Active and Passive 3D Shape Reconstruction Methods summary

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Contents

Concept

- **3D reconstruction** estimates real-world object appearance and 3D shape.
- There are various 3D shape reconstruction applications:
- 3D world modeling, architecture, archeology;
- 3DTV, 3D cinema, games and entertainment;
- scientific imaging
- 3D human activity recognition, kinematic modeling and facial animation.

Classification

Active methods illuminate the scene by using a beam source. Active systems are subdivided based on the type of wave projected: electromagnetic waves and acoustic waves.

Passive methods acquire depth map information out of a still image of an object, taken without active user involvement. Examples of passive systems include shape from shading, focus and texture.

Classification

Active Methods

- ***Electromagnetic waves***
  - Active triangulation
  - Time of Flight(ToF)
- ***Acoustic Waves***
  - Sonar

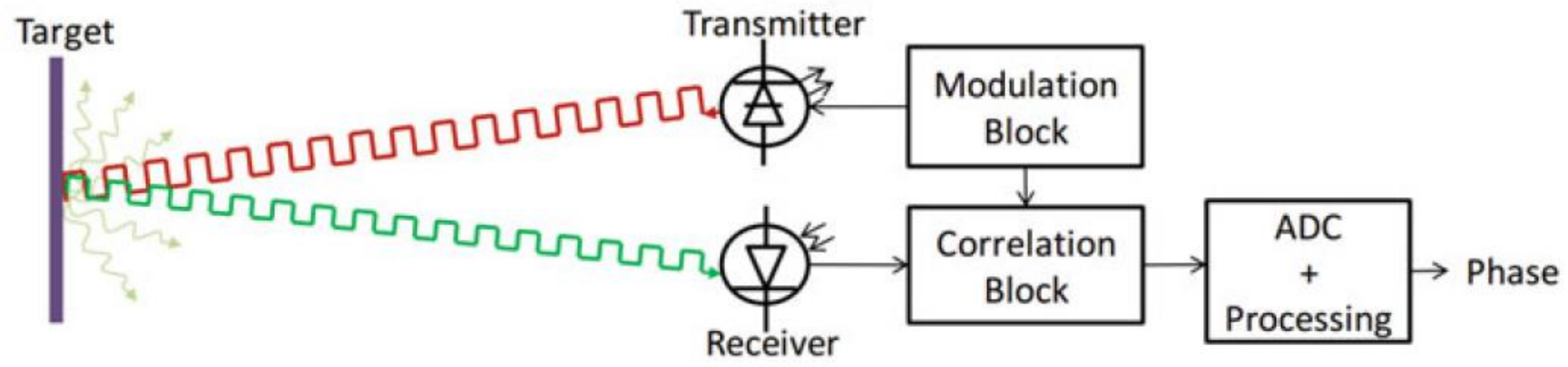
Passive Methods

- Shape from Shading
- Shape from Focus
- Shape from Texture

Time of Flight

- Time-of-Flight techniques are commonly used in measuring distance and uncovering depth information.
- A light beam come from a laser origin and system sensors estimate then the time which is mediated between the light emission and its corresponding echo.
- Calculating the time difference amid emitted light and receipted echo, an exact measurement of the distance can be made multiplying the previous time by the light speed.

Time of Flight



Time-of-Flight procedure (from [ZHA2018])

Time of Flight

Pulsed wave propagation:

Distance (d) information is calculated by estimating the time lapse (Δt) amid the corresponding echo and reception signal emission, as the following type:

$$d = \frac{c\Delta t}{2},$$

- c is the light speed ($c = 3 \times 10^8\ m/s$).

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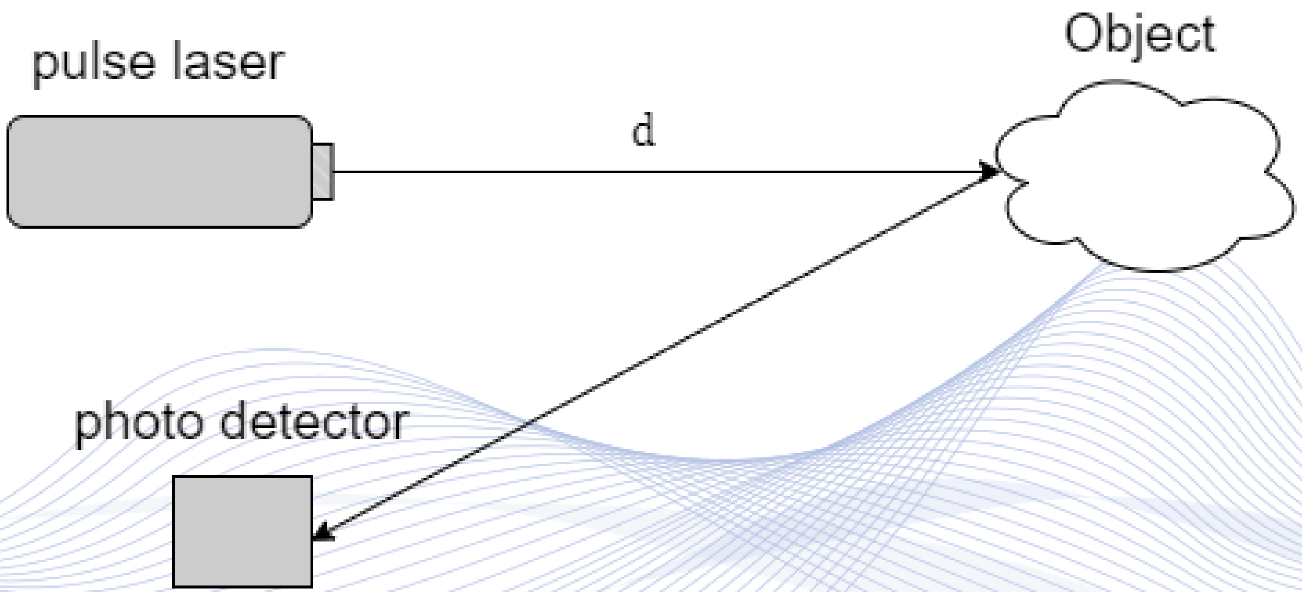
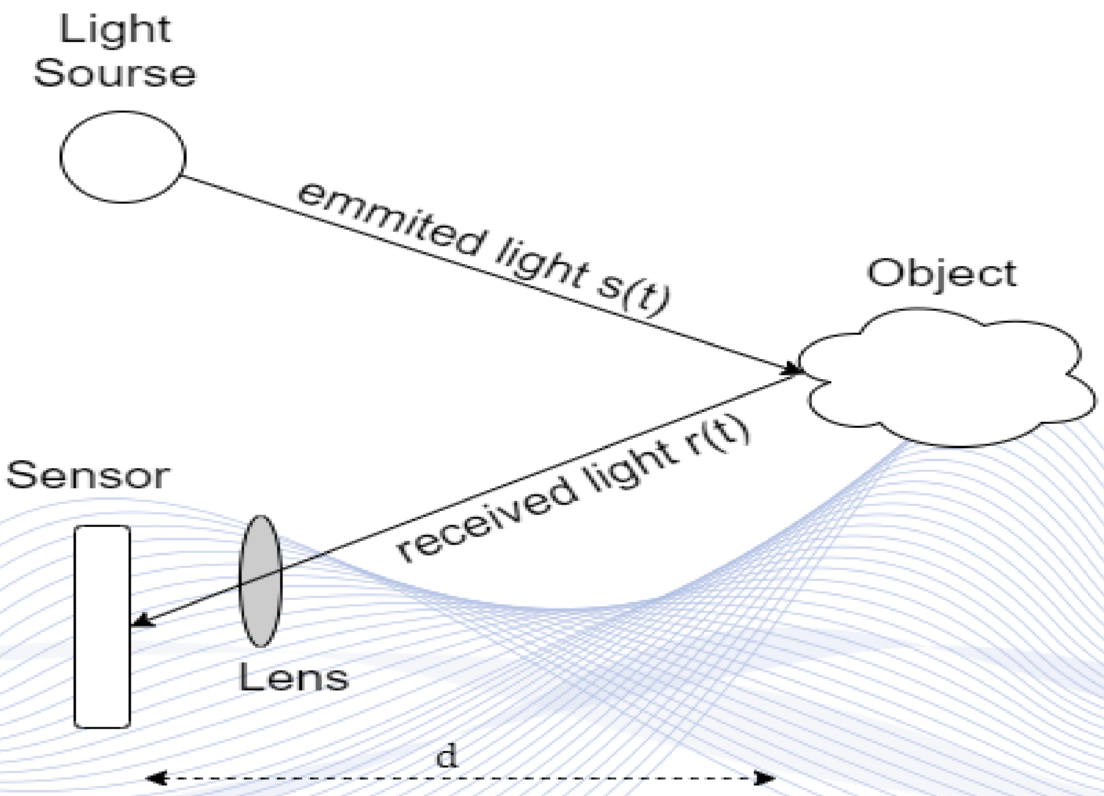
Time of Flight



