Robotics Fundamentals

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Module Agenda

- Robot Definition
- Robot Actuators and Effectors
- **Robot Sensors**
- Robot Computation and Communication
- Robot Design

Robot Sensors

Sensors categories

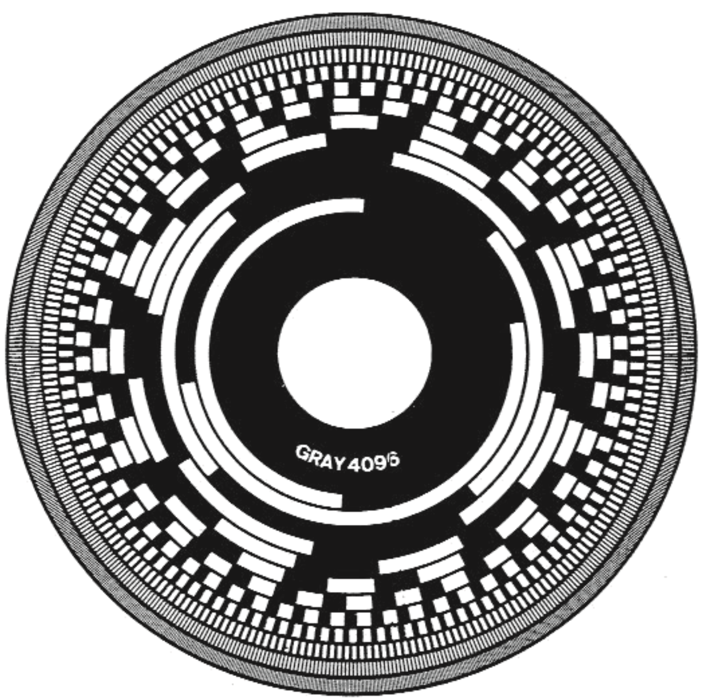
- **Measuring point of view:**
  - **Proprioceptive**: measure properties of the robot itself.
  - **Exteroceptive**: measure properties of the surrounding.

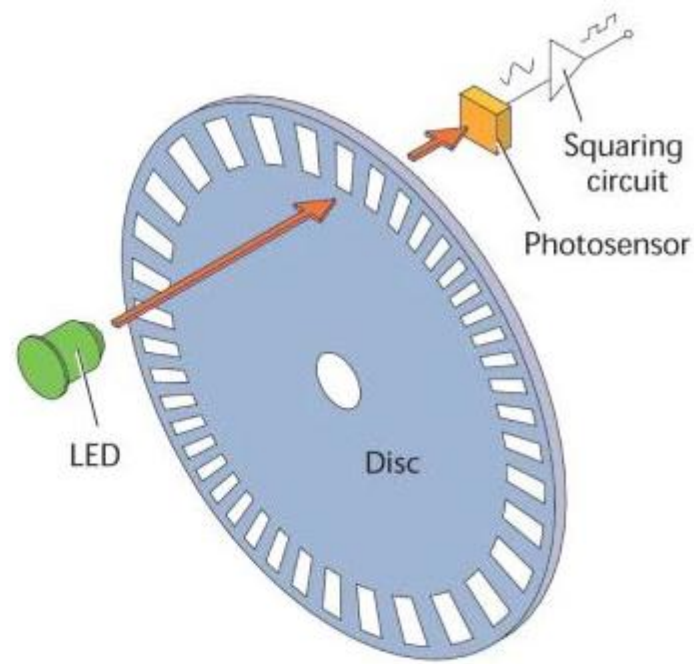
- Power point of view:
  - Active
  - Passive

Rotary encoder

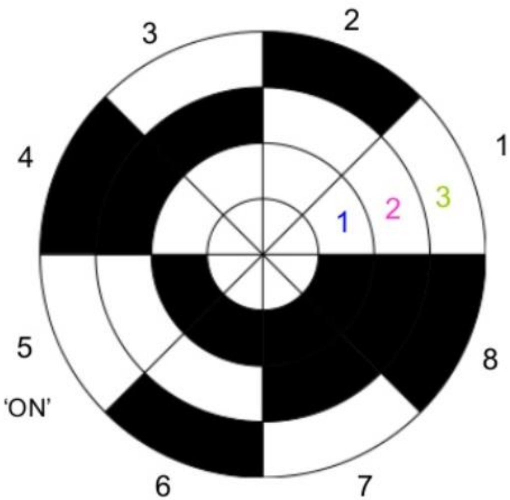
Rotary encoder

- **Function:** Rotary encoders track motor shaft movement.
- Types:
    - Absolute encoders ()
    - Relative encoders





Rotary encoder (Binary coding)



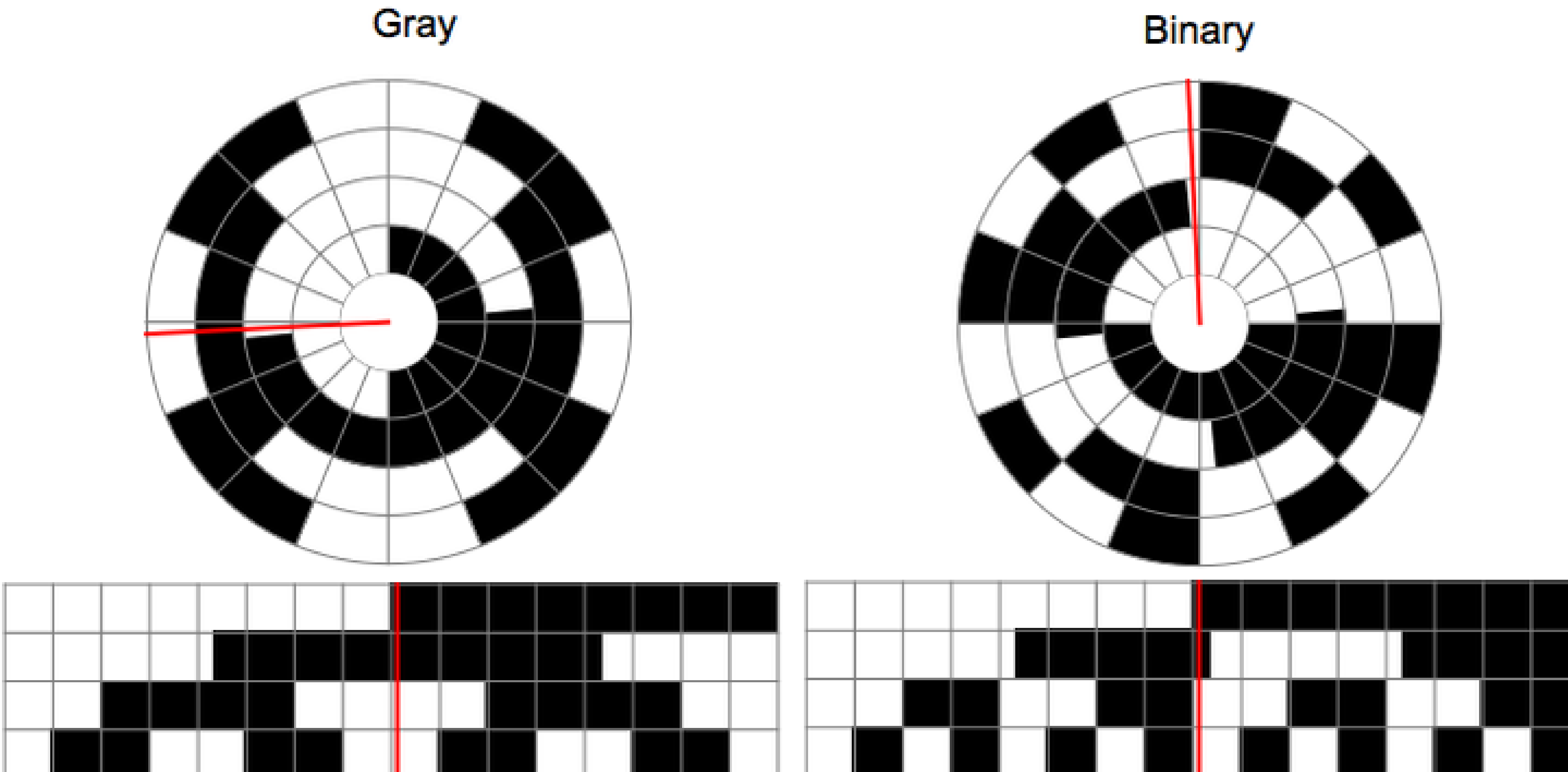
Black sectors are 'ON'

Sector	Contact 1	Contact 2	Contact 3	Angle
1	off	off	off	0° to 45°
2	off	off	on	45° to 90°
3	off	on	off	90° to 135°
4	off	on	on	135° to 180°
5	on	off	off	180° to 225°
6	on	off	on	225° to 270°
7	on	on	off	270° to 315°
8	on	on	on	315° to 360

2 bits change

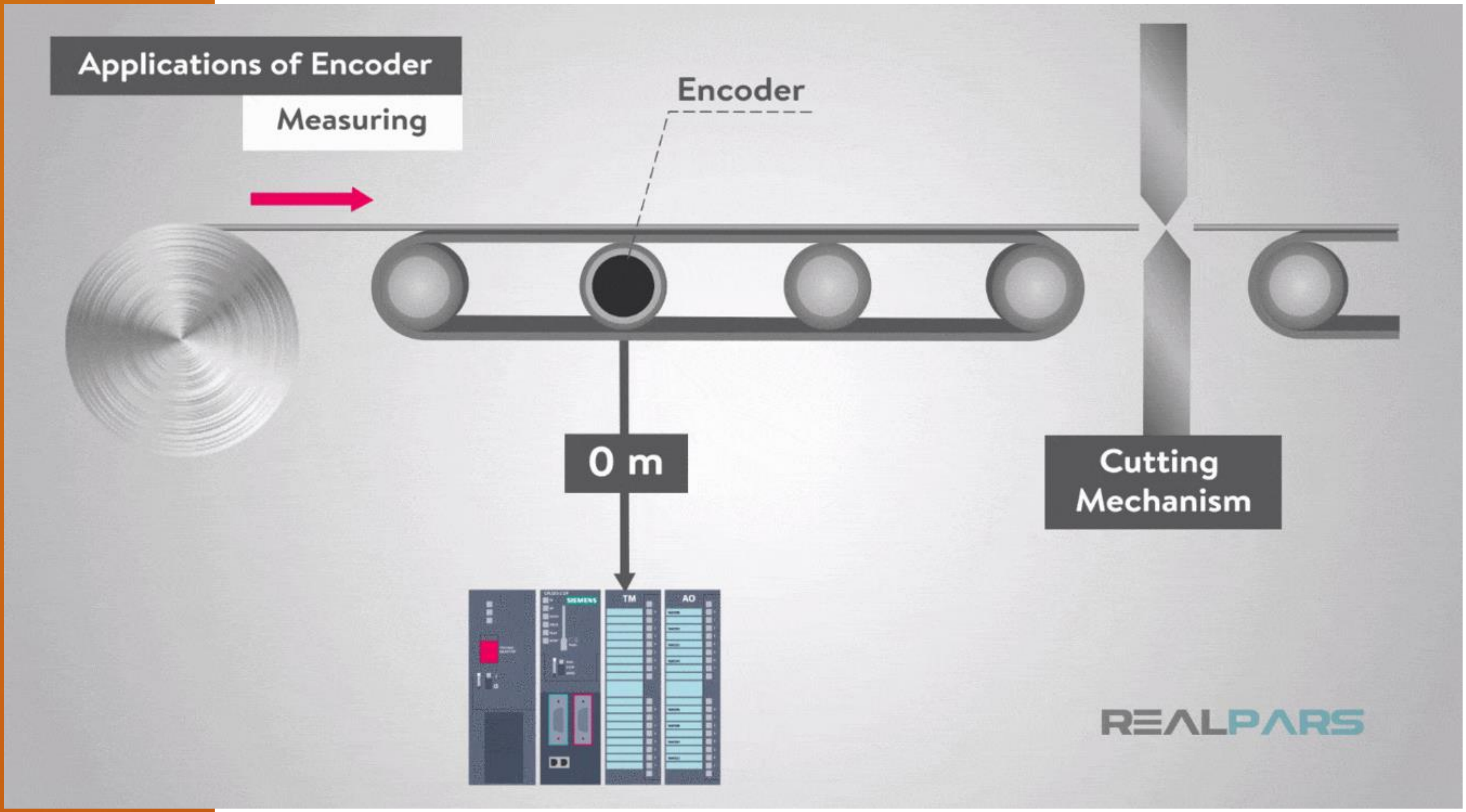
Multiple bits are changed (state 8 to state 1), random results occur at the state transition.

Rotary encoder (Gray coding)



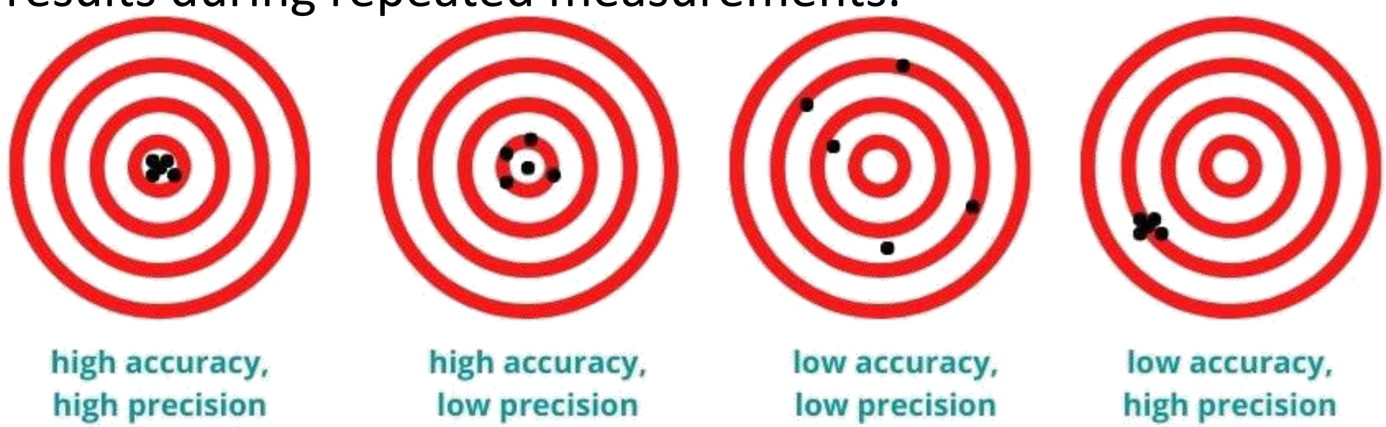
A single bit is changed at a time.

