and nascent industries to adopt LiDAR.
Several factors driving the future growth of LiDAR are:

- There is an emerging demand for autonomous vehicles using LiDAR sensors. LiDAR sensors are a crucial component of autonomous vehicles that are used to generate a 3D map of their environment. This oversees the successful application of LiDAR in averting collisions and many examples of autonomous navigation.
- There is an increased demand for LiDAR that can be applied to a variety of applications in 3D mappings, like construction and mining.
- There is also a growing demand for other applications of LiDAR, such as security, surveillance, and environmental monitoring.
- Ease of access to LiDAR systems at lower costs is going to be a critical factor in the application of LiDAR, as these systems have been expensive until recent times. Affordability opens doors for many more applications which haven't been financially viable until recently.
- The development of new LiDAR technologies, such as solid-state LiDAR and MEMS LiDAR, will also have a significant impact on the advancement of the technology. LiDAR systems of the future will be able to offer lower costs, higher resolution, and a longer range.
- The evolving government regulations are in support of the application of LiDARs, with several governments around the world making it mandatory for vehicles to use LiDAR systems. This is only one of the reasons for the increasing popularity of LiDAR in the automobile industry.

The Market for LiDAR

The LiDAR market can be better analyzed upon its classification into different segments based on technologies, product types, and functional areas. The technology segment is further segmented into 2D and 3D. Similarly, the product segment is divided into terrestrial LiDAR, airborne LiDAR, and others.

A report by Market Research Future (MRFR) presenting forecasts till 2030 makes projections that the LiDAR market will grow at a rate of 22.10% between 2022 and 2030. By 2030, it can be expected to reach USD 5.82 billion. As many factors come together to push things forward, here are key projections expected to unfold during the rest of the decade.

- The key contributors to the growth of the market are suggested to be based on the increasing adoption of LiDAR systems in UAVs and geographical information system (GIS) applications.
- According to the projections, the airborne LiDAR segment and automotive LiDAR segments will be the largest segments of the market for this period.
- According to the forecast, the solid-state LiDAR segment will be the fastest-growing segment of the market.
- The forecast shows that North America will be the largest market for LiDAR.
  Other emerging applications set to grow during the forecast period are navigation, construction, environmental planning, and architecture.

2D vs 3D LiDAR

- 2D LiDAR operates at a fundamental level by emitting a singular laser beam, measuring the times it takes to return, and calculating the distance. Using 2D LiDAR, it is possible to create a 2-dimensional map of an environment.
- 3D LiDAR operates similarly, but by emitting multiple laser beams and measuring the time taken for each of them to return, thus allowing 3D LiDAR to produce a 3-dimensional map.
- 2D LiDAR is lower in cost and is simpler to design. It is also affected less by the weather conditions comparatively. It is suitable for use in robotics, surveying, and mapping.
- 3D LiDAR, on the other hand, is better in accuracy and detailing. It can detect objects and their orientation in the environment. It finds usage in self-driving cars, 3D scanning, and robotics.

Product Type Segment

Airborne LiDAR:
- Airborne LiDAR is the application of LiDAR technology in the aeronautics and aerospace sectors.
- It enables aircraft to measure the distance and map the ground surface.
- A similar application to mapping topography is bathymetric, i.e., measuring the depth of the water body.

Terrestrial LiDAR:
- Terrestrial LiDAR works from the ground surface, where it is installed on vehicles or tripods.
- It can scan objects in a given space to collect data points or point clouds.
- It uses a static LiDAR that scans objects from a fixed location and a mobile LiDAR for collecting data where mobility is needed.

Mobile LiDAR Sensors:
- Mechanical LiDAR, as described above, can physically turn a laser or mirror to collect data from a wide area. It can be mechanical or solid-state in form.
- Solid-state LiDAR sensors use semiconductor technology instead of gears and motors for steering the laser.