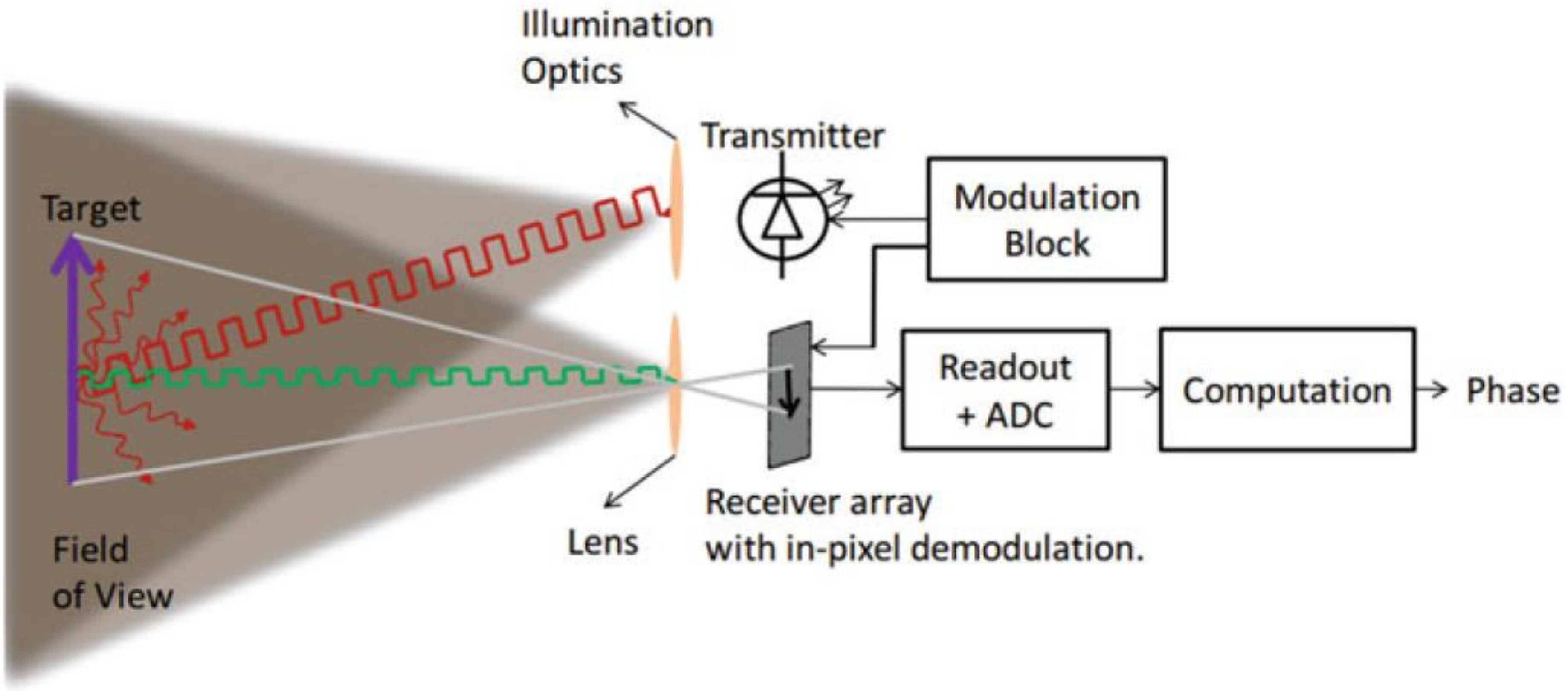
Pulsed-wave ToF method.

Time of Flight



AM phase shift ToF method.

Time of Flight



ToF camera model [GIA2018].

Time of Flight

Device	PMD CamCube 2.0
Technology	Time-of-Flight
Range	0 – 13.0 m
Resolution	200 × 200 pix
Frame Rate	up to 80 fps
Field of View	40° × 40°

Device	PMD CamBoard
Technology	Time-of-Flight
Range	0.1 – 4.0 m
Resolution	224 × 171 pix
Frame Rate	up to 45 fps
Field of View	–

Device	MESA SwissRanger 4000
Technology	Time-of-Flight
Range	0.8 – 8.0 m
Resolution	176 × 144 pix
Frame Rate	30fps
Field of View	69° × 56°

Device	SoftKinetic DS325
Technology	Time-of-Flight
Range	0.15 – 1 m
Resolution	320 × 240 pix
Frame Rate	60 fps
Field of View	74° × 58°

State-of-the-Art ToF Devices [GIA2018].

Time of Flight

Point cloud (right) acquired from the depth map (left) [GIA2018].

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Combining ToF and RGB sensor data

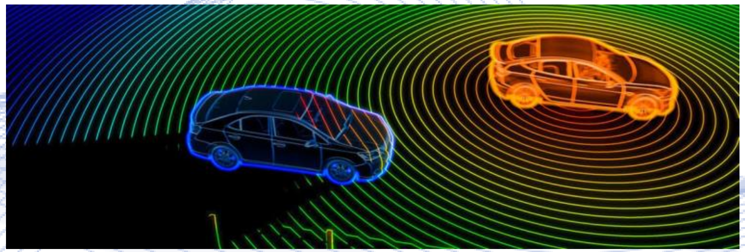
Experiment on how depth estimation is influenced by color (left) Depth Frame, (right) Colored Depth Frame [GIA2018].

LiDAR

Light Detection And Ranging (***LiDAR***) is a distant detection and ranging technique that uses ***lasers.***

