LiDAR in Robotics and Autonomous Systems. summary

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Contents

Introduction

3D scene mapping technology is -slowly but surely- becoming part of our day to day life. To this day, there have been numerous practical applications of 3D scene mapping , targeting a wide variety of fields such as:

- Aeronautics
- Medical imaging
- Architecture
- Transportation
- Security

and many more…

3D scene mapping methods

3D scene mapping methods can be divided in two main categories:

- Active 3D scene mapping methods
- Passive 3D scene mapping methods

3D scene mapping methods

Active 3D scene mapping methods

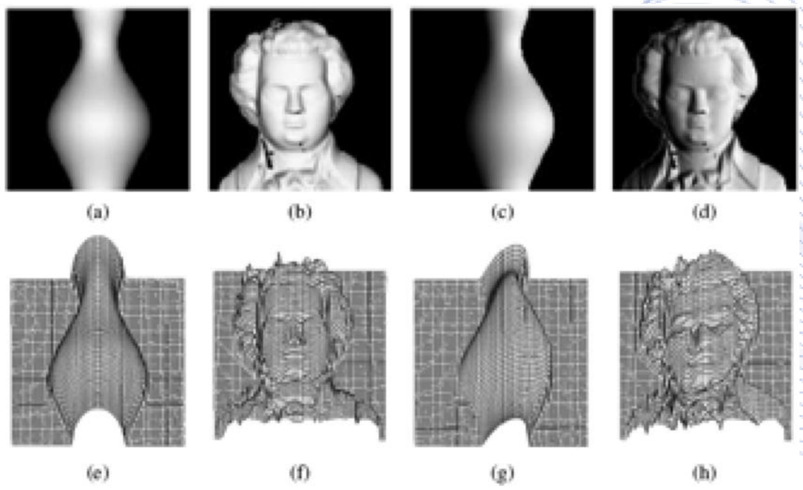
- A 3D scene is illuminated by a laser beam.
- By measuring the visual echo of the laser beam, we can obtain a number of images, describing the 3D scene or object.

Scene Illumination from iPhone LiDAR [VEN].

3D scene mapping methods

Passive 3D scene mapping methods

- Passive methods acquire depth map information out of an object, without user active involvement, e.g., for object illumination.
- In comparison to active methods, passive methods can be applied to a wider range of situations.



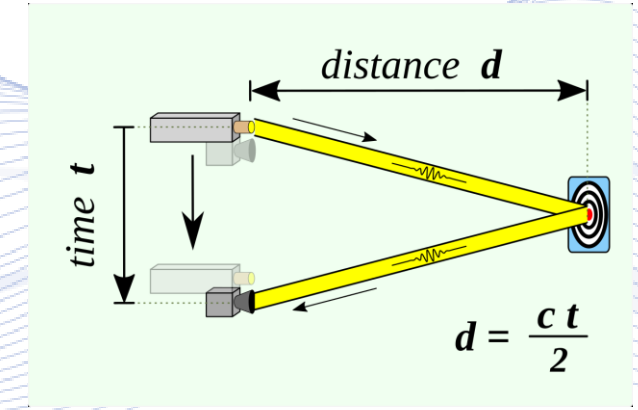
Shape from shading [RES].

Contents

The Time-of-Flight principle

Time-of-Flight (ToF)

- In this technology, a light beam emanates from a laser source. Time-of-Flight uses the time difference between the transmission of a pulse and the corresponding reception of an echo, to provide an accurate estimation of the range (distance traveled).



ToF applied to laser range-finding [EUR].

The Time-of-Flight principle

Time-of-Flight Cameras (ToF Cameras)

- ToF cameras, using an artificial LED light signal, are able to provide range images in high frame rates and resolutions. They have become quite popular, inexpensive and more compact.
- A disadvantage, is that they cannot yet attain the depth accuracy offered by other types of sensors, such as laser scanners.

Industrial Helios2 Time-of-Flight Camera [THI].