Technology Trends for LiDAR Solutions
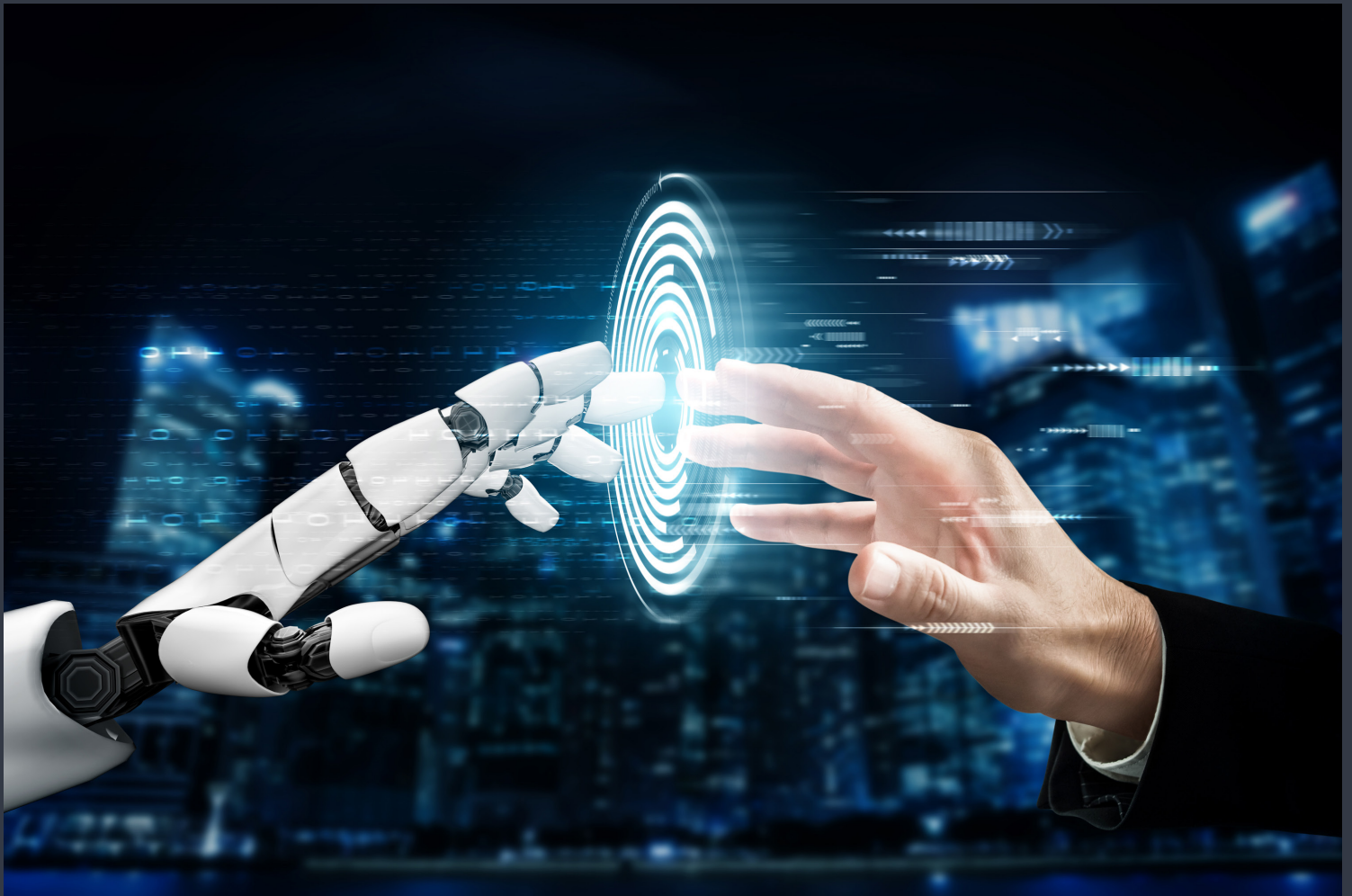
As the race toward LiDAR adoption is picking up, many technological trends are taking shape due to the research, development, and application of this technology. This includes developing solid-state LiDAR technology, LiDAR miniaturization, and spectrum scan LiDAR.

Let us try to understand these trends one by one.

Adoption of LiDAR systems in UAVs

UAVs can be attached with LiDAR sensors for various applications, including mapping, surveying, and inspection. Drones equipped with LiDAR generate data with high accuracy and detail, making them suitable for use in construction, agriculture, and mining.

With further developments, the cost of assembling a LiDAR system can be expected to drop, leading to the large-scale adoption of LiDAR with many innovative applications.

LiDAR in GIS applications

LiDAR data can be used to create high-resolution and detailed maps of Earth's terrain. These maps can serve several objectives, such as ground mapping, urban planning, and environmental monitoring.

Drones will be instrumental in geospatial applications owing to their speed and accuracy. The growing demand for geospatial data in the planning, construction, and gaming industries will further drive the need for LiDAR.