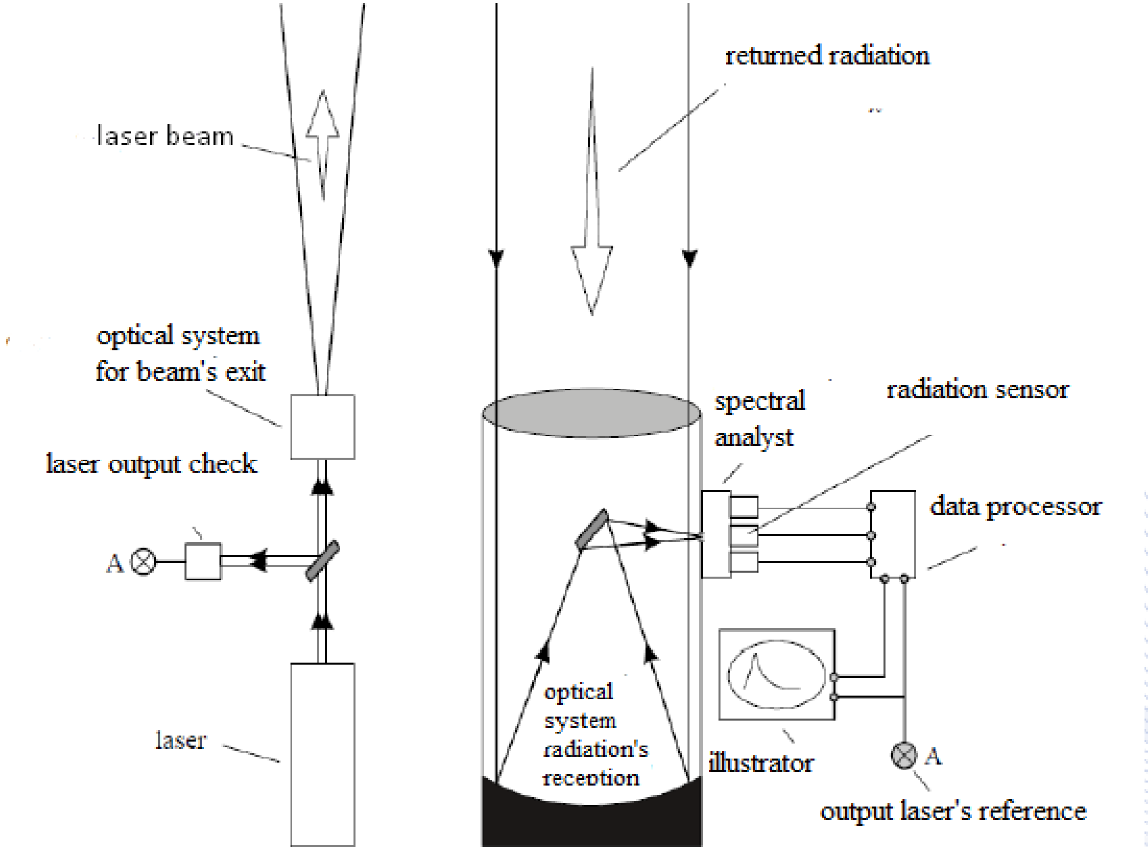
- It sends out ***infrared light pulses*** *to* calculate how long they take to return after hitting close objects.

The Time-of-Flight allows distance measurement.



LiDAR potential integration into vehicles [MES-LSC].

LiDAR



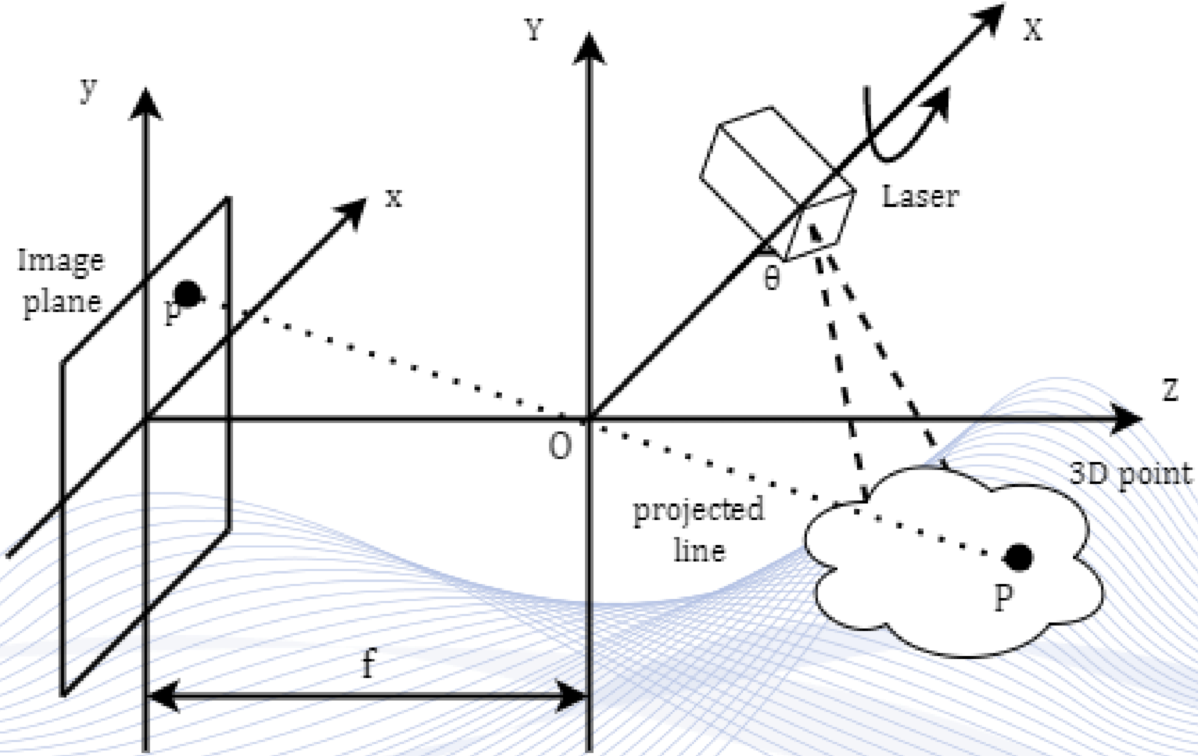
Lidar system architecture.

Active triangulation

Active triangulation methods calculate depth by utilizing the triangle formed by a 3D object surface point and two devices, a laser scanner and a camera.

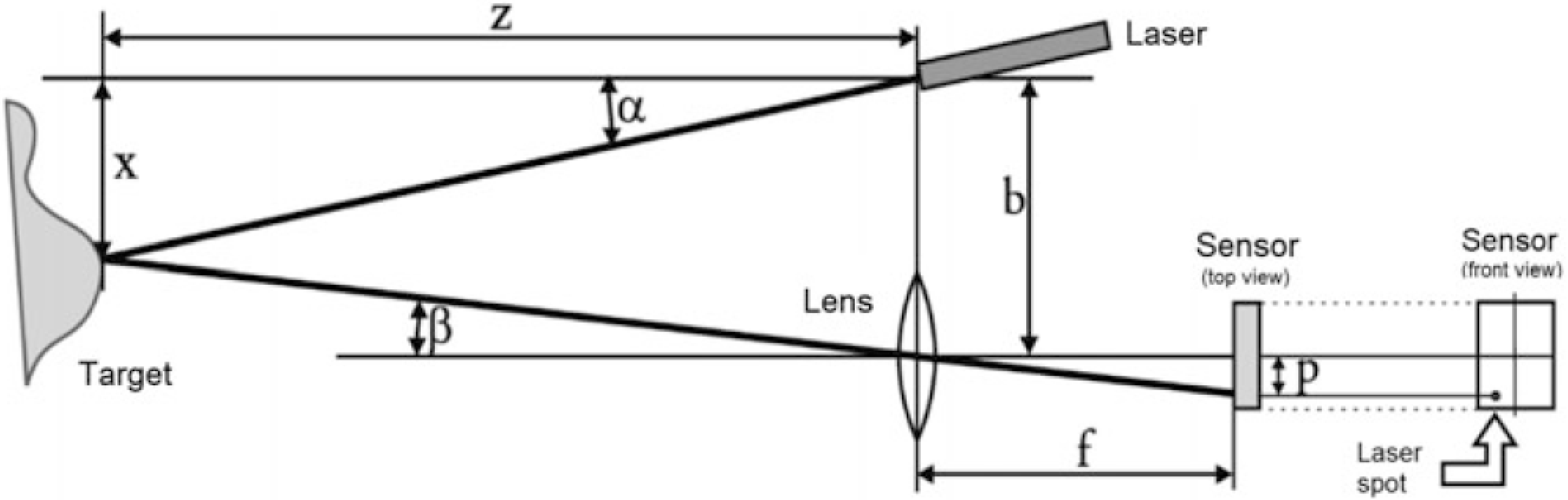
- RGB-D sensors as the Asus Xction, Microsoft Kinect and the Orbbec Astra utilize the ***structured light*** technology.