Applications length/distance measurements



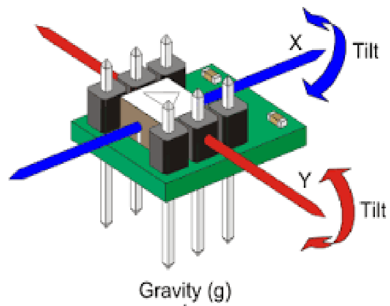
Rotary encoder :resolution

- How many positions per revolution:
- Dependent on number of output bits
- Minimum angle $=\dfrac{360^{\circ}}{rotary\ resolution\ (ppr)}$
- For 12 bits 4096→ min. angle$=\dfrac{360^{\circ}}{4096}=0.087890625\approx0.09$
- According to approximation :
- Accuracy is defined as : difference between real and measured
- Precision : the term precision refers to the repeatability of results during repeated measurements.



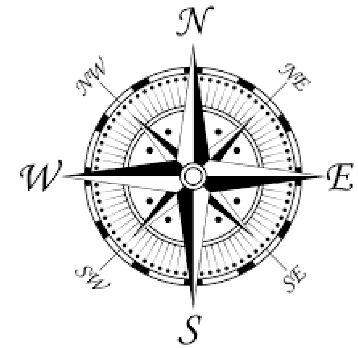
Inertia measurement unit

IMU, Inertia measurement unit



Accelerometer

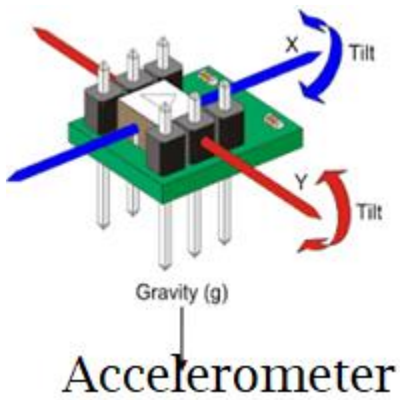
Gyroscope

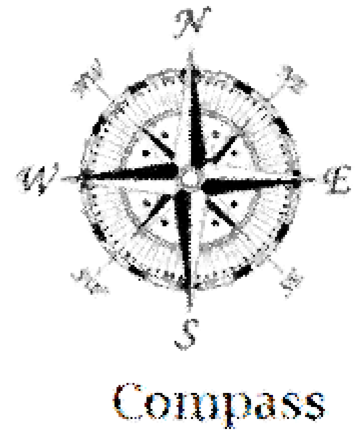


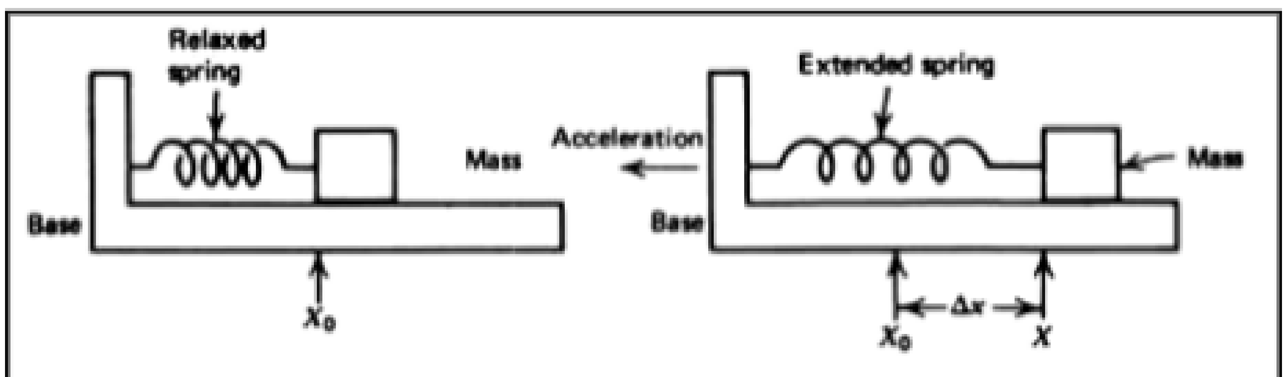
Compass

Accelerometer : measure linear acceleration
Gyro : measure the object orientation
Magnetometer : measure the direction

IMU, Inertia measurement unit

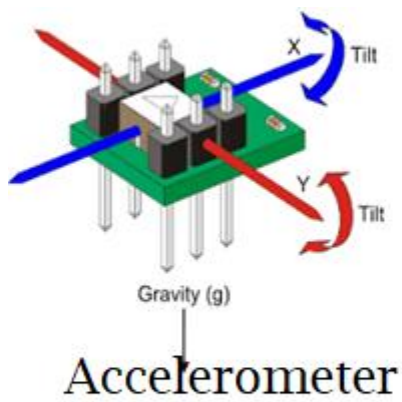


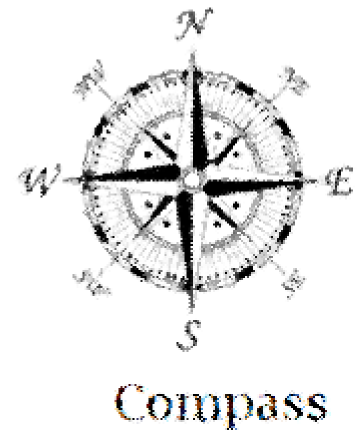


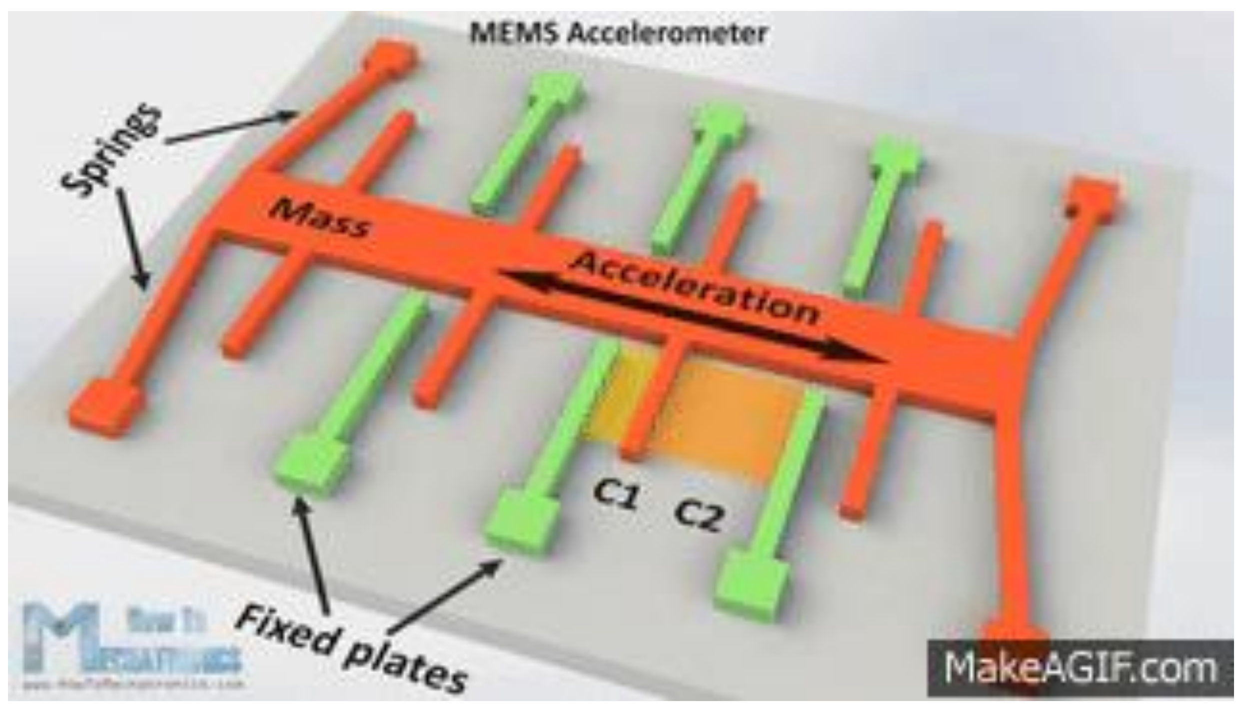


a) Spring-mass system with no acceleration b) Spring-mass system with acceleration

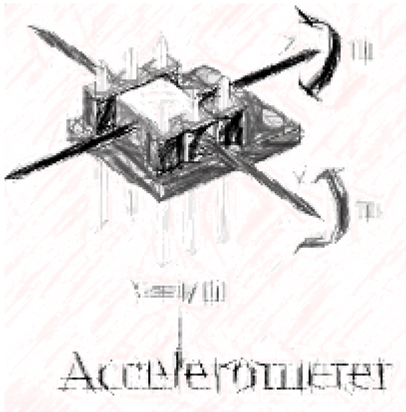
IMU, Inertia measurement unit



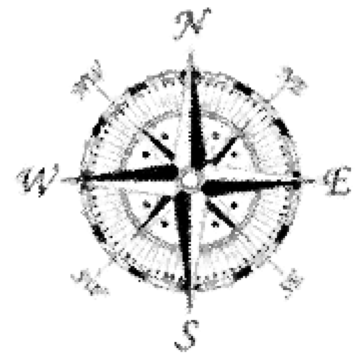




IMU, Inertia measurement unit




Gyroscope

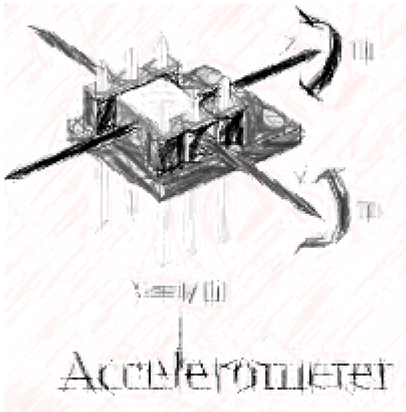


Compass


Léon Foucault
French physicist

The angular momentum of the spinning rotor caused it to maintain its attitude even when the gimbal assembly was tilted.

IMU, Inertia measurement unit

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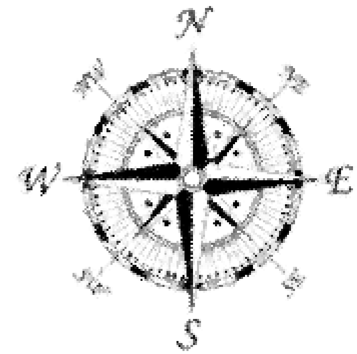
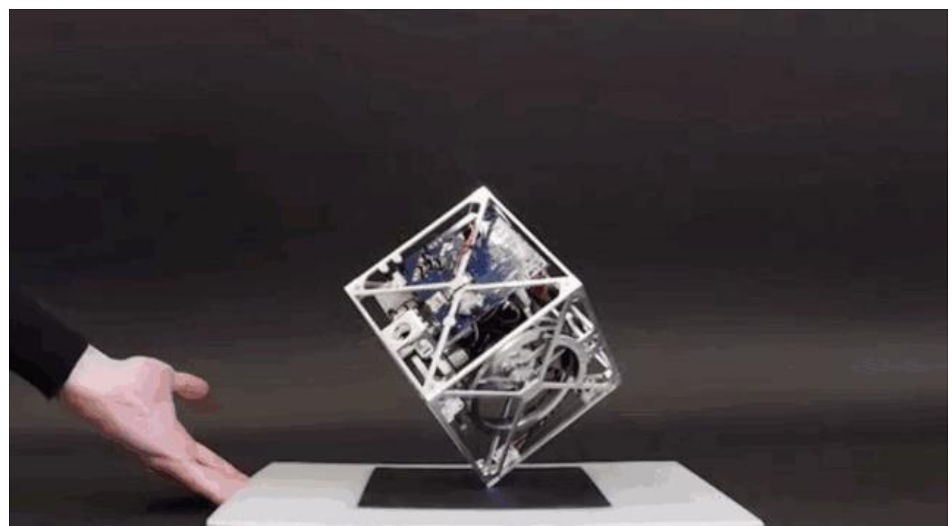
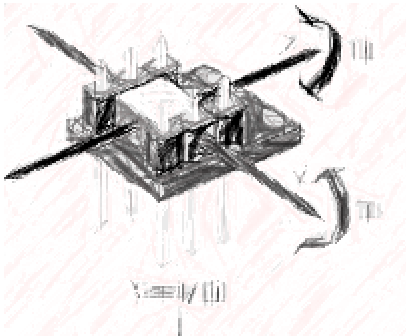