Solid-state LiDAR

Solid-state LiDAR technology is garnering traction by eliminating the need for complex scanning mechanisms and moving parts. The use of 3D mapping with a multitude of laser beams makes it easier to scan objects.

Vertical-cavity surface-emitting lasers (VCSELs) use low power and can be used as laser sources in solid-state LiDAR, making them reliable and durable. Moreover, solid-state LiDAR can be coupled with artificial intelligence algorithms with multiple modules for wider coverage to serve objectives like counting the number of people in crowded areas.

Thanks to their high resolution and precision, solid-state LiDARs are viable alternatives to today's scanning mechanisms.

Miniaturization of LiDAR

The automotive LiDAR industry is exploring the use of Frequency Modulated Continuous Wave (FMCW) technology. FMCW is a continuous-wave operation that can lead to the creation of smaller LiDAR systems while improving upon the performance of a pulsed LiDAR.

Silicon (Si) photonics is a key technology for miniaturizing LiDAR. Ceramic packaging also has added advantages like thermal management and low inductance levels, which could be crucial in the adoption of FMCW LiDAR in automobiles.

Ceramic packaging technology can potentially miniaturize LiDAR modules and lower their costs.

Spectrum-Scan LiDAR

Spectrum-Scan LiDAR takes a unique approach to scanning with the help of the refraction of light through an optical prism. As opposed to mechanical LiDAR systems, Spectrum-Scan LiDAR has a higher range and better precision. It uses random-modulation continuous wave signal processing.

The system works by passing a tunable wavelength laser through the prism to create high-resolution scan patterns, eliminating the need for moving parts. This system is capable of scanning hundreds of lines of photos more than 1 million times per second. The sensor here is less susceptible to environmental interference and scans an area with higher density.

Major Applications of LiDAR

Autonomous vehicles

LiDAR is an essential component in autonomous vehicles. Autonomous vehicles use LiDAR to map their surroundings in 3D to navigate and avoid obstacles such as buildings, roads, and other vehicles. This information can be combined with data to detect road signs, traffic signals, and road markings to give a real-time hazard analysis and maintain safe distances.

It enables the vehicle to "see" with a 360-degree view. It is currently being used in Advanced Driver Assistance Systems to automatically control speed, braking, and safety systems. It will be crucial in the development of autonomous vehicles.

Agriculture

LiDAR drones make it easy for operators to map out the terrain, leading to their application in the agricultural industry. Drones equipped with LiDAR sensors can monitor cattle herds with the scans of a grazing area and trigger an alarm system if the animals cross the limits of their grazing area. With LiDAR, farmers can ensure the safety of their cattle even in the dark.

Thanks to the accuracy of LiDAR, farmers can use it to carry out precision farming methods with crop monitoring and generate better yields. It can even capture the soil condition, crop height, mass, and volume to estimate the amount of fertilizers needed to generate maximum yield.

Survey and mapping

LiDAR scans can create high-resolution maps of the Earth's surface, which can be applied to a myriad of purposes like land surveying, urban planning, and environmental monitoring. LiDAR drones are also capable of creating 3D models of objects and environments. Thus fields related to surveying and mapping, such as architectural visualization and historical preservation, can benefit by using LiDAR sensors combined with other data.

Renewable energy

LiDAR also finds usage in inspecting solar panels and wind turbines for defects and malfunction. By identifying the problems in these structures early on, businesses can take preventive steps to avoid power outages and make renewable energy production more efficient.

Robotics

LiDAR applications in the field of robotics include creating 3D maps of the environment for the robots to use to navigate and interact with objects, much similar to their applications in autonomous vehicles. Robots need robust hardware and sensors to navigate their way through complex outdoor environments like mines or ports.

In addition to 3D LiDARs, most robotic applications employ 2D LiDAR sensors, such as Autonomous Mobile Robots (AMRs) and Automated Guided Vehicles (AGVs). These devices typically find applications in warehouses to pick and place packages and in industrial plants to carry raw materials between assembly stations.

With LiDAR, it is also possible to detect unsuitable weather and extreme temperatures to maintain the robot's reliability and ensure that the operations aren't adversely affected.

However, the level of accuracy largely depends on the LiDAR sensor chosen to perform the mission-critical operations flawlessly. These sensors also reduce the chances and impact of damages through obstacle detection, avoiding disruption to ongoing processes

Inspection and maintenance

LiDAR-based 3D mapping can assist in the inspection of infrastructure, such as bridges, pipelines, and power lines. Preemptive use of data generated by the LiDAR system can indicate signs of damage, thus preventing accidents and outages.