Active triangulation



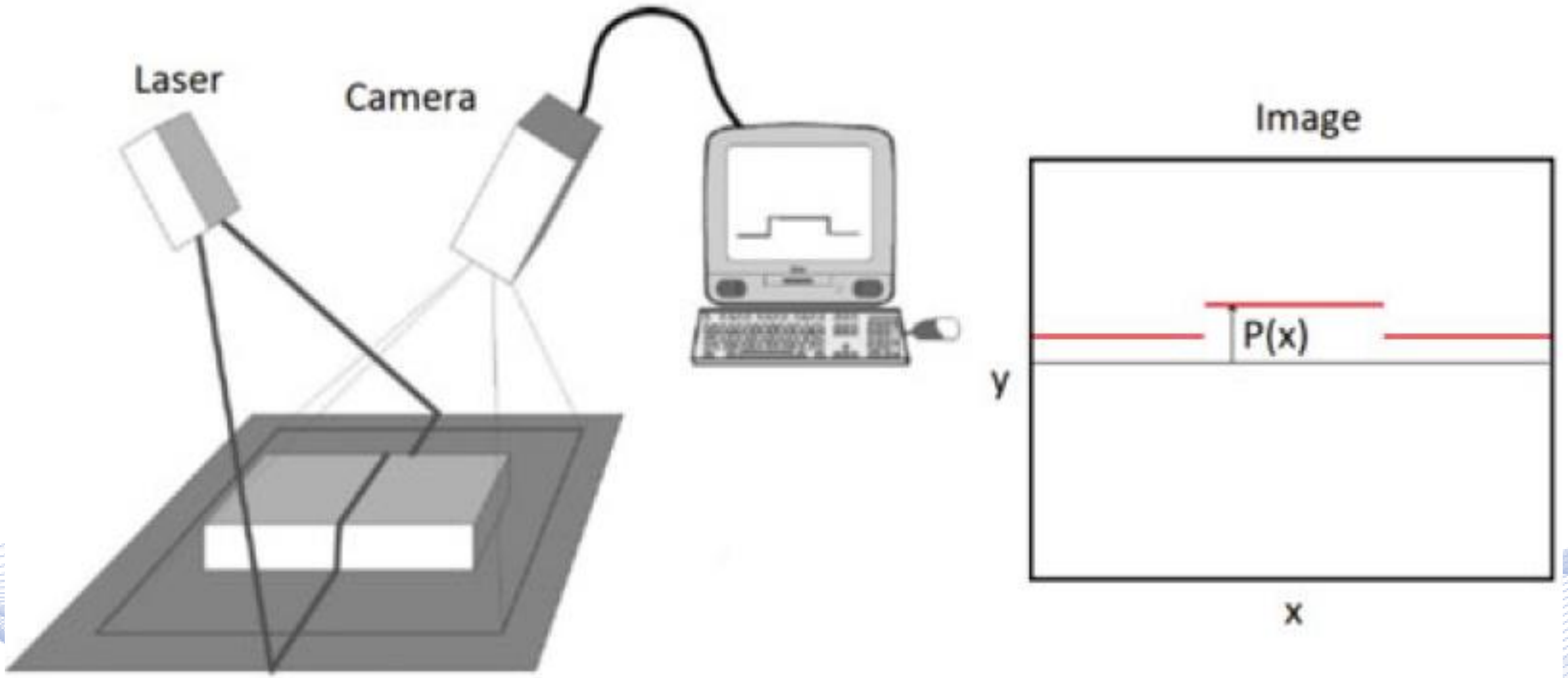
Laser scanner geometry.

Active triangulation



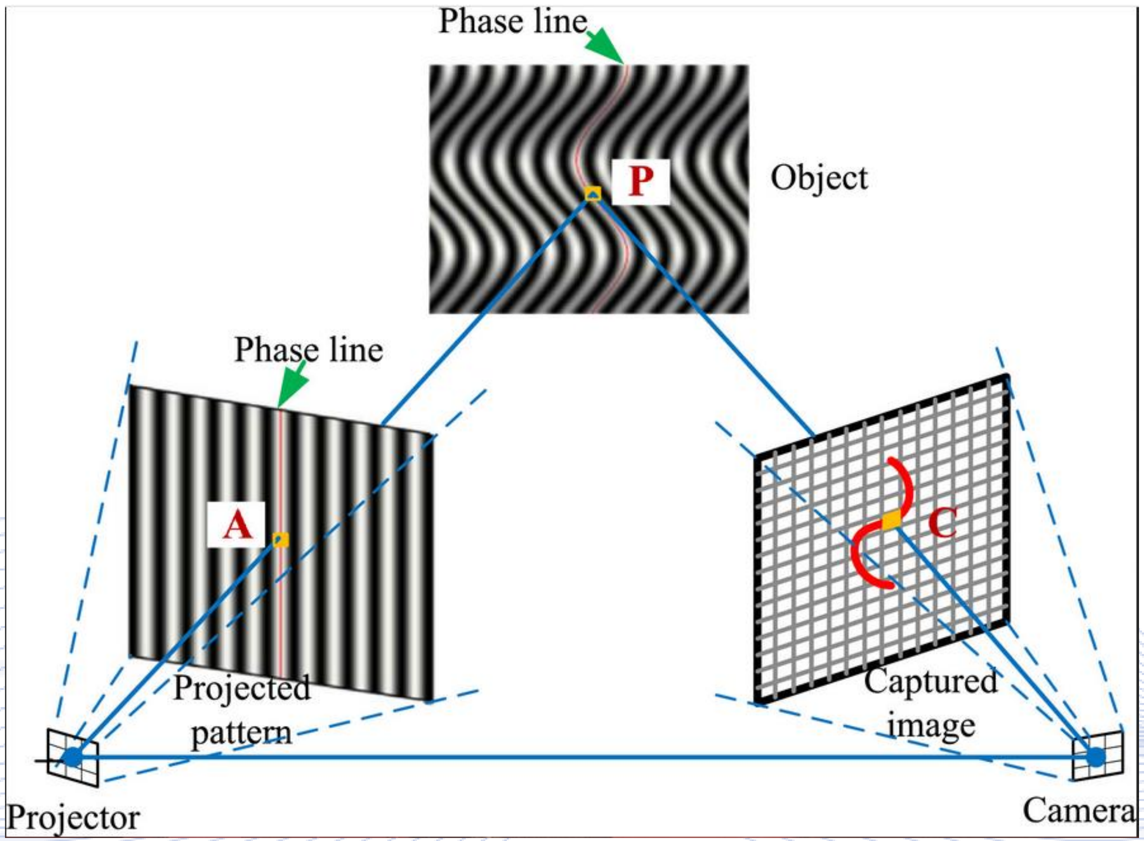
Triangulation method using a single laser spot [GIA2018].