Compass

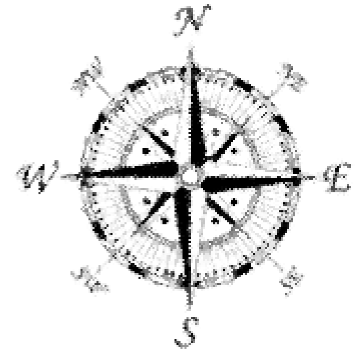


IMU, Inertia measurement unit



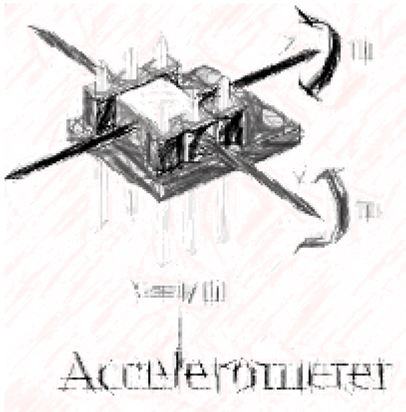
Accelerometer

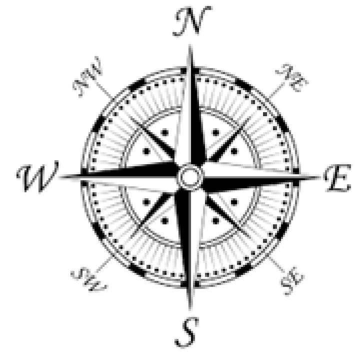
Gyroscope



Compass

IMU, Inertia measurement unit

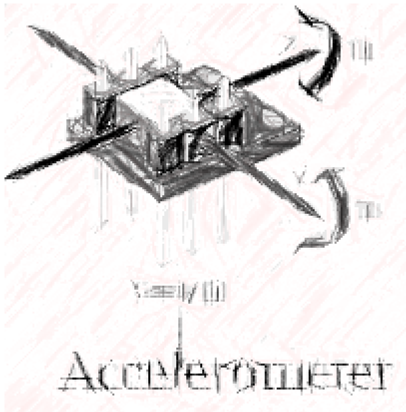


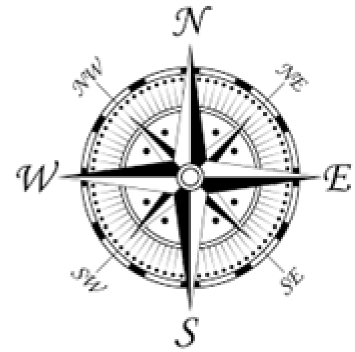


Compass

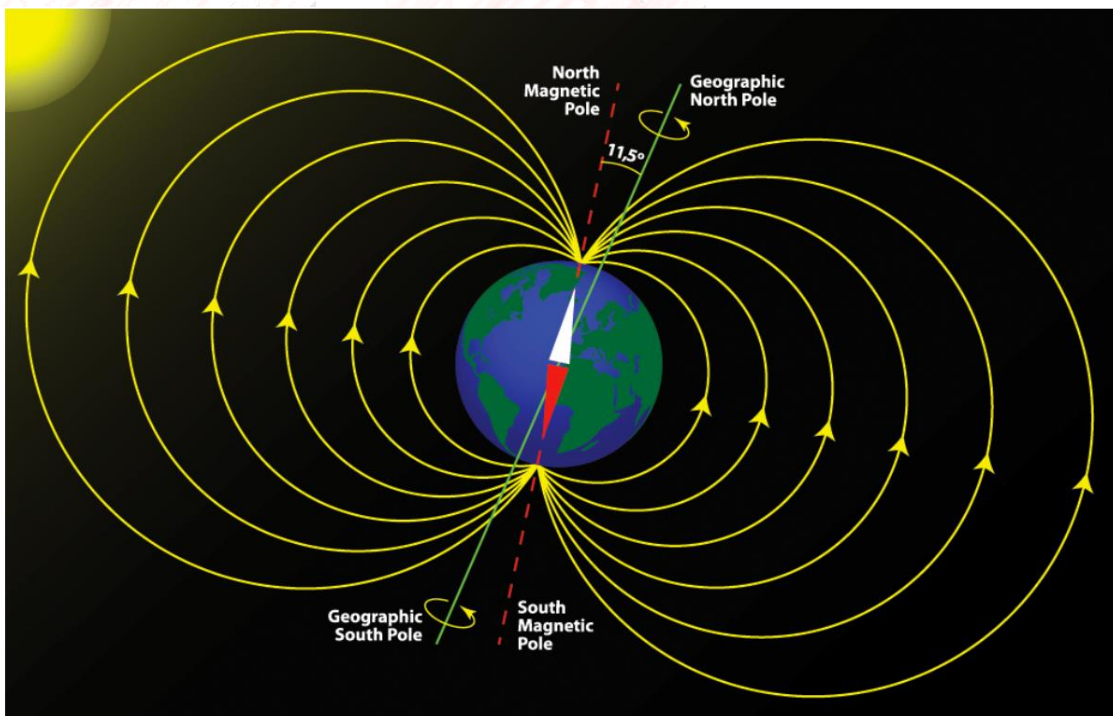
measure earth's magnetic field in Gauss or uT

IMU, Inertia measurement unit





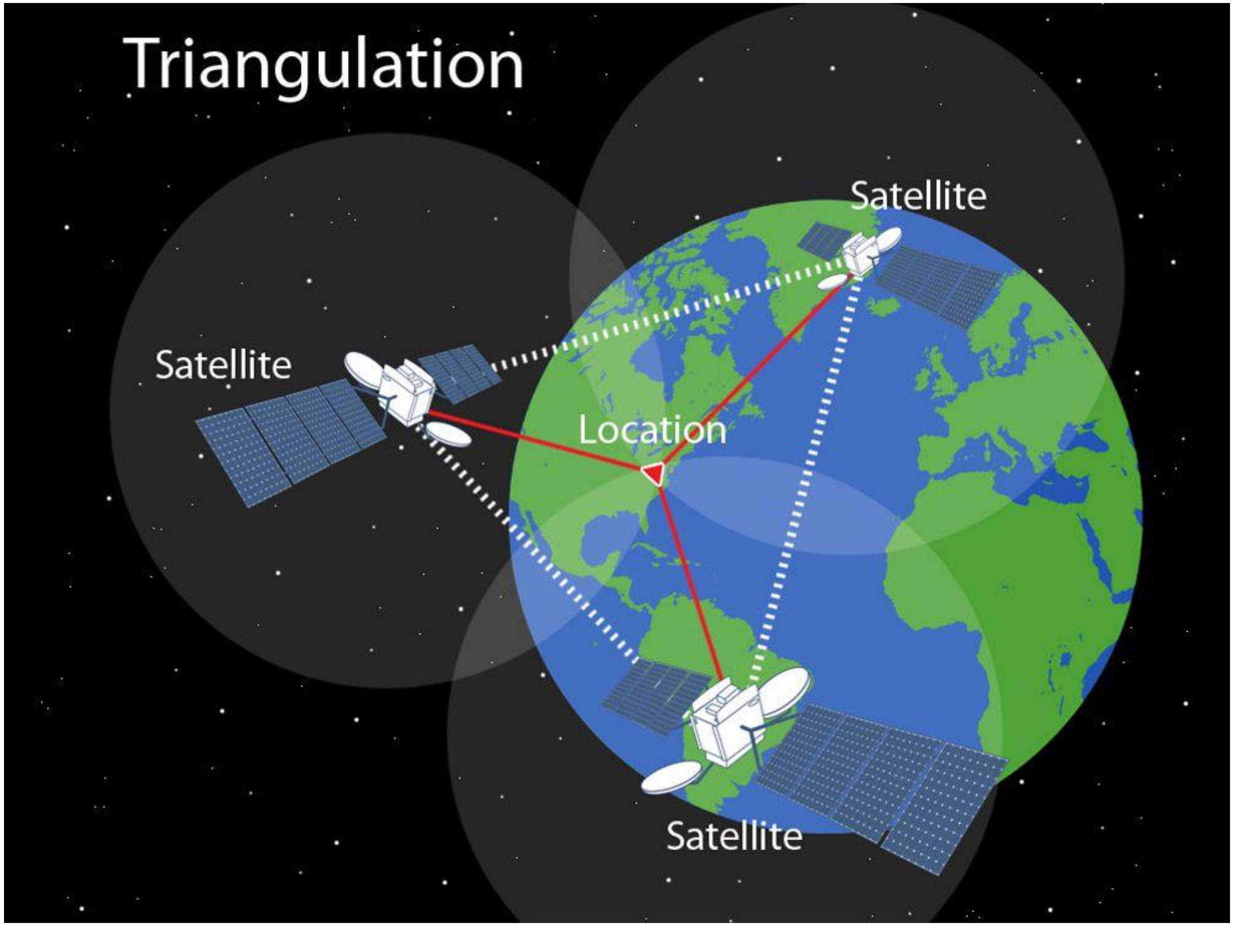
Compass



Global Positioning System (GPS)

GPS : definitions

- uses triangulation from satellites to determine **geolocation and time**.



GPS : definitions

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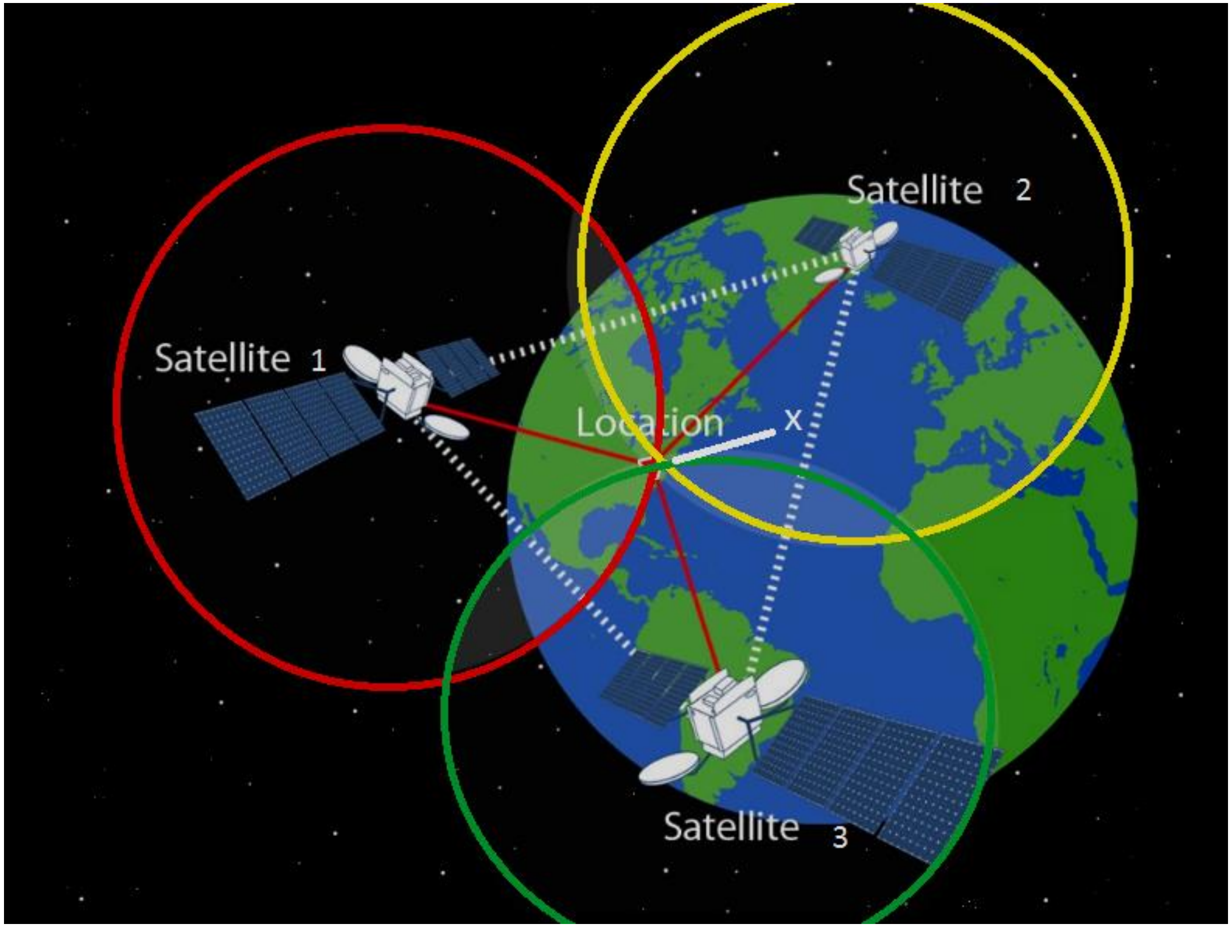
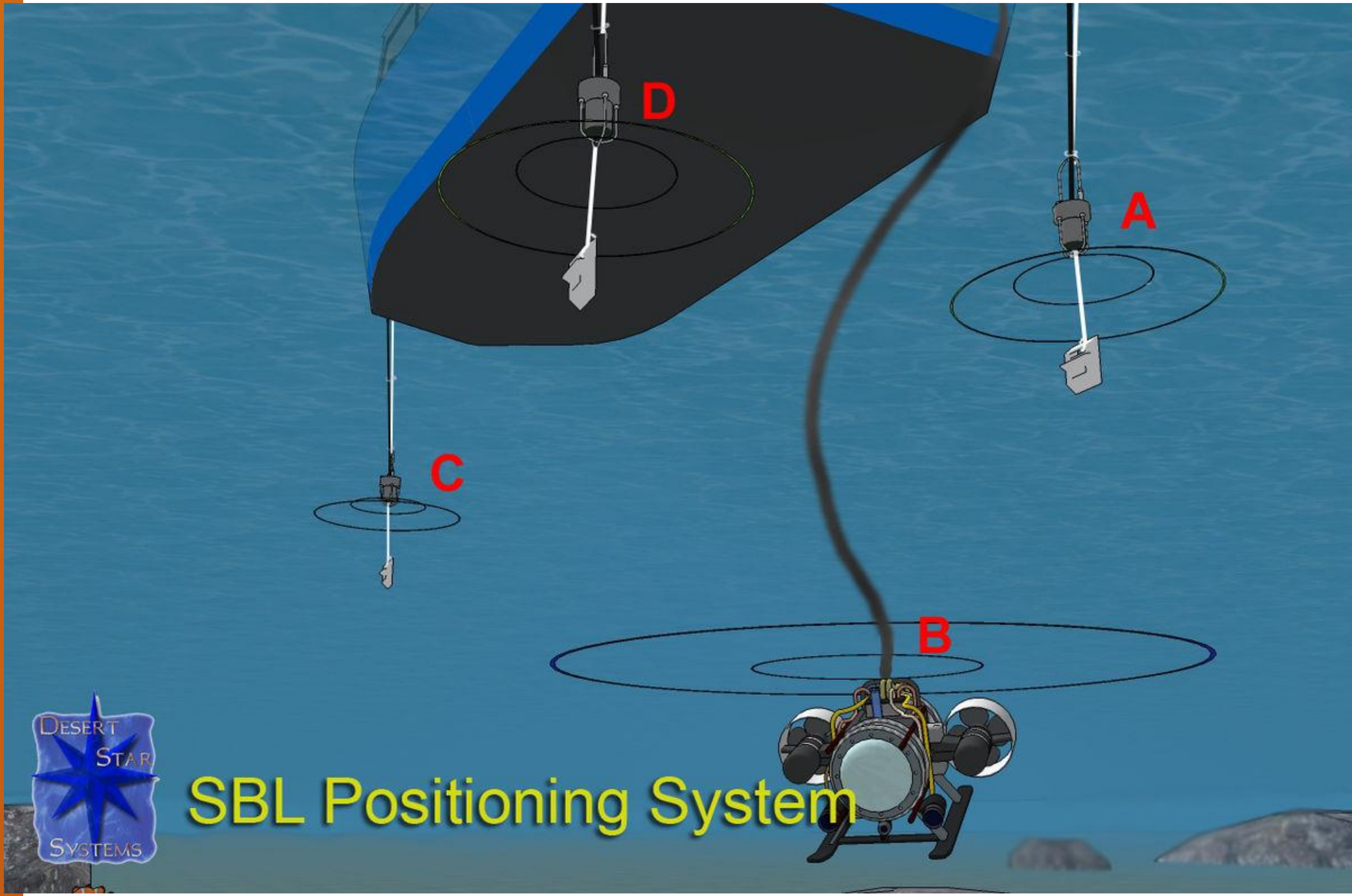