Contents

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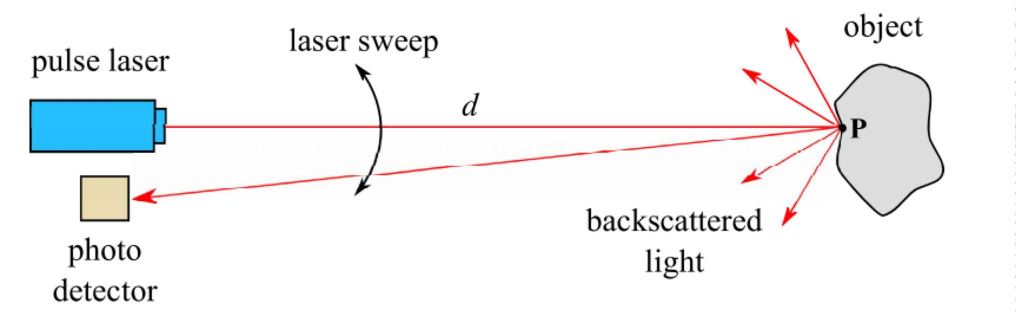
The Time-of-Flight principle

In general, systems based on time delay ToF methods are extensively used for measuring extremely small $(in\ the\ scale\ of\ 0\ to\ 10\ mm)$ or large $(10\ m)$ field of view, thus there are no significant applications of these methods for intermediate distance ranges.



Pulsed-wave ToF method [PIT2020].

Contents

The Time-of-Flight principle

Continuous-wave propagation

Methods using continuous wave-based sensors can be classified into two, light modulation categories of waves:

- Amplitude Modulation (**AM**)
- Frequency Modulation (**FM**)

Continuous-wave propagation

***Amplitude modulation* (*AM*)**

In the AM phase-shift method, range information is determined by applying amplitude modulation and measuring the phase shift between the emitting and the received light beams.

- Emitted signal is described by the sinusoid:

$$s(t) = \sin(2\pi f_m t).$$

- f_m: modulation frequency.

- The signal is reflected back to the sensor, with a phase shift φ:

$$r(t) = R\sin(2\pi f_m t - \varphi),$$

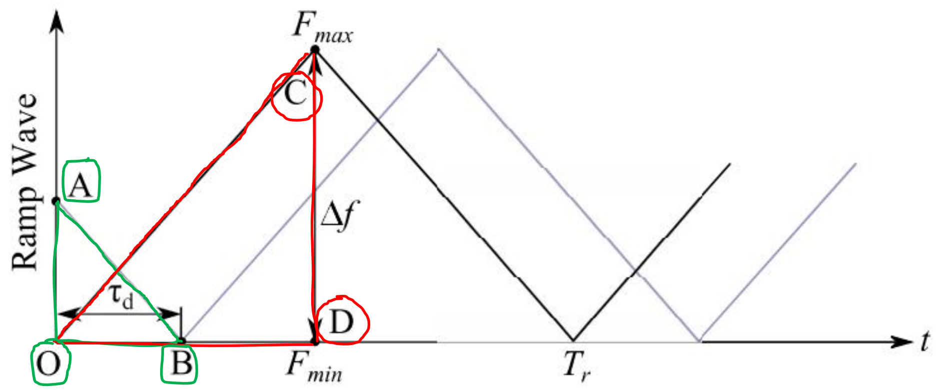
- R: reflected light intensity

Continuous-wave propagation

- By comparing the similar triangles OAB and OCD, we find:

$$\frac{f_B}{\tau_d} = \frac{\Delta f}{\frac{T_r}{2}} \qquad (1.3)$$

- f_B: the beat frequency
- $\Delta f = F_{max} - F_{min}$
- T_r: the period of the wave.



Ramp wave modulating frequency and resultant beat frequency [PIT2020].