Active triangulation



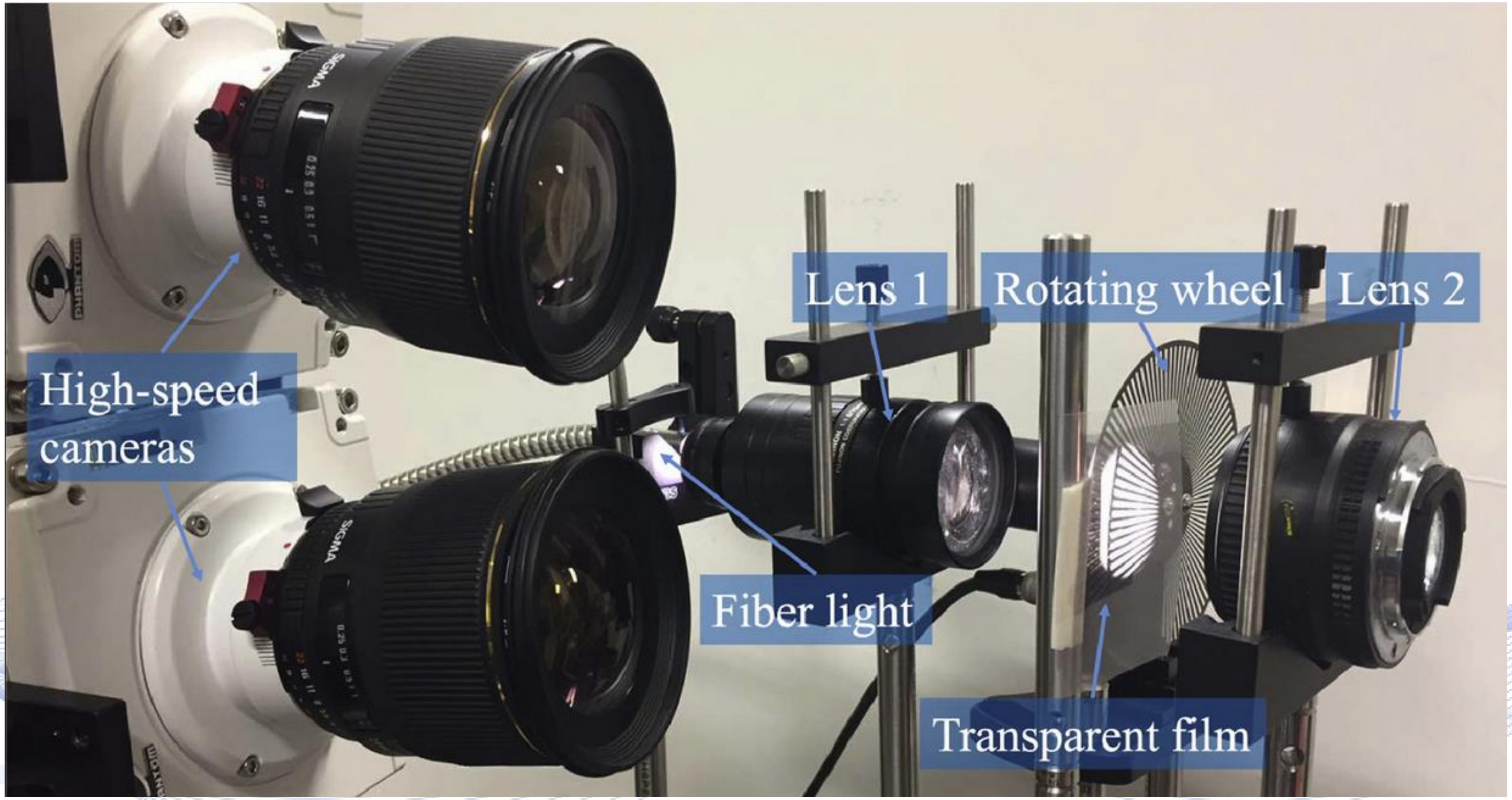
Triangulation based method using a laser blade. (from[GIA2018])

Active triangulation



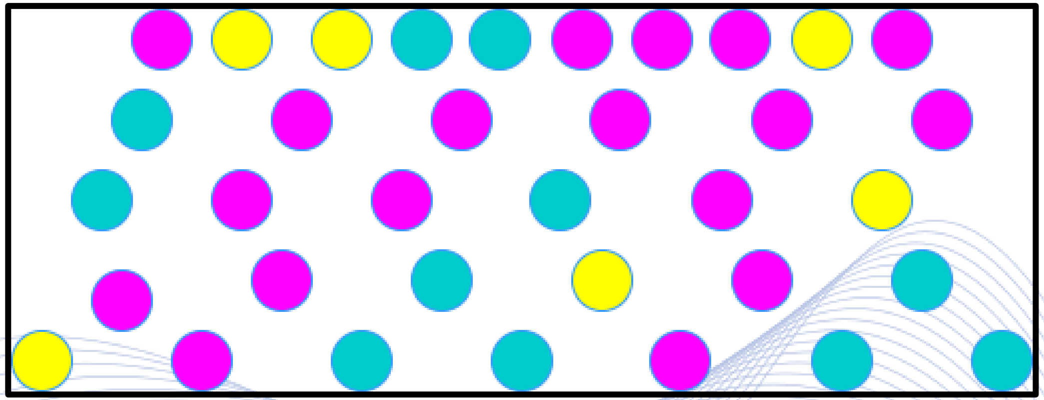
Structured light technology [ZHA2018].

Active triangulation



Structured light system [ZHA2018].

Active triangulation



M-array pattern consisting of color dot symbols.

Active triangulation

Reconstructed 3D geometry (left) of a 3D face (right), using structured light and triangulation (left) [ZHA2018].

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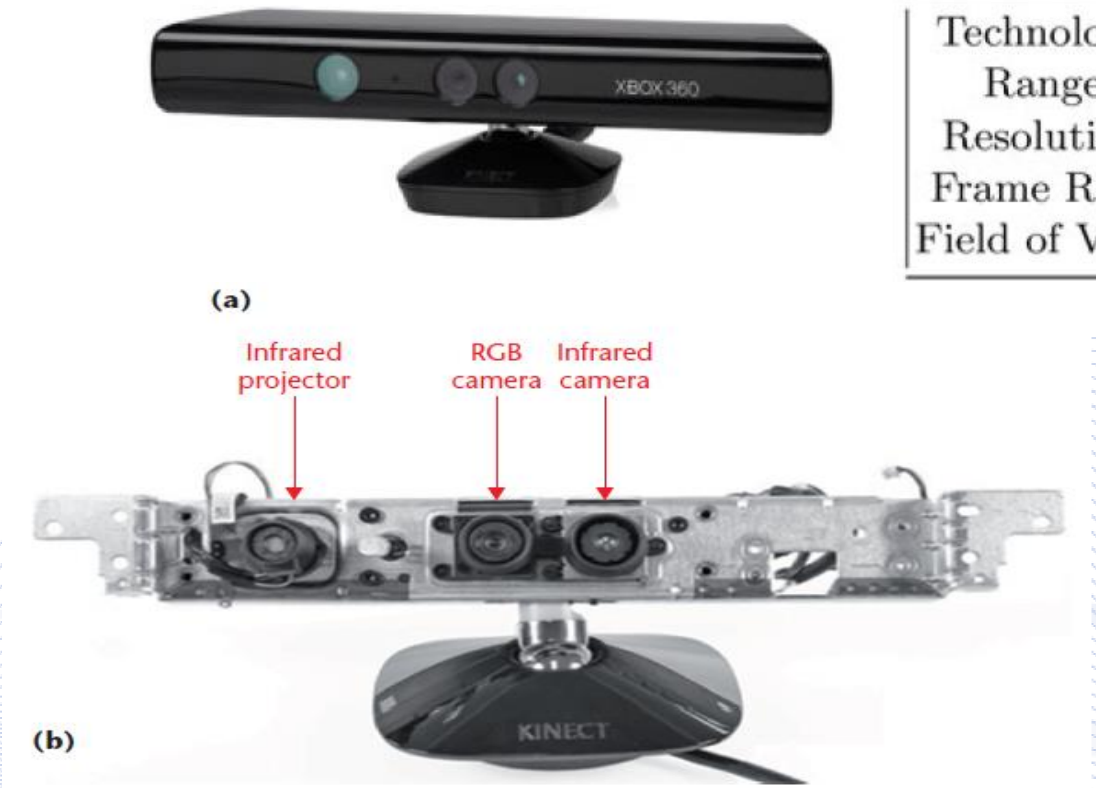
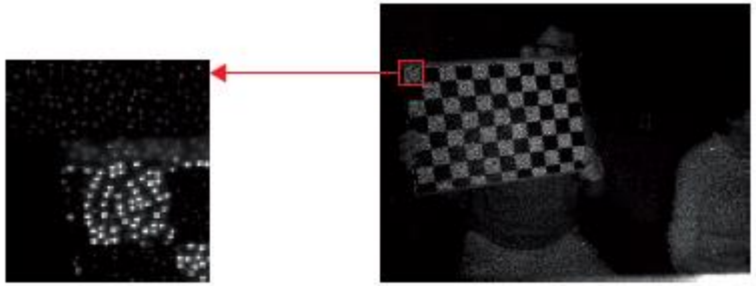
Microsoft Kinect

Device	Kinect V1
Technology	Structured-Light
Range	0.8 – 4.0 m
Resolution	640×480 pix
Frame Rate	30 fps
Field of View	$57^\circ \times 43^\circ$



a) Kinect sensor; b) Kinect components [ZEN2012].