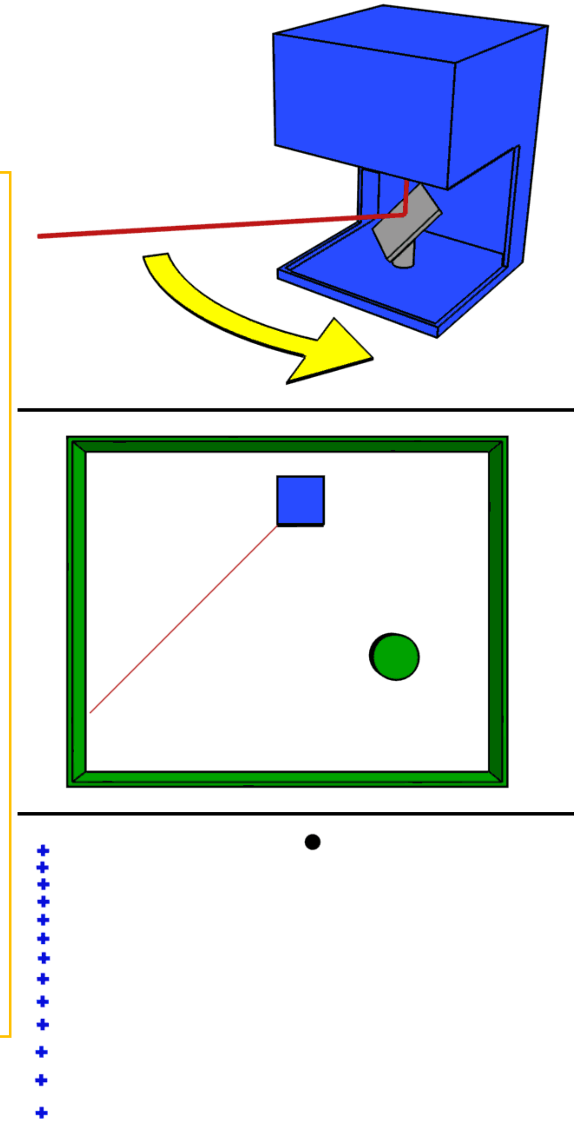
ROV (Ultra short baseline -USBL)



LiDar

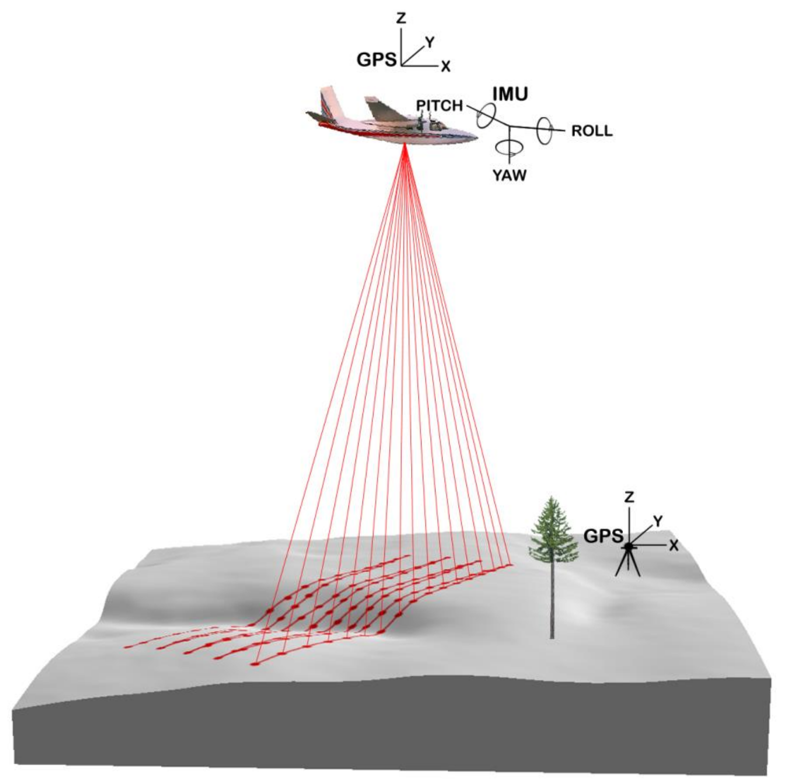
LiDAR (Light Detection And Ranging)

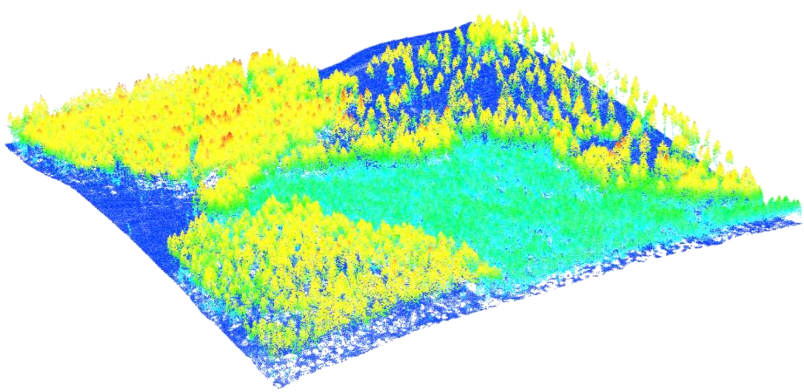
- Each time the laser is pulsed:
  - Laser generates an optical pulse.
  - Pulse is reflected off an object and returns
    to the system receiver
  - High-speed counter measures the time of flight from the start pulse to the return pulse
  - Time measurement is converted to a distance.
- Up to 200,000+ pulses/second



Features

- 3D representation.
- Both at day and night-time.
- Affected by:
  - Similar wavelength (sun).
  - Dust
  - Fog , mist , vapor





Reflectivity

- Laser detector could be saturated :
  - Sun
  - Highly reflective objects.
- producing an invalid or less accurate reading

MATERIAL	REFLECTIVITY @ λ = 900 nm
Dimension lumber (pine, clean, dry)	94%
Snow	80-90%
White masonry	85%
Limestone, clay	up to 75%
Deciduous trees	typ. 60%
Coniferous trees	typ. 30%
Carbonate sand (dry)	57%
Carbonate sand (wet)	41%
Beach sands, bare areas in desert	typ. 50%
Rough wood pallet (clean)	25%
Concrete, smooth	24%
Asphalt with pebbles	17%
Lava	8%
Black rubber tire wall	2%

Source: www.riegl.co.at

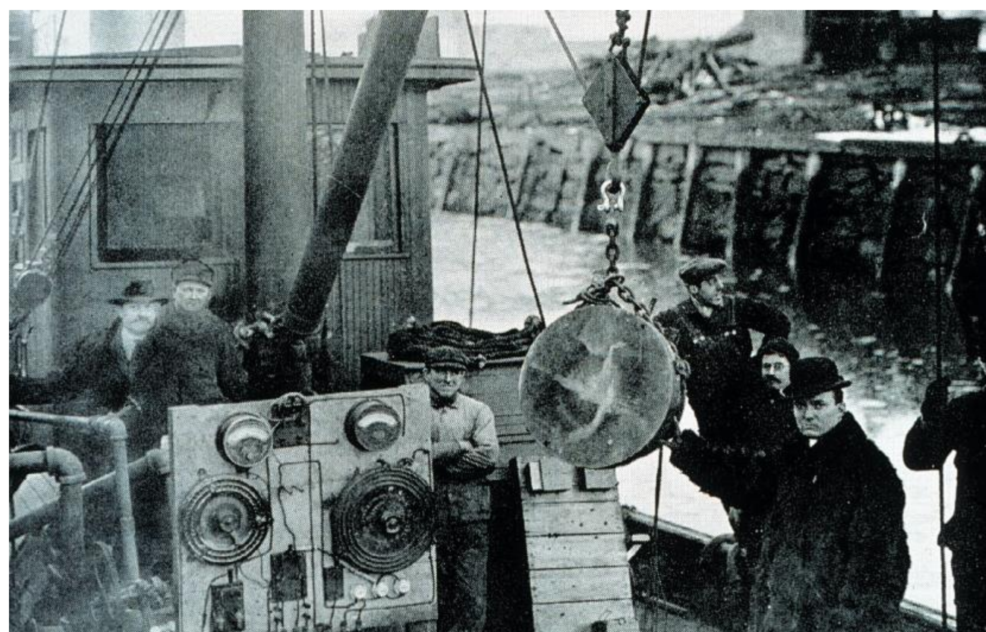
Sonar

Sound Navigation And Ranging

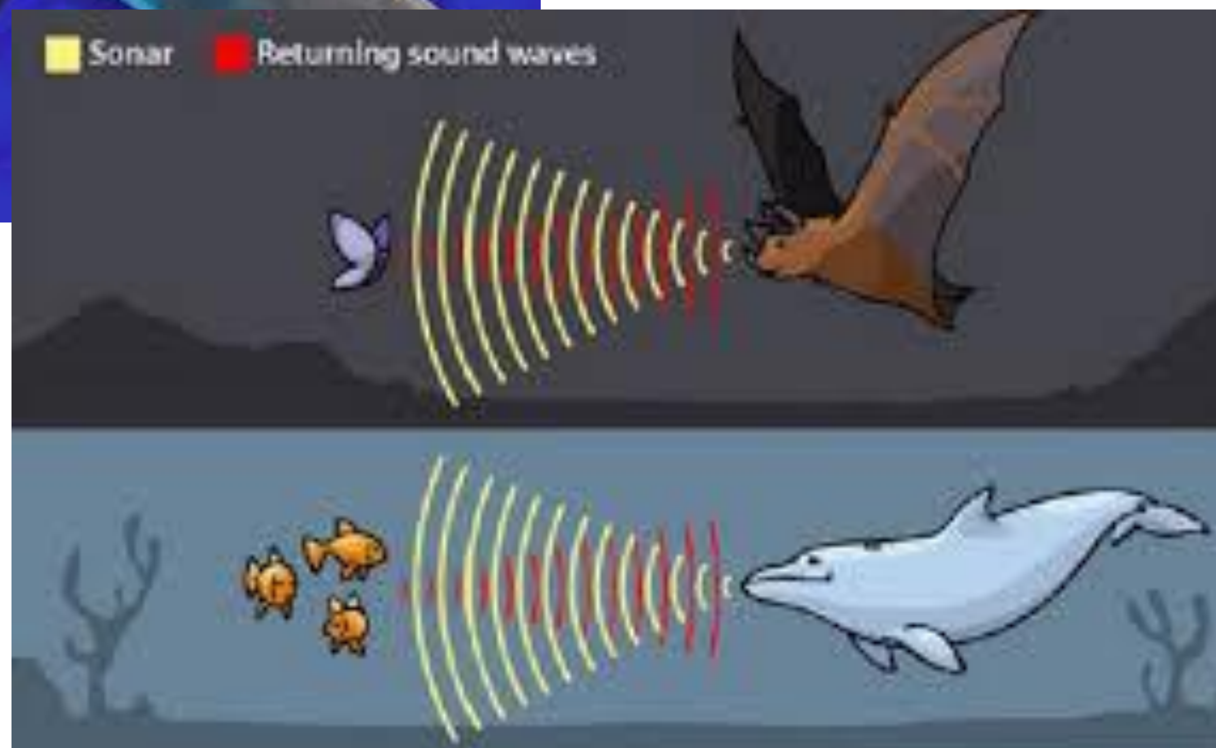
- If you cause your ship to stop and place the head of a long tube in the water and place the outer extremity to your ear, you will hear ships at a great distance from you.