Contents

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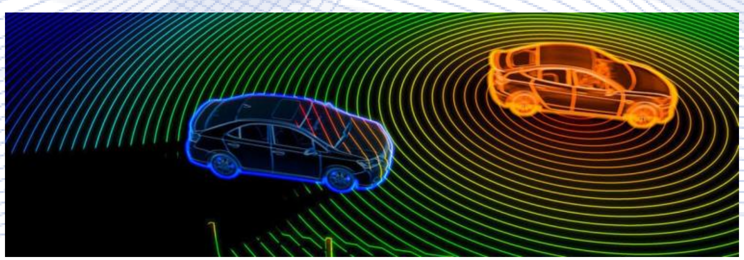
LiDAR

Light **D**etection **A**nd **R**anging

LiDAR is a remote detection and ranging method that that utilizes *lasers,* and emits *infrared light pulses to* measure how long they take to come back after hitting nearby objects.

- The time between the output *laser pulse* and the reflected pulse allows the LiDAR sensor to calculate the distance to each object precisely, based on the speed of light.

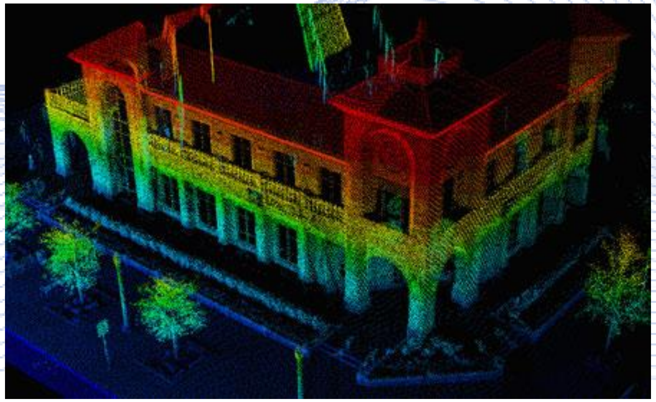


LiDAR's potential integration into vehicles [MES].

LiDAR

Light Detection And Ranging

- LiDAR captures millions of such precise distance measurement points each second, from which a 3D matrix of its environment can be produced.
- Information on objects' position, shape, and behavior can be obtained from this comprehensive mapping of the environment.



LiDAR mapping of the top view of a building [SAN].

Contents

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LiDAR in Modern Autonomous Systems

Autonomous Systems

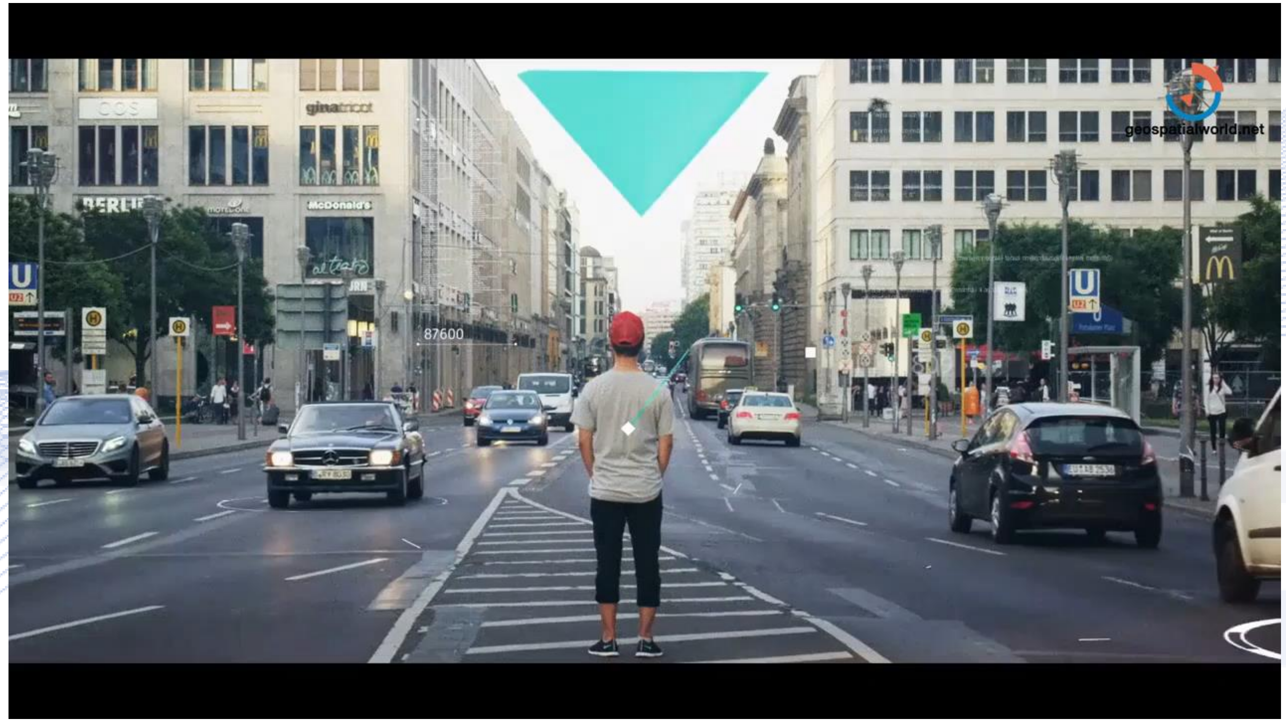
In robotics, an Autonomous System describes a machine that performs behaviors or tasks with *a high degree of autonomy* (without external influence). Autonomous systems are considered a subfield of artificial intelligence, computer vision, and information engineering.