For instance, a drone fitted with LiDAR can show live data about a structure. More specifically, LiDAR drones ensure safety at construction sites by performing structural inspections aerially.

LiDAR sensors also have a large field of view (FoV) with accurate distance-measuring capabilities. This spatial data can be used in obstacle detection, enabling workers to perform building surveys safely. Further, inspectors can conduct the entire operation of aerial inspection from a safe point on the ground.

Another possible use case is to equip LiDAR drones with thermal imaging capabilities for identifying hotspots in the structure. This early detection helps in taking preventive measures to avoid structural failure. These drones also find usage in the inspection and maintenance of industrial facilities and power plants.

LiDAR generates high-resolution data that aids technicians in detecting damage to power lines, turbines, and pipelines quickly and efficiently. This not only reduces the hazard but also leads to substantial savings in time and inspection costs.

LiDAR-enabled maintenance can save millions by indicating the chances of sudden breakdowns and accidents and allowing the application of preventive measures.

Search and rescue

The data generated by the LiDAR-equipped drone provides us with a 2D/3D mapping of an area, which can be helpful in the event of a disaster or accident to search for missing persons or objects. Thus LiDAR is an effective tool in carrying out search and rescue operations.

Once the drone locates the individual or object, the LiDAR mapping can help guide the rescue teams through the best routes to rescue the person safely. Its use at night can be instrumental as it does not rely on light for searching. It can also work in all kinds of weather conditions with a suitable design.

LiDAR-integrated drones can also conduct search and rescue operations underwater using Bathymetric LiDAR sensors that map the depth of water bodies and measure the distances. This operation is carried out by the combined use of a low-frequency infrared pulse that reflects from the surface of the water body and a high-frequency infrared pulse that can penetrate the water surface and reflect from the ocean bed, thus giving a measure of its depth.

Law enforcement

Drones find extensive use in security and surveillance. For instance, law enforcement agencies can tactically assess large areas through LiDAR sensor-equipped drones.

Such drones enable officials to capture and monitor crime scenes remotely from a safe distance. This system is particularly useful in dark environments. The recorded data is then reconstructed to establish a timeline of events for presentation as reliable evidence in courts of law.

Another important use case of LiDAR in law enforcement is in containing the damage in the case of armed hostages or mass shootings.

A drone mounted with LiDAR sensors can convey a complete picture of the situation so that law enforcement officials can come prepared with the essential tools and tactics as per the situation and respond effectively.

LiDAR Technology: Advantages and Disadvantages

Advantages

- **Accuracy:** LiDAR technology creates some of the most accurate and consistent results. It can detect and precisely map even small objects, making it ideal for identifying objects in a specific environment.
- **Speed:** LiDAR sensing happens in a matter of nanoseconds. With LiDAR, it is possible to scan large areas in a remarkably short period.
- **Long-range capabilities:** LiDAR systems can capture data over long distances, making them suitable for wide-area scanning and remote sensing applications.
- **Accessibility to environments:** The sensor can scan areas inaccessible to humans, such as high mountains or even ocean beds.
- **All-weather performance:** LiDAR technology can operate effectively in various weather conditions, including rain, fog, and darkness, making it reliable in challenging environments.

Disadvantages

- **Requires experience to operate:** It takes previous surveying experience to take check shots, run base stations, and check in to benchmarks. The LiDAR is complex and requires a deep understanding of the sensor.
- **LiDAR might have difficulties in bad weather conditions:** Heavy rain, fog, or heavy rainfall can hinder the "vision" of some LiDAR sensors, disrupting operations and causing difficulties.
- **Limited color information:** Traditional LiDAR systems typically capture only depth information, lacking the ability to capture color or texture details, although recent advancements have addressed

How to Choose the Right LiDAR Sensor

There are several factors that you need to consider based on the application of the LiDAR sensor. Use the following information to select a suitable sensor that serves the purpose without incurring environmental damage or affecting its accuracy and reliability.

These factors include environmental rating, scanning frequency, range, and accuracy.

Environmental Rating: This rating indicates the sensor's ruggedness and resistance to the elements. LiDARs can be rated for their resistance to water, dust, or other environmental factors.