Leonardo da Vinci, 1490

1914 Fessenden: first active sonar system (detect iceberg 2 miles)



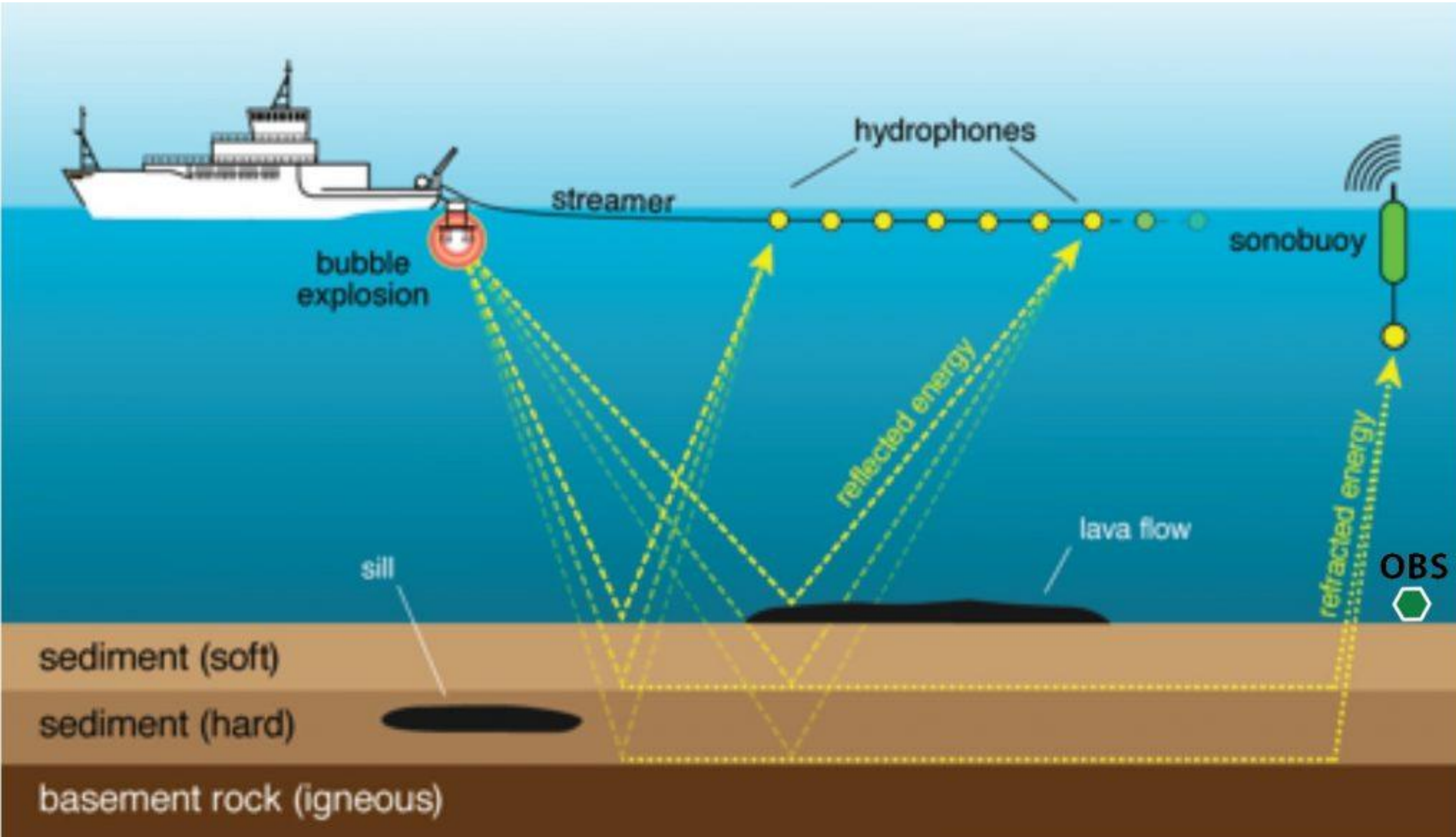
Bio-Sonar (Masters)



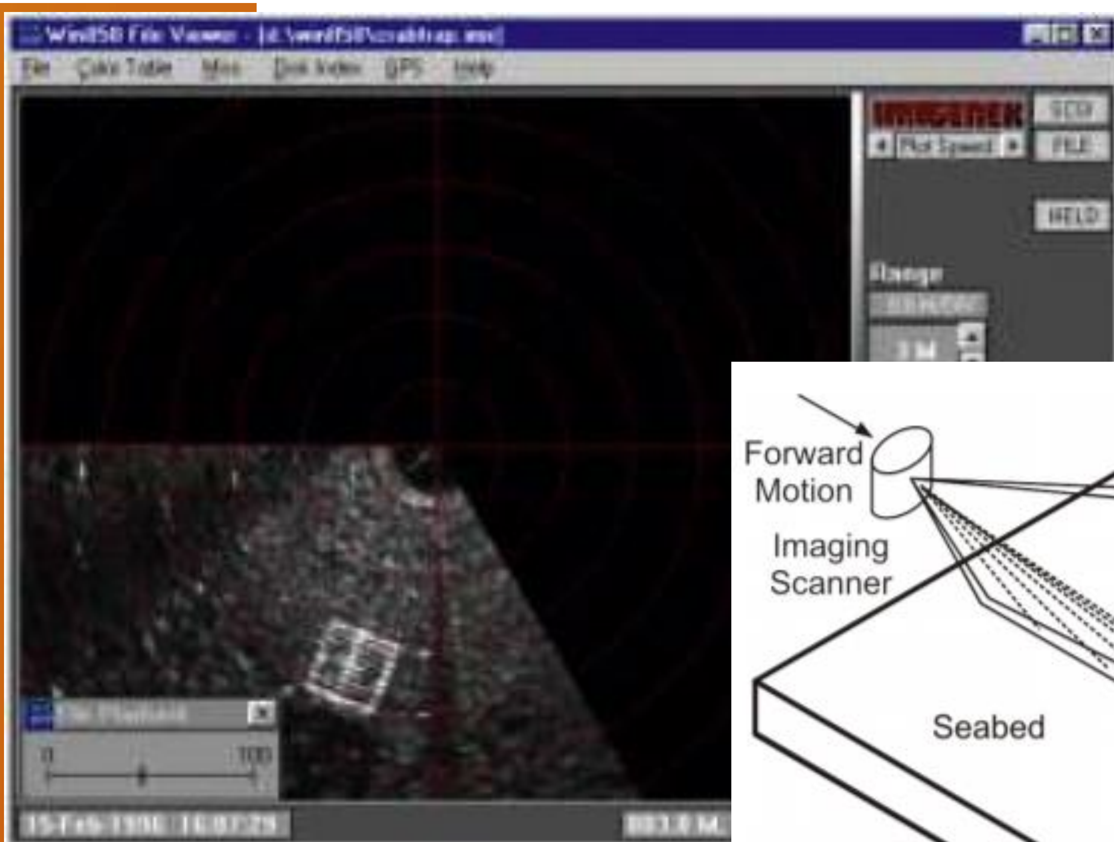
SONAR (Sound Navigation and Ranging)

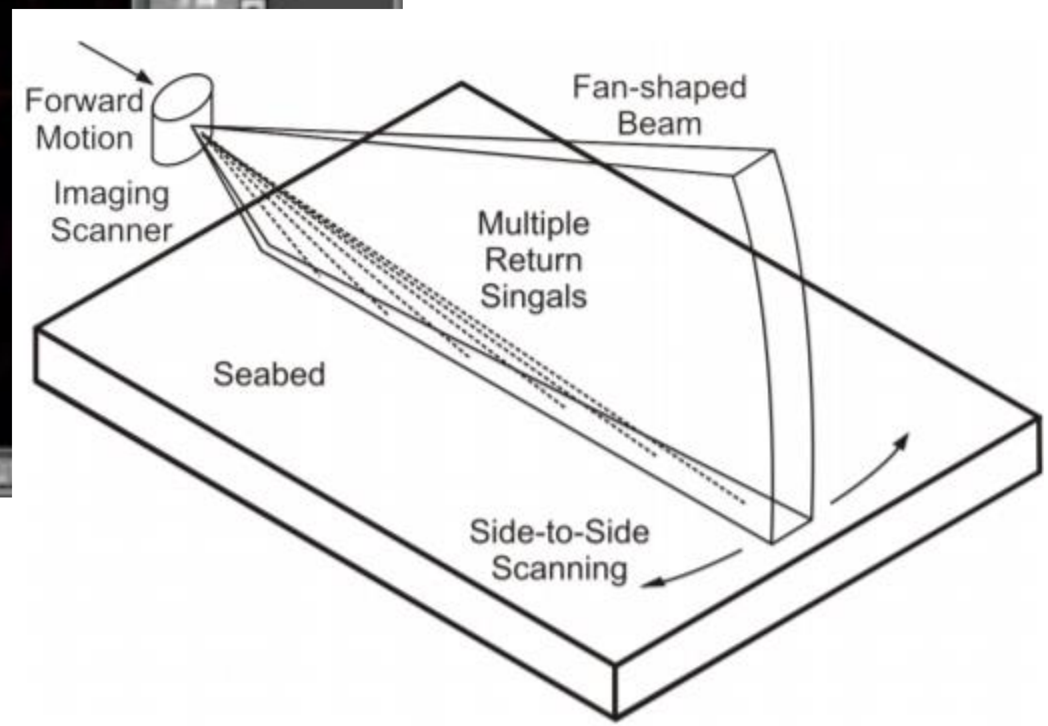
- Acoustic beams to create a map of the surrounding environment using the time-of-flight technique.
- Has adv. Underwater than Lidar, Radar.
- Acoustic absorption in seawater is frequency dependent

ROV (Ultra short baseline -USBL)



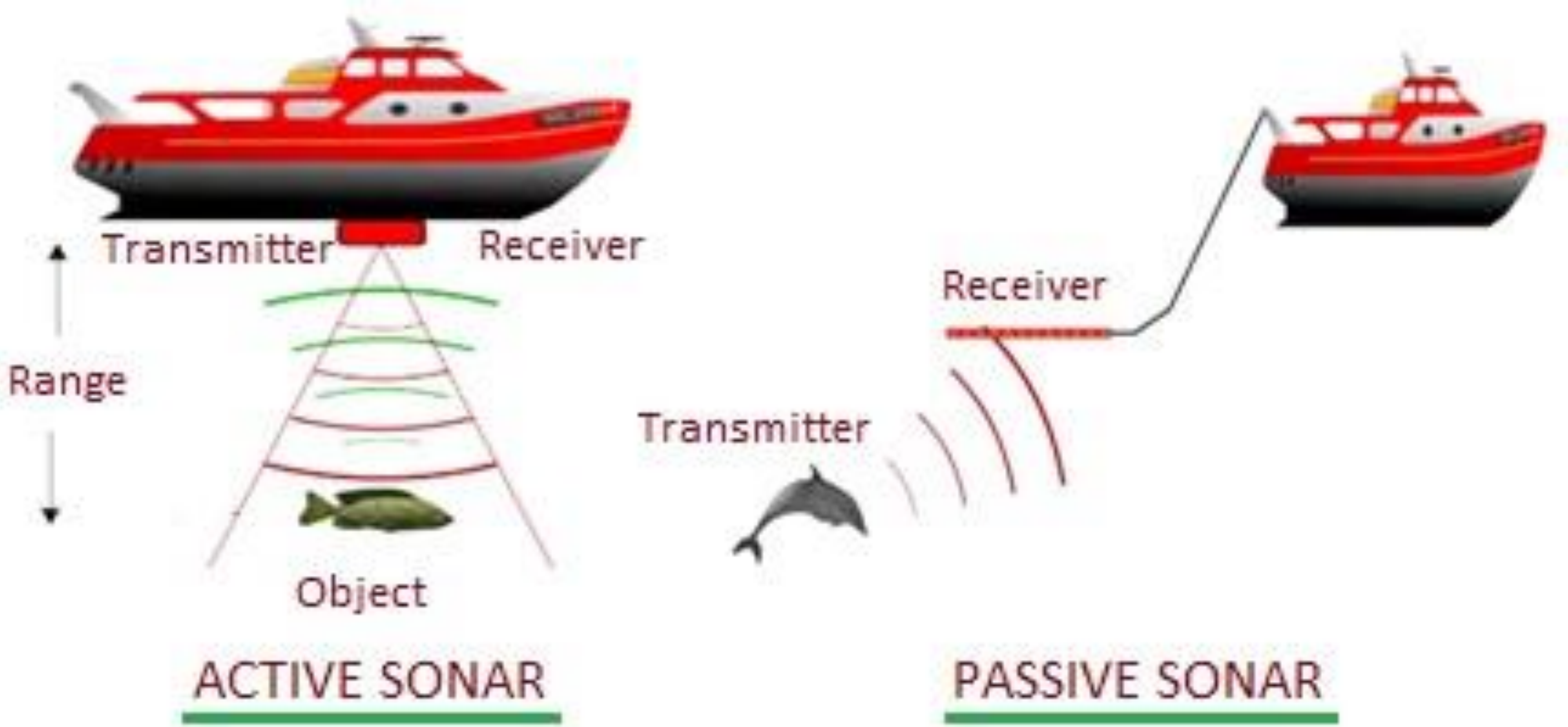
Sonar types (Image sonar)





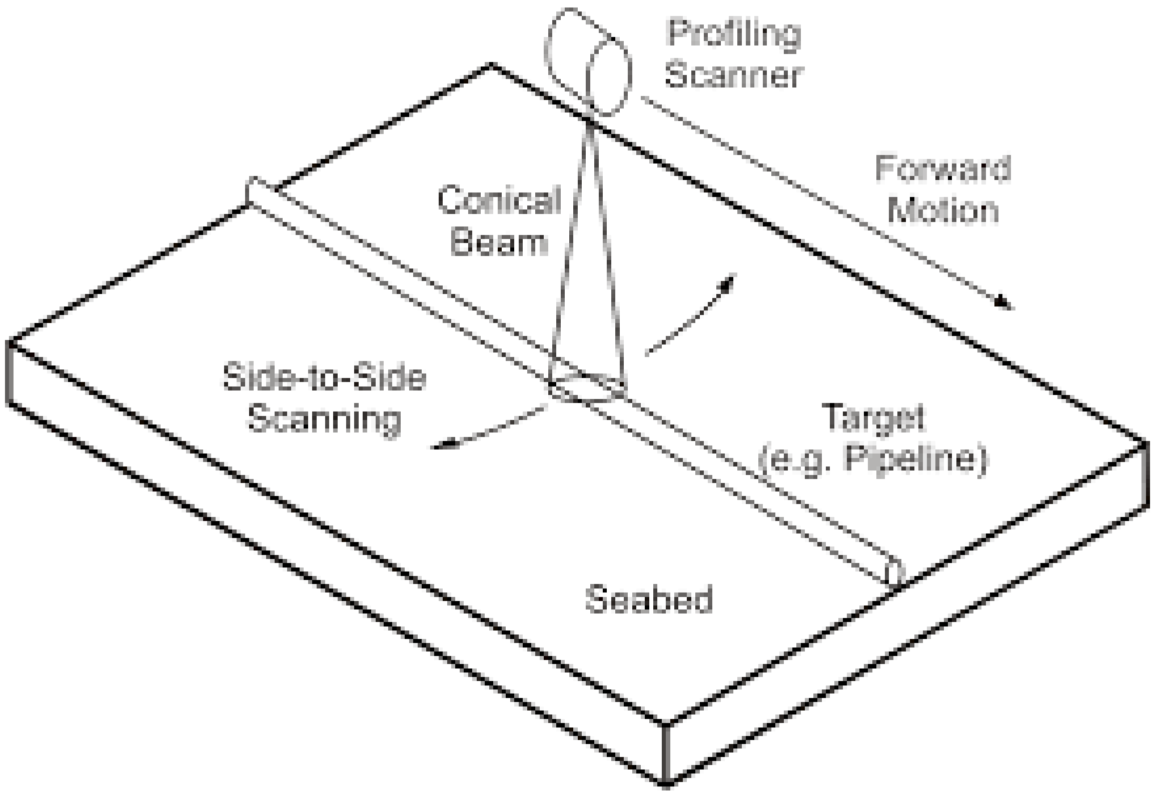
Mechanically Scanning Imaging Sonar

Sonar types (Active/Passive)



Sonar types (mechanical scanning profiling sonar)

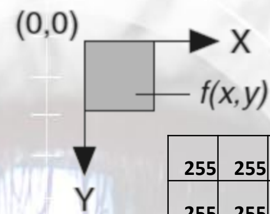
A mechanically scanning sonar rotates a transducer through a series of angular ping positions defined by a scan width. The sonar can continuously or part-scan a full 360°

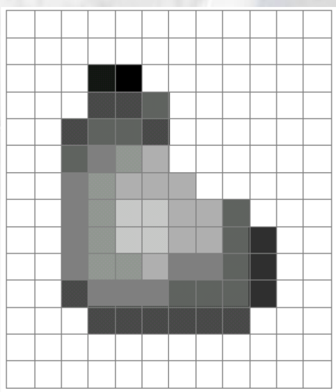


RGB Camera

What is an image?