Amazon’s Prime Autonomous Delivery Robot [WIR].

LiDAR in Modern Autonomous Systems

Autonomous Vehicles

LiDAR acts as an eye of the self-driving vehicles. It provides them a 360-degree view of the surrounding that precisely estimates external factors. Continuously rotating LiDAR system sends thousands of laser pulses every second.

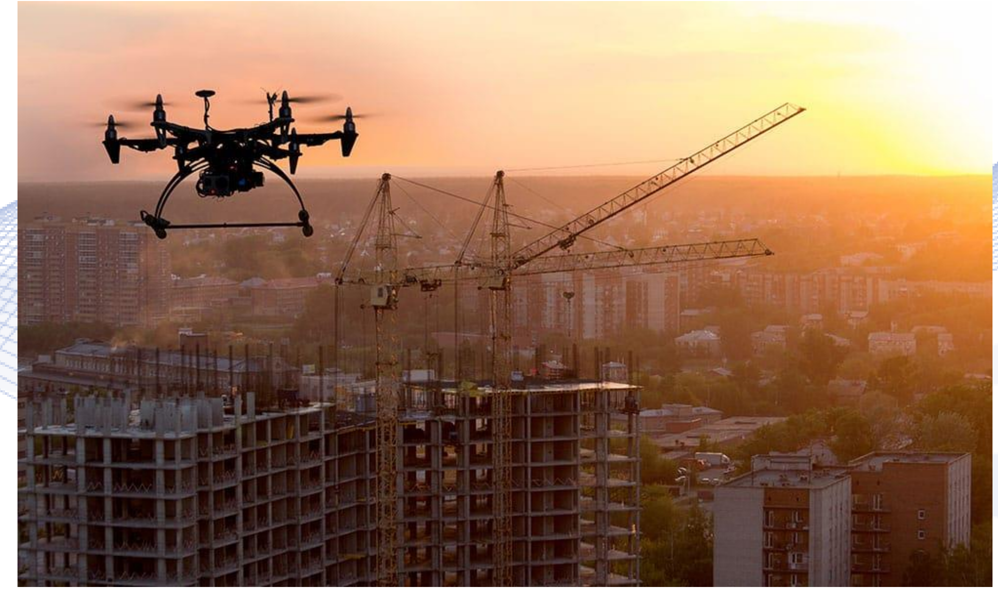


LiDAR in autonomous Vehicles [GEO].

LiDAR in Modern Autonomous Systems

Autonomous Drones in Archeology and Structure Building

Autonomous Drones, using LiDAR technology are able to map an area, analyze structure data, and perform accurate measurements.



3D Infrastructure scanned by Drone’s LiDAR [RED].

LiDAR in Modern Autonomous Systems

Security Solutions

Security applications of the future will be smart, efficient, and automated. LiDAR-based sensors provide centimeter-level distance measurement data to facilitate highly reliable object detection and tracking.