Microsoft Kinect



IR dots captured by the IR camera (right). Close-up of the red boxed area dot picture (left) [ZEN2012].

Depth image using Kinect sensor [ZEN2012].

Orbbec

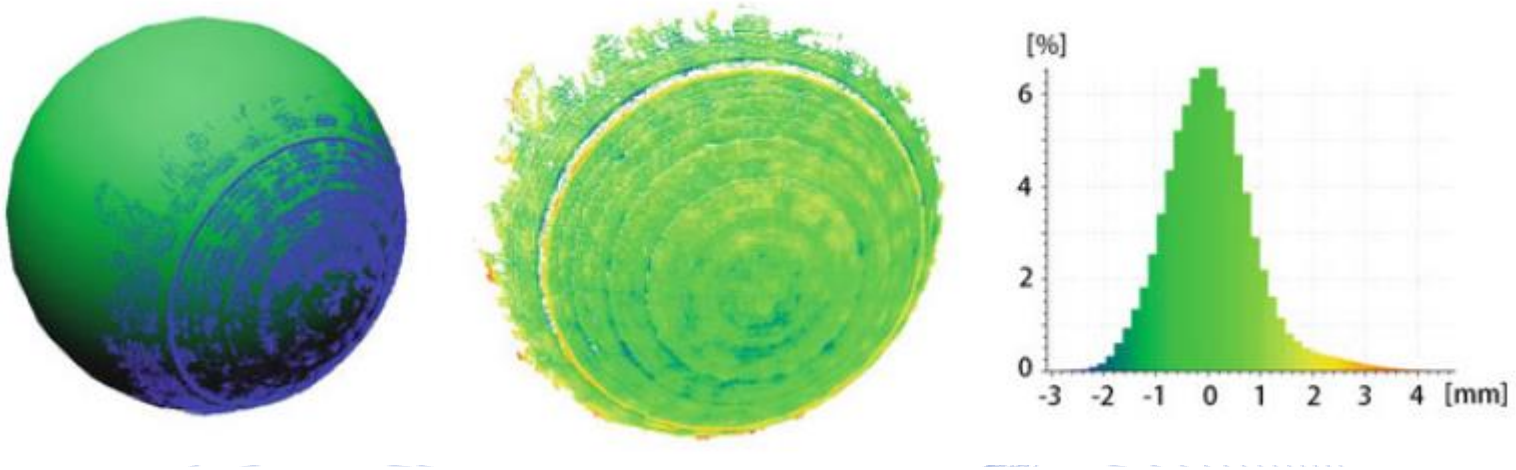
Device	Orbbec Astra S
Technology	Structured-Light
Range	0.4 – 2.0 m
Resolution	640 × 480 pix
Frame Rate	30 fps
Field of View	60° × 49.5°

Orbbec Astra S [GIA2018].

Parameter		IR camera Nominal	IR camera Estimated	RGB camera Nominal	RGB camera Estimated
Focal length	f	2.98 mm	3.04 mm	1.98 mm	1.96 mm
Optical center X	c_x	320 pixel	313.3 pixel	320 pixel	316.3 pixel
Optical center Y	c_y	240 pixel	241.3 pixel	240 pixel	238.3 pixel
Translation X	t_x	–	–	−25 mm	−25.48 mm
Translation Y	t_y	–	–	0 mm	−0.43 mm
Translation Z	t_z	–	–	0 mm	−0.64 mm
Rotation X	r_x	–	–	0°	−0.8°
Rotation Y	r_y	–	–	0°	0.4°
Rotation Z	r_z	–	–	0°	−0.1°

Orbbec Astra S camera intrinsic parameters [GIA2018].

Orbbec



(a) (b) (c)

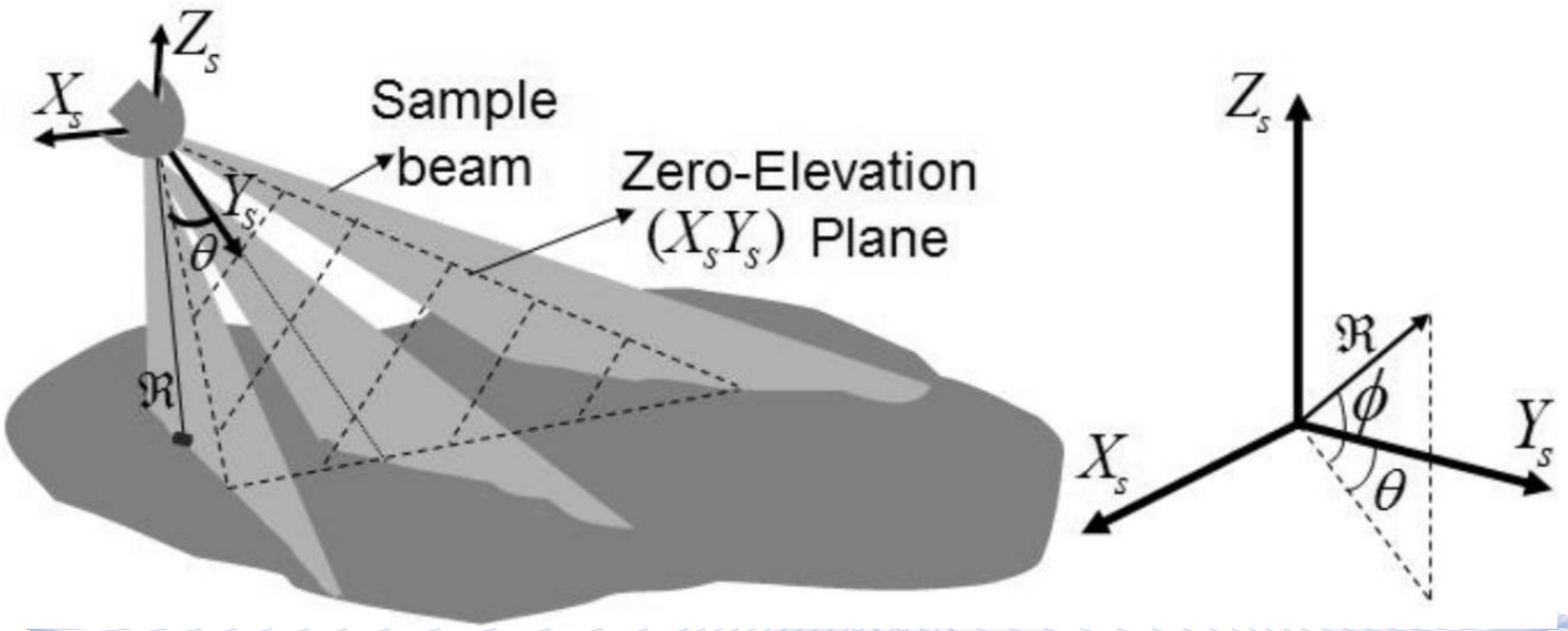
Reconstruction of a 3D ball, using an Orbbec Astra STM device: a) Best fitting sphere; b) Point-to-model distances; c) Sphere distance histogram [GIA2018].

SONAR

- Laser-based ranging sensors and imaging sensors are inappropriate in ***underwater 3D scene reconstructions***.
- ***Acoustic waves*** travel long distances without losing considerable power.

- ***Sound Navigation And Ranging*** (***Sonar***) are acoustic sensors and can produce underwater mapping.