(common to use one byte per value: 0 = black, 255 = white)





=

255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	20	0	255	255	255	255	255	255	255
255	255	255	75	75	75	255	255	255	255	255	255
255	255	75	95	95	75	255	255	255	255	255	255
255	255	96	127	145	175	255	255	255	255	255	255
255	255	127	145	175	175	175	255	255	255	255	255
255	255	127	145	200	200	175	175	95	255	255	255
255	255	127	145	200	200	175	175	95	47	255	255
255	255	127	145	145	175	127	127	95	47	255	255
255	255	74	127	127	127	95	95	95	47	255	255
255	255	255	74	74	74	74	74	74	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255	255	255

Definitions

255	255	255	255	255
255	255	255	255	255
255	255	255	20	0
255	255	255	75	75
255	255	75	95	95
255	255	255	255	255

Resolution =5x6
Bit depth = 8bits

1

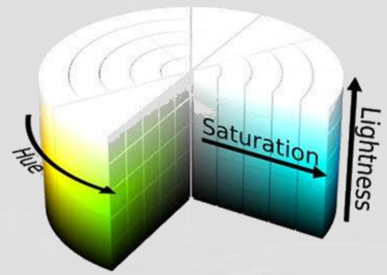
Image Resolution

An image composed of *m* columns and *n* rows has a resolution of $m \times n$.

3

Bit depth

The number of bits used to encode the value of a pixel. For a given bit depth of *n*, meaning a pixel can have 2^n different values.
IMAQ Vision 8-bit, 10-bit, 12-bit, 14-bit, 16-bit,floating point, or color encoding.

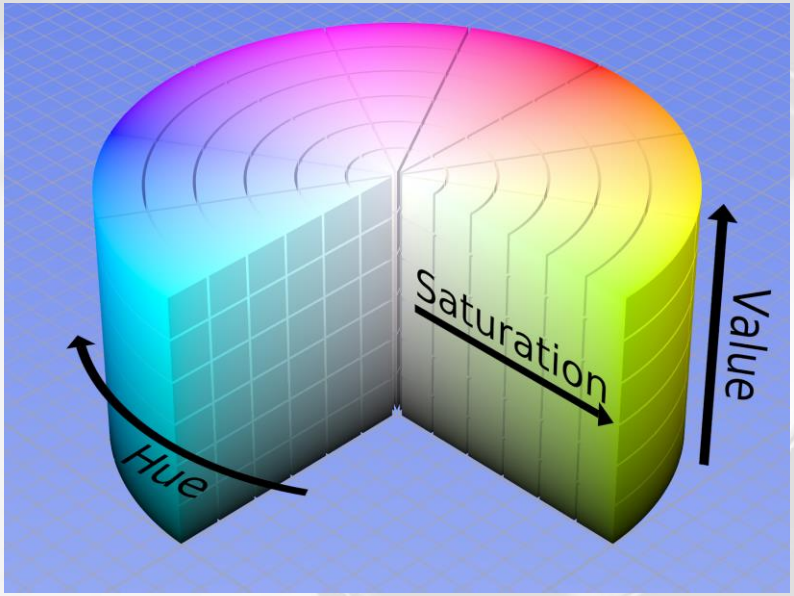


2

Image Planes

1. Grayscale.
2. pseudo-color
3. RGB (RED Green Blue)
4. HSL (hue, saturation, luminance
5. HSV (hue, saturation, and value).

HSV or HSL



Hue – the color itself.
Saturation – intensity of the color (refers to the amount of white added to the hue).
Value – The darkness or lightness of a color (used for grayscale conversion).

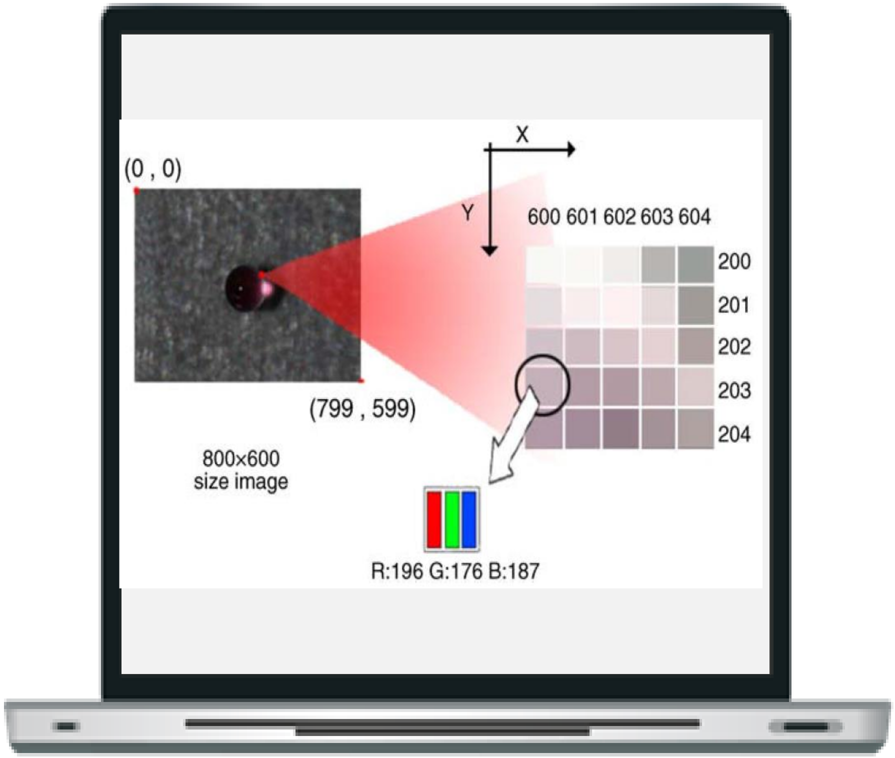
Memory Images!!

Memory Required =H_Resolution x V_Resolution x Bit_Depth

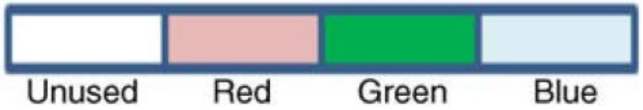
For example, a 1024 x768 8-bit grayscale would require:

Memory Required =1024 x768 x8
= 291456 bits
= 768kBytes

RGB Images



Representation



This is due to the computer's natural representation of an integer as a 32 bit number

Pixel Frame

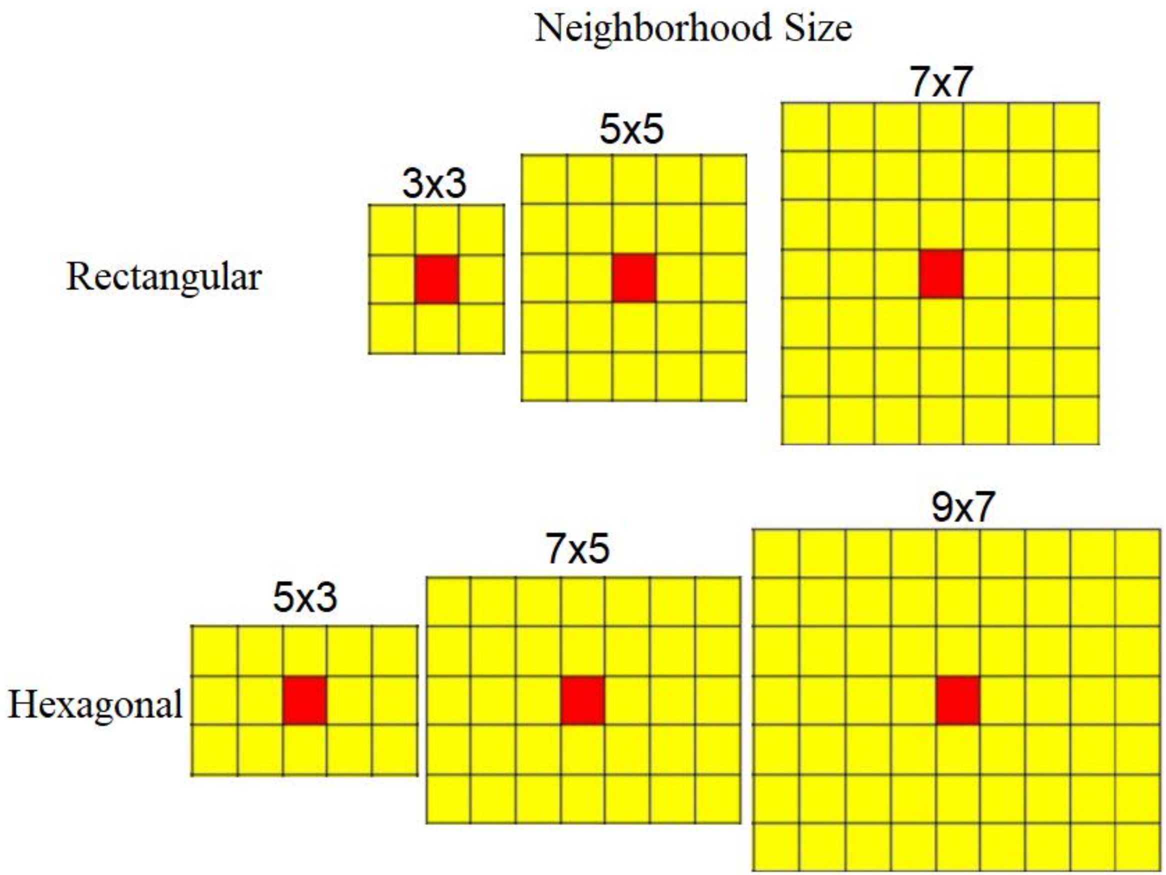

Neighborhood Size
Rectangular
3x3
5x5
7x7
Hexagonal
5x3
7x5
9x7

Image Data Reduction : **Image Segmentation**

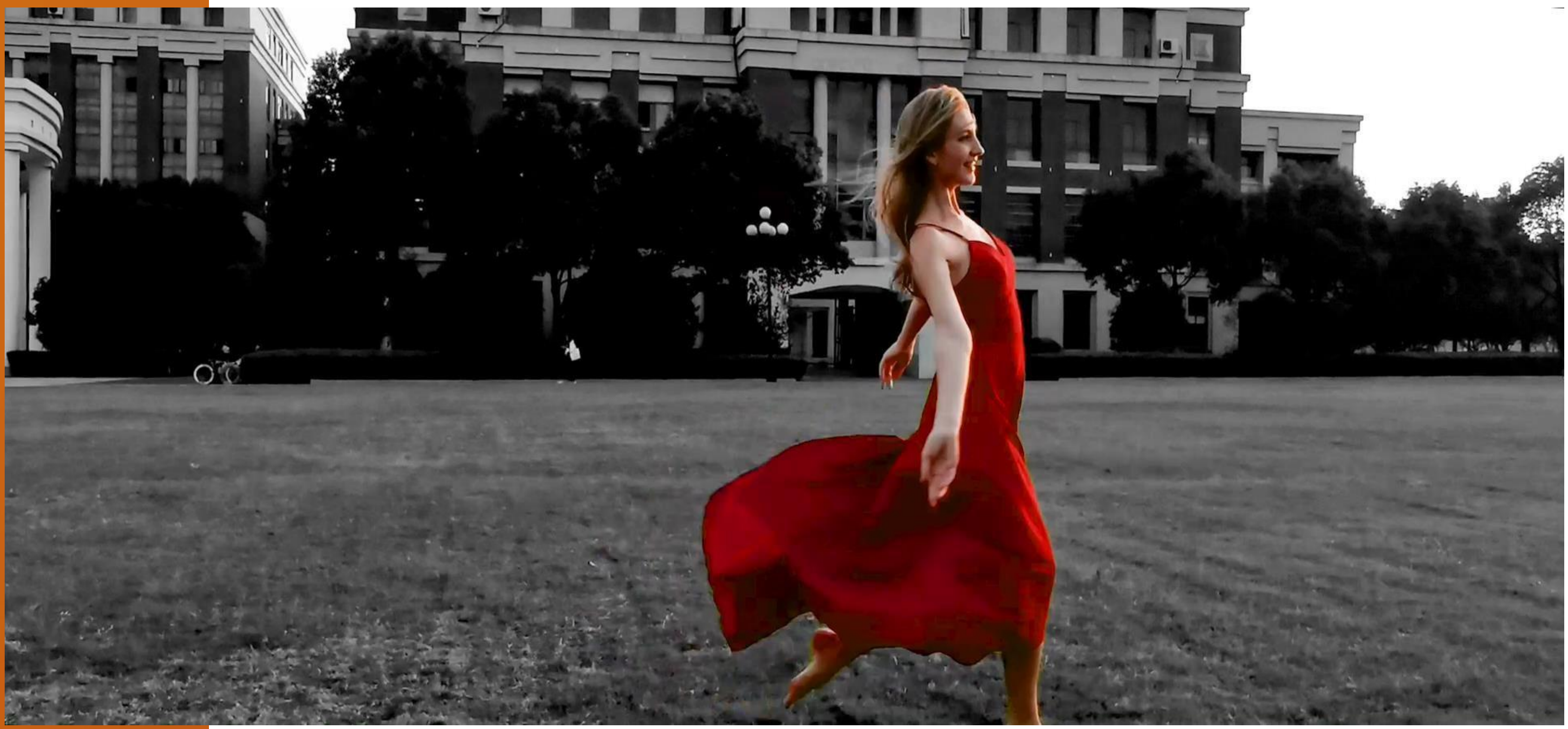
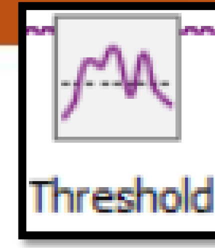


Image Threshold



Target : To create a binary image and focus inspection on specific areas of interest.