Object Tracking in Airports using LiDAR [VEL].

LiDAR in Modern Autonomous Systems

Security Solutions

Accurate, real-time notification in airports, retail, intersections, both private and public spaces. LiDAR will play a key role in enabling the next generation of security solutions.

Motion Detection using LiDAR [VEL].

Contents

RADAR

Radio **D**etection **A**nd **R**anging

RADAR, Radio Detection and Ranging, uses radio waves to estimate range.

- A RADAR system consists of a transmitter producing electromagnetic waves, a transmitting antenna, a receiving antenna and a receiver that determines the object’s properties.
- Radio waves from the transmitter reflect off the object and return to the receiver, giving information about the object’s location and speed.

Long-range radar antenna, used to track space objects [AUD].

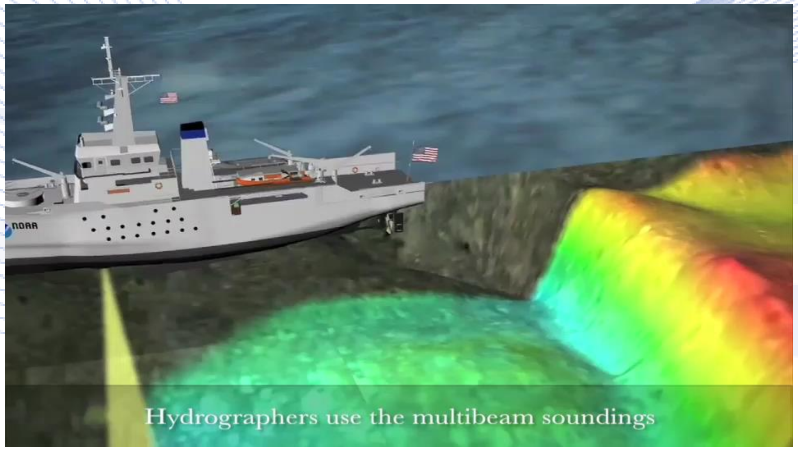
Contents

Sonar

Sound **N**avigation **A**nd **R**anging

Active Sonar

- Active sonar creates a pulse of sound, often called a "ping", and then listens for reflections (echo) of the pulse. By determining the time between the emission of the sound pulse and its reception, the transducer can determine the range and orientation of the object.



Soundscapes of Sonar [OCE].

Contents

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Drone’s HW: LiDAR

LEDDAR M16 LiDAR [LED].

Drone’s HW: LiDAR

LeddarTech LiDAR technology [LED].

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Technical Specifications of Current LiDAR Model

Characteristics	M16-LSR	M16-LED
Wavelength	905 nm	940 nm
Number of segments	16	16
Power supply	12 to 30 V	12 or 24 Vdc (jumper selectable)
Interfaces	USB, RS-485, CAN, UART	USB, RS-485, CAN, UART

System Performance	M16-LSR	M16-LED
Accuracy	±5 cm	
Data refresh rate	Up to 100 Hz	
Distance precision	± 6 mm	
Distance resolution	± 1 cm	
Power consumption	4 W	

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Drone’s HW: LiDAR

Does the team need an upgrade/ alternative?

Drone’s HW: LiDAR

Velodyne’s alternative

Puck

Compact, Powerful, Intelligent

Puck LITE

Specialized Excellence

Puck Hi-Res

Focused Performance

Ultra Puck

Proven, Versatile, Robust

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Conclusion

VML

- Given that the experiment environment, is an area of approximately 35 x 15 square meters, our LiDAR range satisfies to cover that distance.
- The viewing angles may not cover 360 or 180 degrees rotation, but they do cover 100 degrees rotation horizontally.
- Our LEDDAR M16 LiDAR has lesser Power Consumption, and weights significantly less.
- Velodyne’s LiDARs output UDP packets over Ethernet, which is convenient.

Overall, if an upgrade was to be scheduled, it would mainly concern FOV Rotations, both vertical and Horizontal.

Contents

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Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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