SONAR

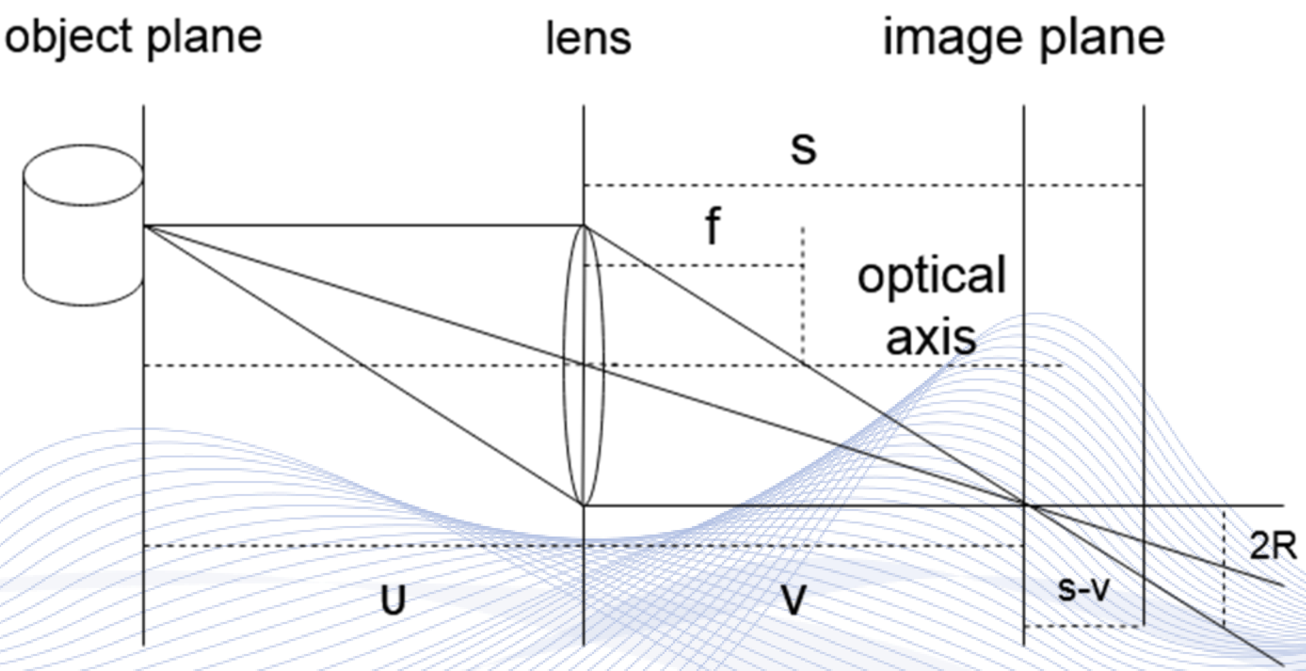


3D sonar geometry (left), where the 3D scene is represented in the zero-elevation plane (X_s, Y_s); 3D sonar coordinate system (right) [ALD2020].

Shape from Focus

- ***Shape from Focus*** uses a variety of two-dimensional pictures with alternative levels of focus for calculating tree-dimensional object information.
- Depth estimation of the object with an unidentified surface is acquired by the best focused frame for every object point with practicing a focus measure.

Shape from Focus



Formation of image in optical lens.

Shape from Focus

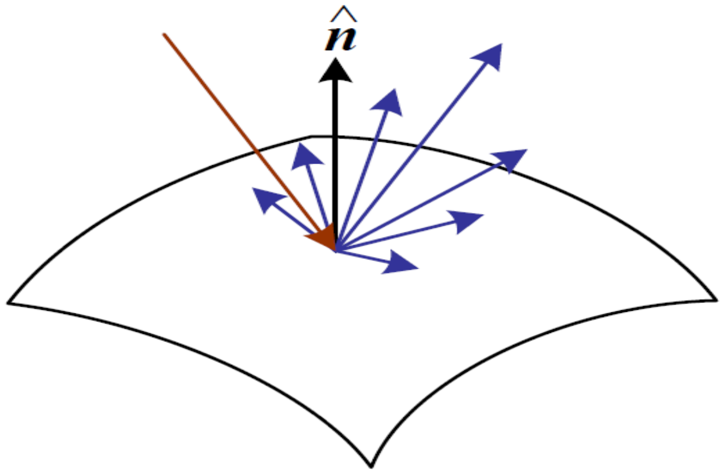
The distance of the corresponding object point is computed by using the camera parameters for the frame, and utilizing the ***lens formula*** as follows:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v},$$

- f is the focal length,
- v and u are the image and object distances from the lens.

Shape from Shading

As the surface changes across the object, the phenomenal brightness alters as a function of the angle amid the incident lighting and the topical surface orientation.



Light reflection, when it hits a surface [WAN2020]/

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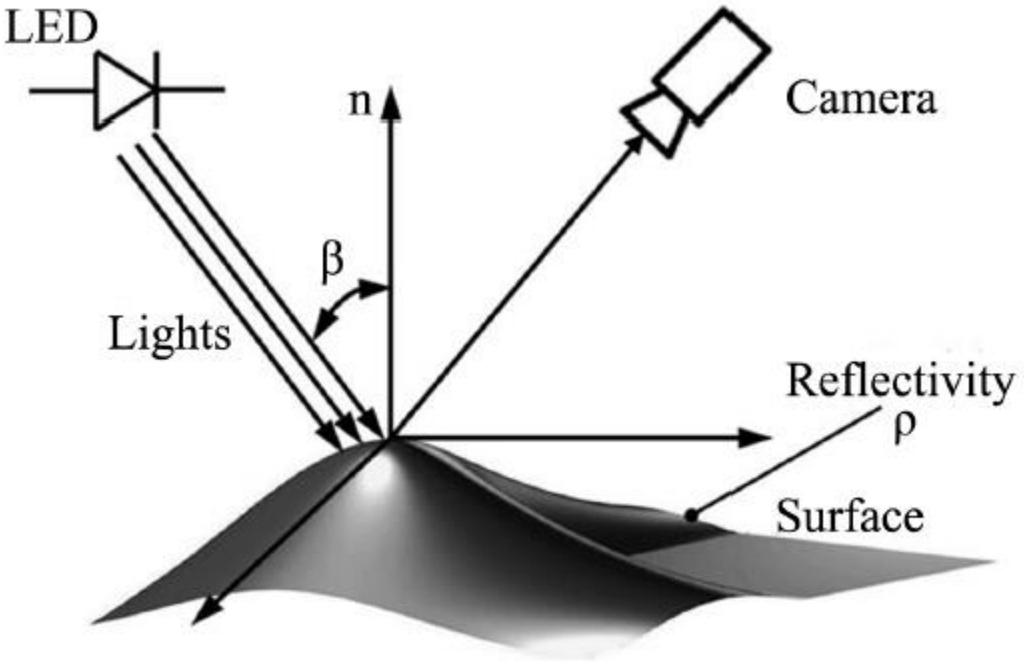
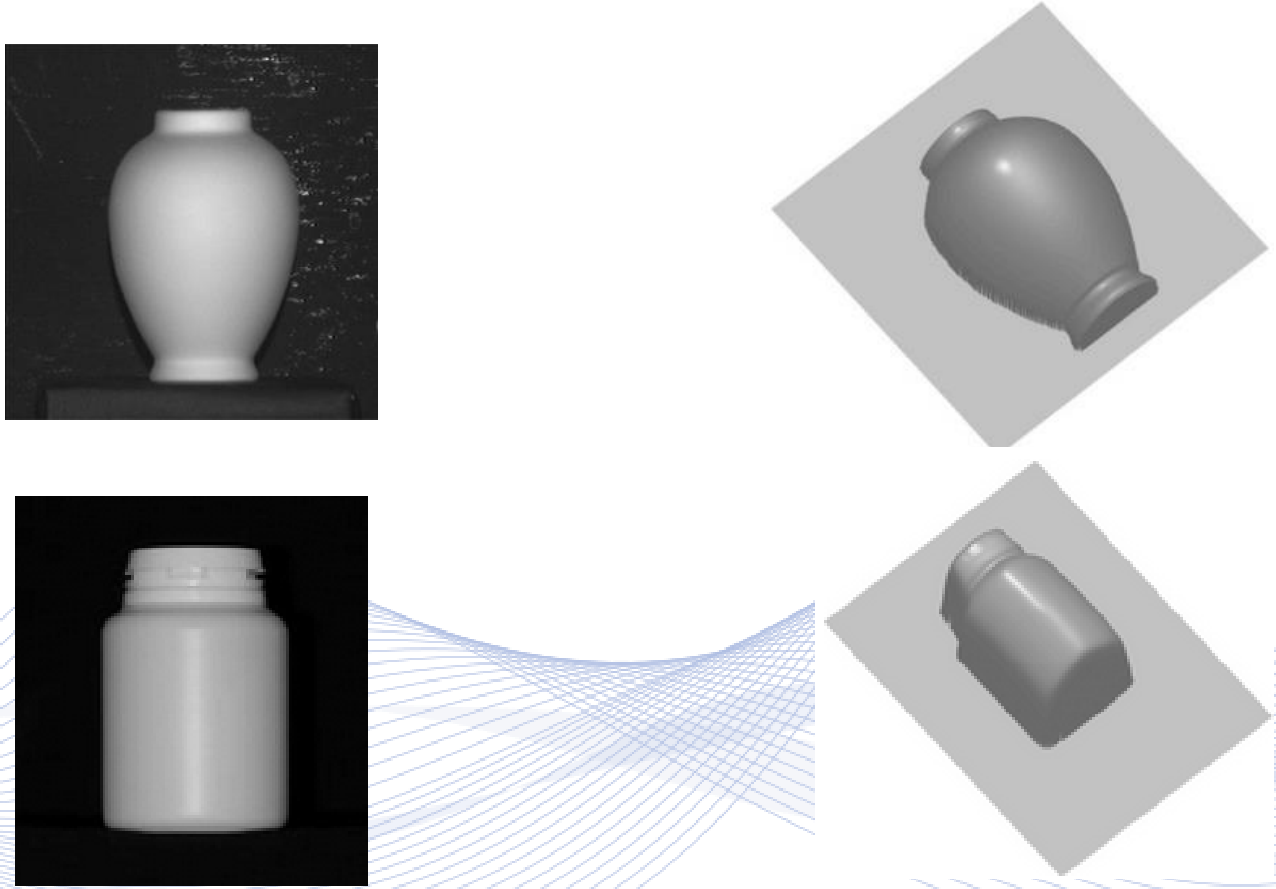
Shape from Shading