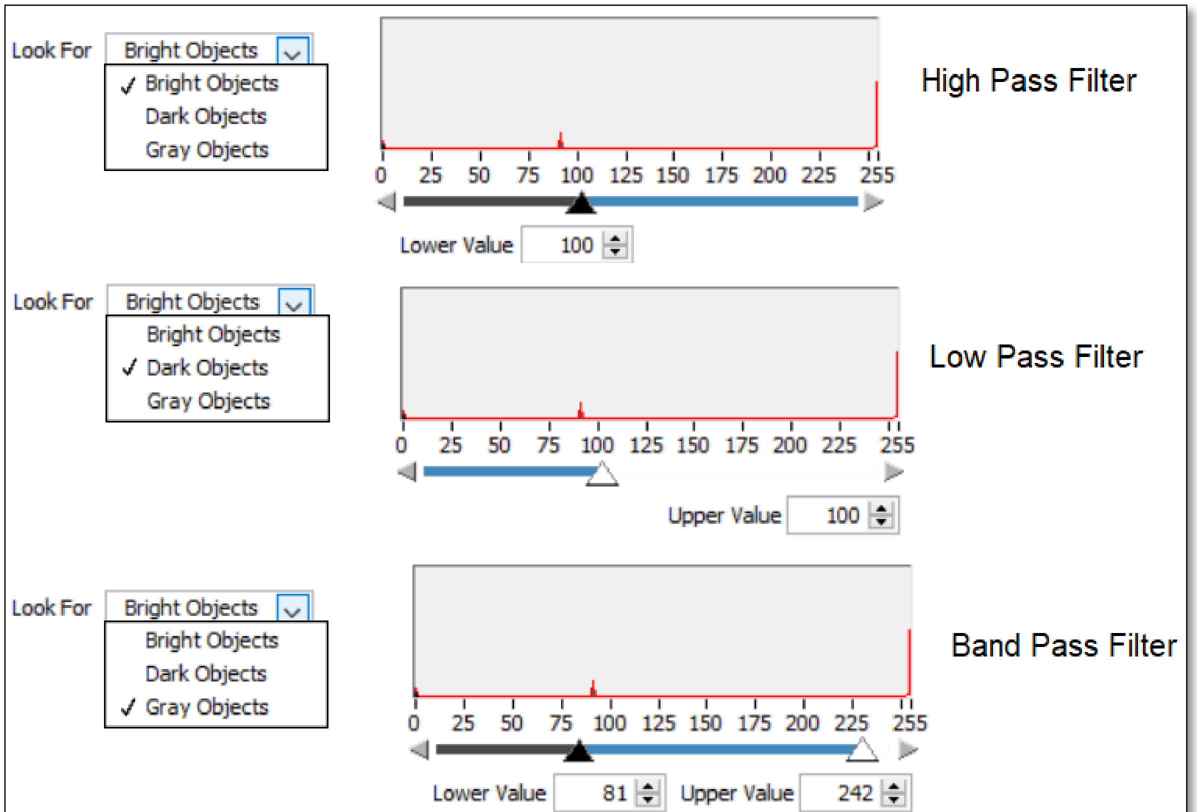
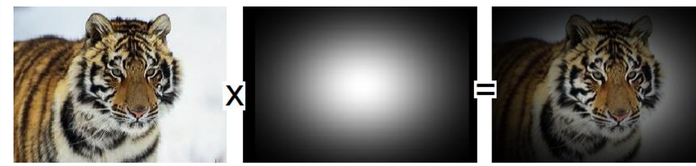
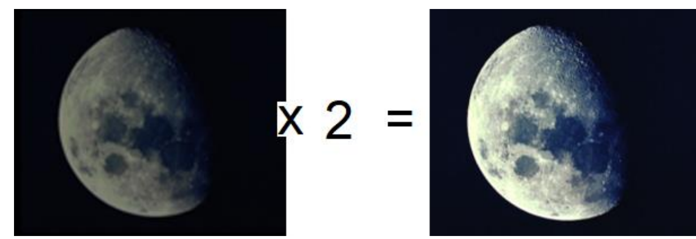


Image :Arithmetic Operation (masking)

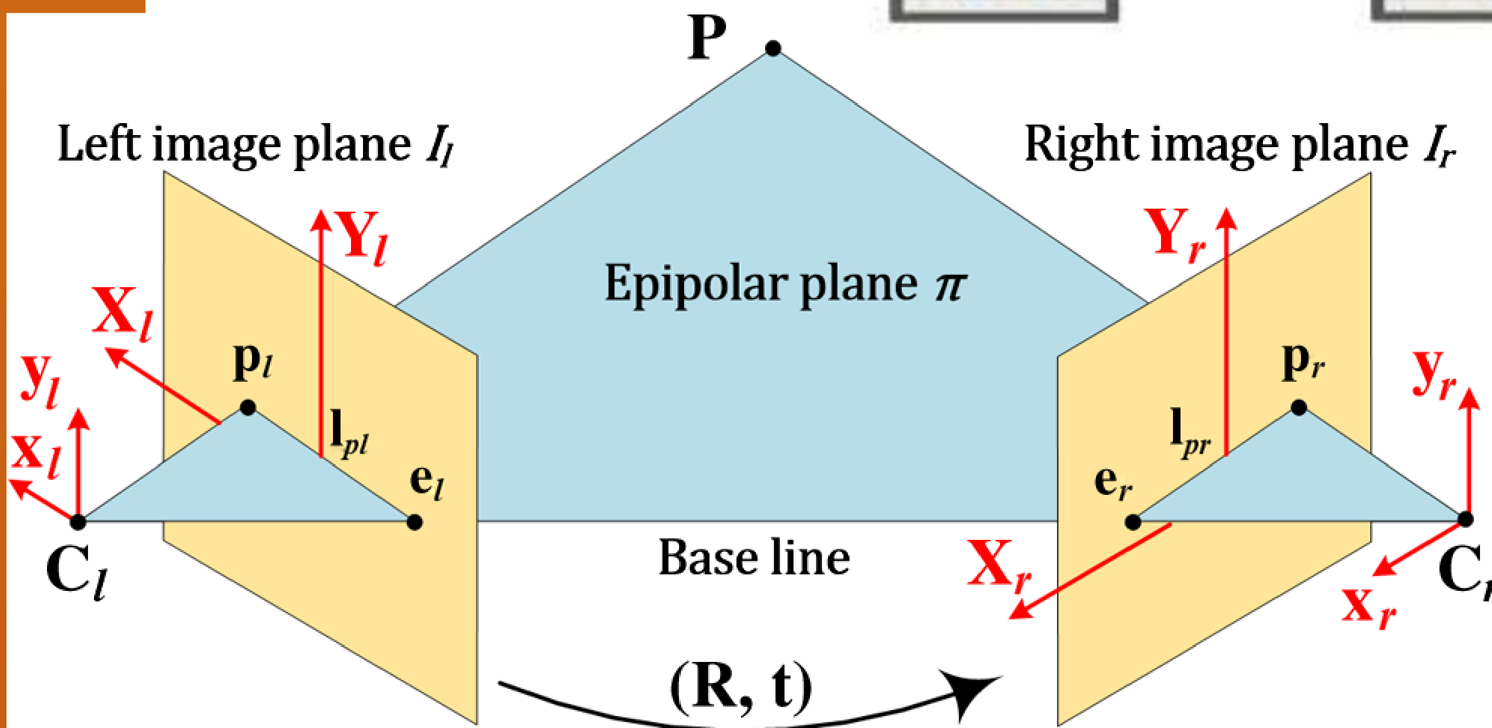
Operator	Equation
Multiply	$p_n = \min(p_a \times p_b, 255)$
Divide	$p_n = \max(p_a / p_b, 0)$
Add	$p_n = \min(p_a + p_b, 255)$
Subtract	$p_n = \max(p_a - p_b, 0)$
Modulo	$p_n = p_a \bmod p_b$
Absolute Difference	$p_n = \lvert p_a - p_b \rvert$





Stereo camera

Epipolar Geometry



Ref. : “Multiple View Geometry in Computer Vision”, Richard Hartley Andrew Zisserman

Image stitching

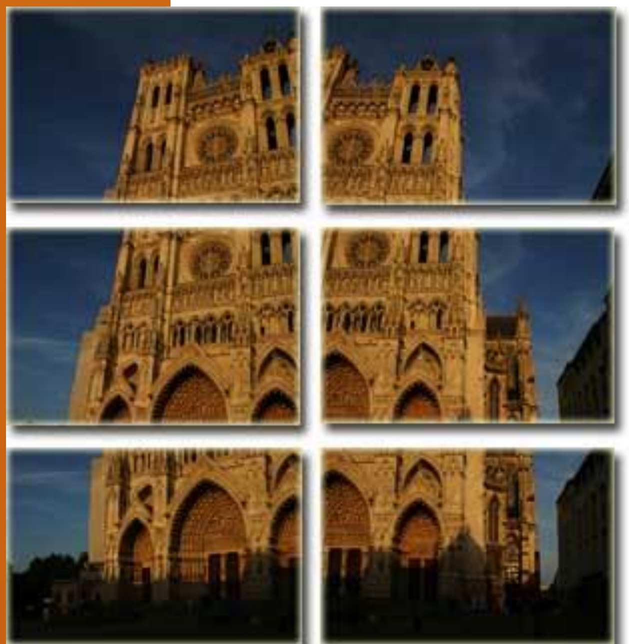
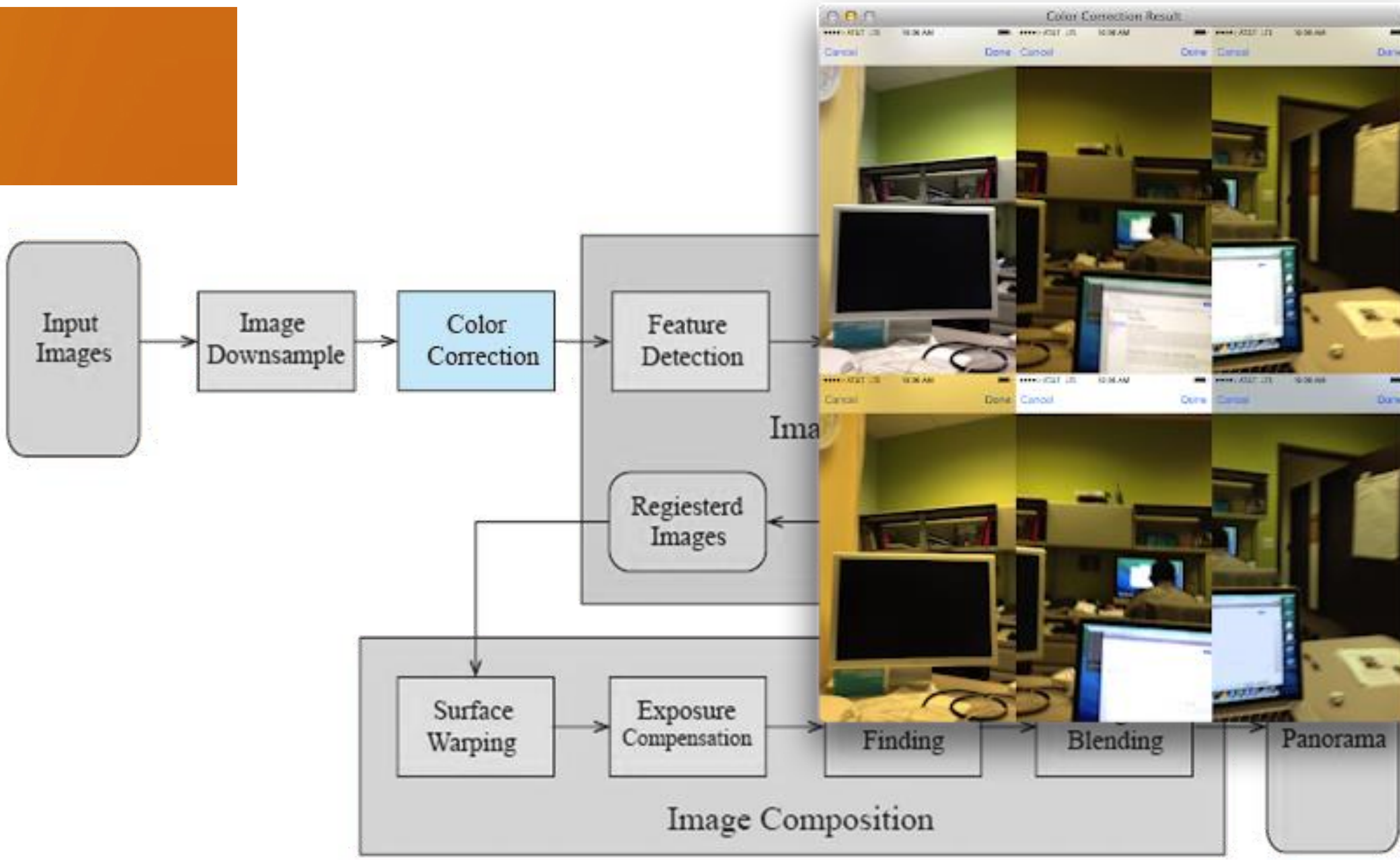
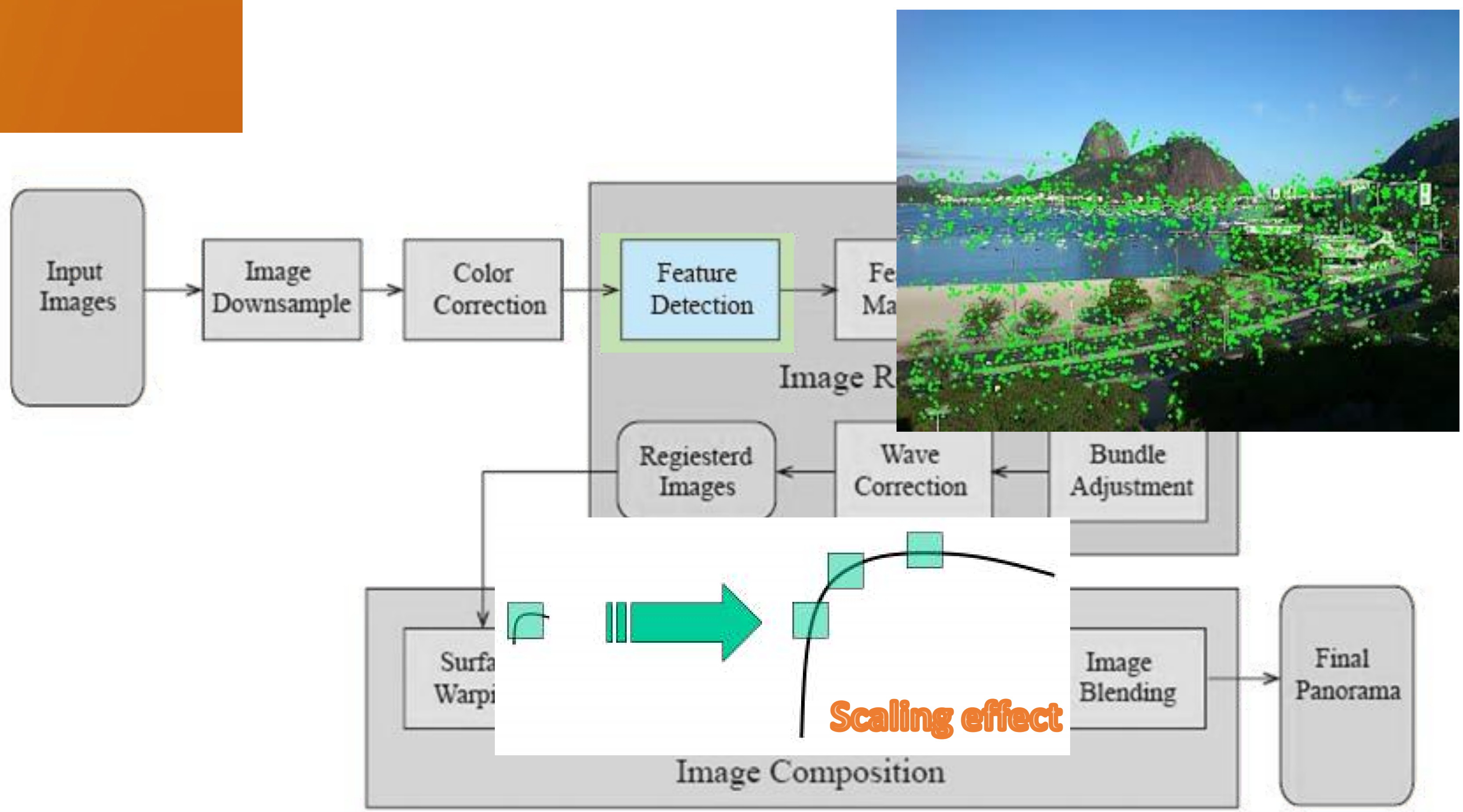