Frequency: This metric indicates the frequency of the laser emitted. Airborne topographic mapping lidars will typically use 1064 nm lasers, while bathymetric (underwater depth research) systems generally use 532 nm frequency lasers.

Range: The range is the measure of the maximum distance up to which the sensor can scan objects accurately. A longer range is needed depending on the distance from the source to be measured. LiDARs can have ranges starting from a few meters to more than 200 m.

Accuracy: It is the degree of correctness of a sensor's measurements. Higher

The Road Ahead for LiDAR Technology

LiDAR technology is among the most exciting trends and developments in engineering and data science. The increasing demand for LiDAR systems is attributed to various applications in both emerging fields, such as autonomous vehicles, and established ones, such as construction and mining. These applications are pushing the research and development of this technology forward.

LiDAR technology is one of the most promising endeavors, with ongoing research expected to lead to future improvements such as higher resolution, farther range, and better accuracy.

The miniaturization of LiDAR systems, advancements in solid-state LiDAR technology, and the development of spectrum-scan LiDAR are driving further innovation and expanding the potential applications of LiDAR. These advancements in LiDAR are making LiDAR systems more affordable, efficient, and reliable, opening doors to new applications and industries.

The technology trends in LiDAR solutions are also shaping the future of the technology. LiDAR systems integrated with unmanned aerial vehicles (UAVs) are revolutionizing industries such as mapping, surveying, and inspection. The use of LiDAR in geographical information system (GIS) applications is enabling high-resolution mapping and detailed terrain analysis.

LiDAR will continue to be extensively used in various fields, such as autonomous vehicles, agriculture, forestry and land management, surveying and mapping, renewable energy, robotics, inspection and maintenance, search and rescue, and law enforcement.

These applications demonstrate the versatility and effectiveness of LiDAR technology in solving real-world challenges and improving efficiency and safety in diverse industries.

Moreover, with the integration of Artificial Intelligence and Machine Learning, LiDARs in the future will become more efficient and accurate at 3D mapping, object recognition, and scene interpretation.

Yet, with LiDAR becoming more prevalent across industries, ensuring the integrity and privacy of data generated through these sensors will be paramount. As a result, security protocols, encryption, and data authentication will play a key role in keeping LiDAR systems reliable and trustworthy in the future.

The future outlook for LiDAR technology looks promising, equipping machines and humans across various industries with precise and efficient perception capabilities.

LiDAR Solutions from Hokuyo

LiDAR sensors serve as input to various autonomous machines, and they are the core of many industries today. They play an integral role in scanning and modeling objects and environments. Therefore, choosing the highest-quality LiDAR sensors is critical to ensure accuracy in scanning and distance measurement applications.

Hokuyo Automatic USA Corporation is a subsidiary of Hokuyo Automatic Co., Ltd. of Japan, which offers a range of industrial sensors and other products for use in the automation of various industries. We cater to leading OEMs, integrators, R&D firms, and resellers in manufacturing, material handling, autonomous robotics, and the metal industry.

We offer a wide range of sensing products, including collision-avoidance sensors, safety laser scanners, optical data transmission devices, laser rangefinders (LIDAR), and hot metal detectors. At Hokuyo, reliable technology, comprehensive distribution, and exceptional service are our key focus areas.

Our LiDAR sensors are a good choice for all-weather, outdoor applications. These sensors come with a high environmental rating, scanning frequency, long range, and accuracy.

For more information about our LiDAR sensors, **contact us** today.

SOURCES

https://coast.noaa.gov/data/digitalcoast/pdf/lidar-101.pdf

https://www.prnewswire.com/news-releases/lidar-the-key-to-unlocking-the-future-of-autonomous-vehicles-says-idtechex-301830526.html

https://spie.org/news/its-a-3d-world-sensing-a-bright-future-for-lidar-

https://www.laserfocusworld.com/test-measurement/article/14284102/seeing-a-bright-future-for-lidar

https://ai.reportlinker.com/en/resources/blog/market-trends/opportunities-into-the-lidar-technology-and-its-growth-forecasts-to-2027

https://lidarmag.com/2023/06/14/top-geospatial-trends-to-watch-in-2023/

https://enterprise-insights.dji.com/blog/lidar-equipped-uavs

https://www.globenewswire.com/news-release/2023/04/06/2642904/0/en/Global-LiDAR-Market-Size-To-Surpass-USD-4-83-Billion-By-2030-CAGR-of-13-8.html

HOKUYO USA

www.hokuyo-usa.com