SfS model for reconstructing surface. (from [WAN2020])

Shape from Shading

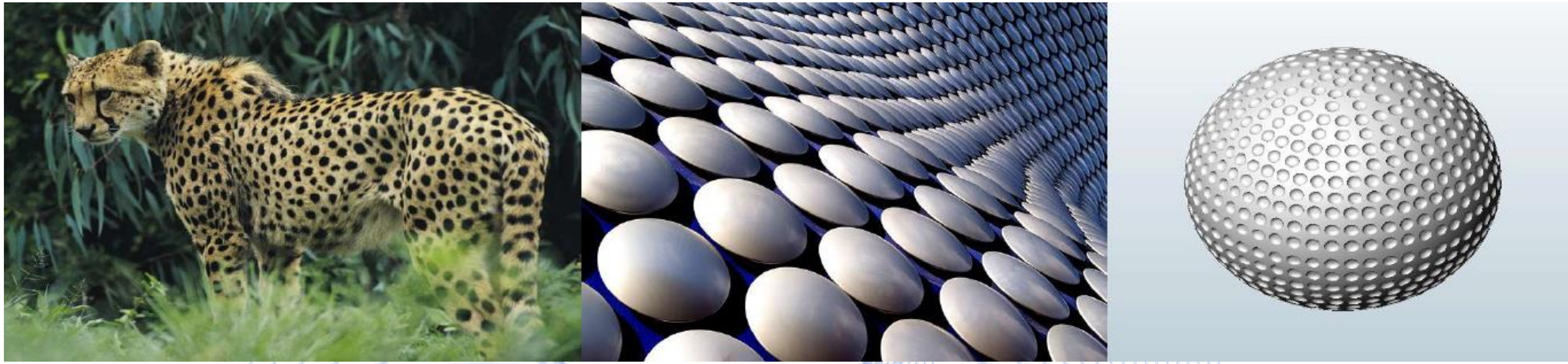


(left) Real object's image and (right) 3D Reconstructed surface. (from [WAN2018])

Shape from texture

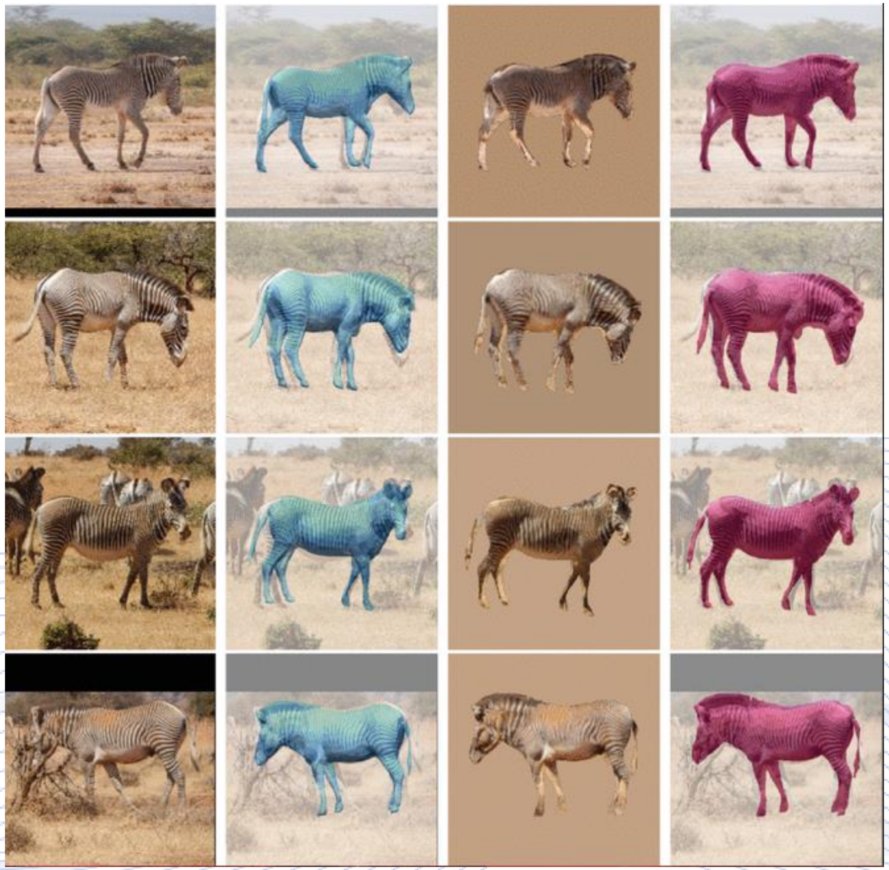
- An other 3D reconstruction technique which utilizes and analyses 2D images to create depth maps.
- Texture: the iteration of an element or the appearance of a specific contour over a surface.
- These element or surface is called texel (TEXture ELement)
- Shape from texture comes from observing at distortion from distribution of individual texels or texels on a surface.

Shape from texture



Texture examples. (from [LIV-ZSC])

Shape from texture



3D reconstruction of zebra using Shape from texture technique.(from [ZUF2019])

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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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