Image stitching algorithm



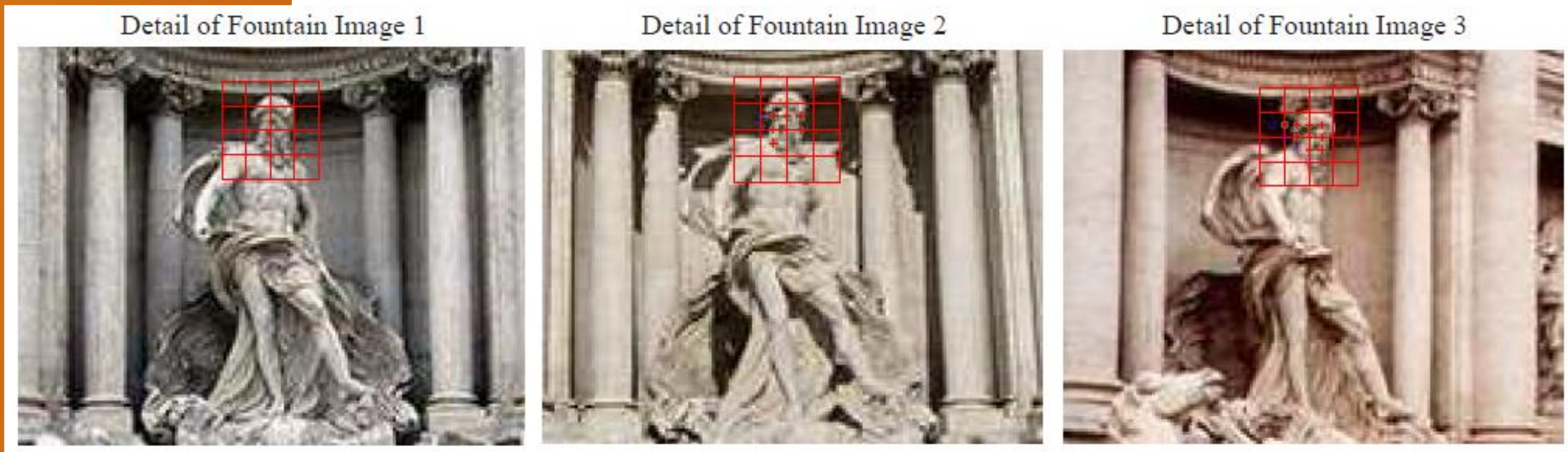
https://sites.google.com/site/ritpanoramaapp/project-stage-iii

Image stitching algorithm



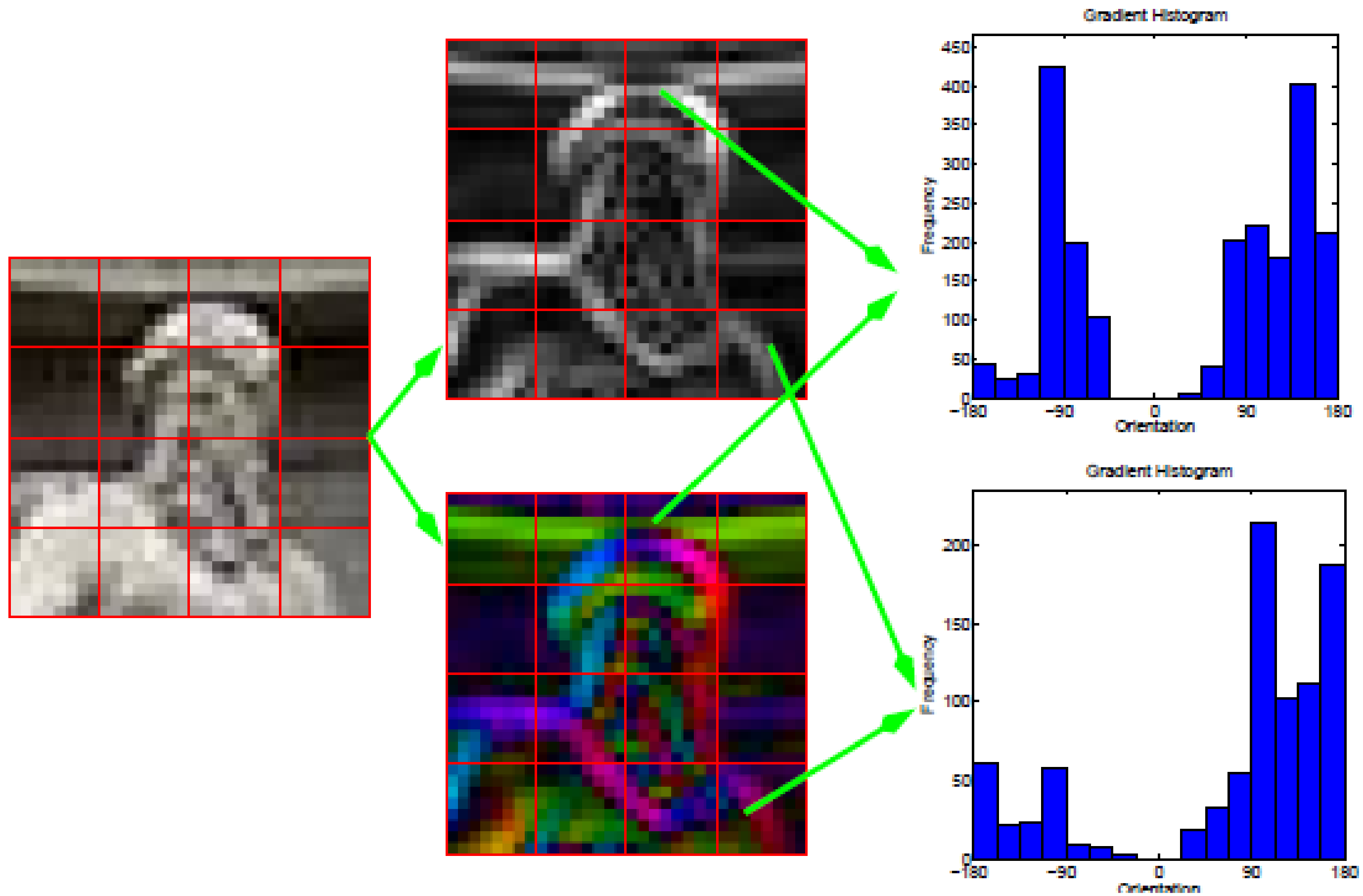
SIFT (Scale-Invariant Feature Transform)

Feature extraction



1. Ignore the variations.
2. **Insensitivity to Image Deformations.**
3. **Insensitivity to Lighting**

Histograms of Gradient (HoG) Features



- Compute image gradient magnitudes and directions over the whole image, thresholding small gradient magnitudes to zero.
- Center the cell grid on an image location.
- The resulting HoG vector is normalized (often simply to unit length).

Hog results

Fountain Image 1

Fountain Image 2

Fountain Image 3

Image stitching algorithm

Local registration assumes that the rotation matrices of the camera used for capturing each image are the same unity matrices

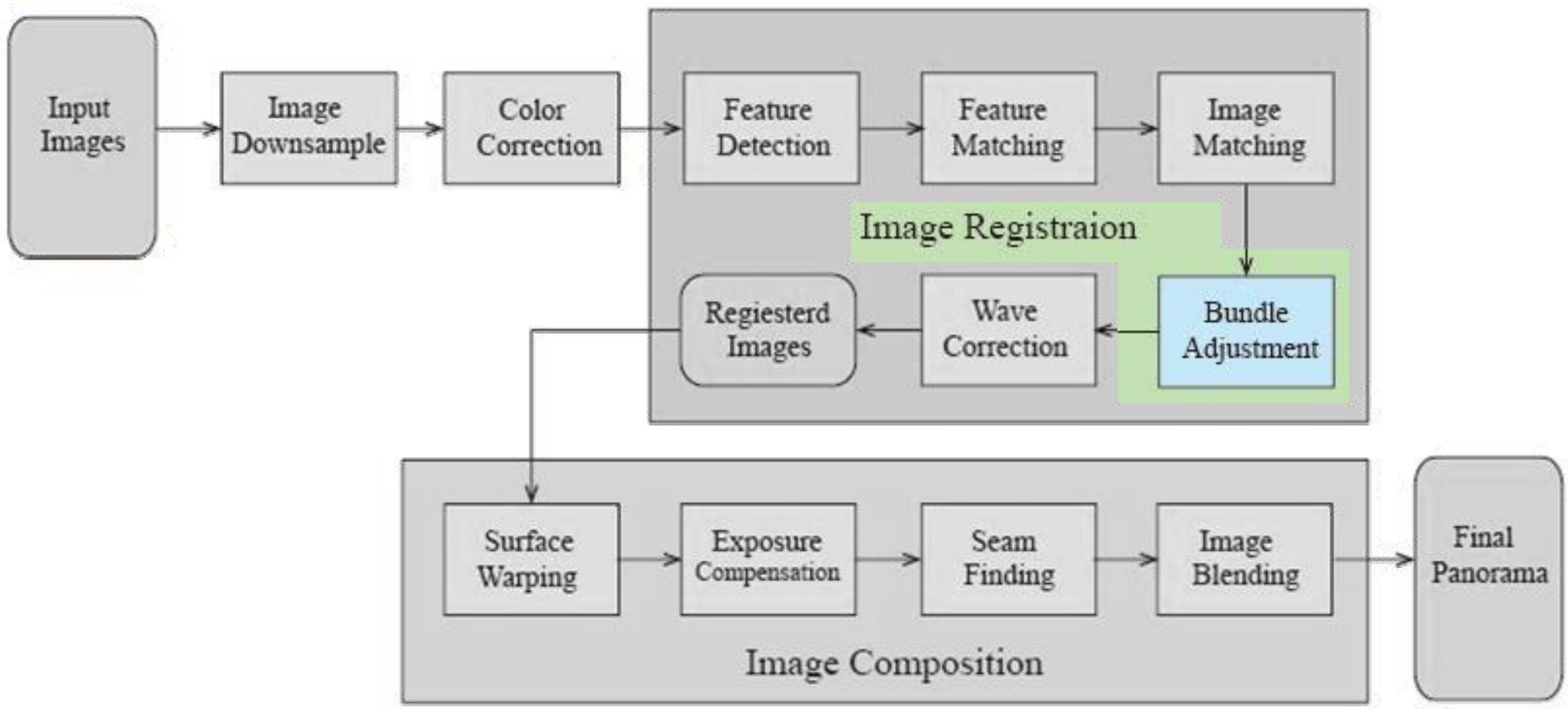


Image stitching algorithm

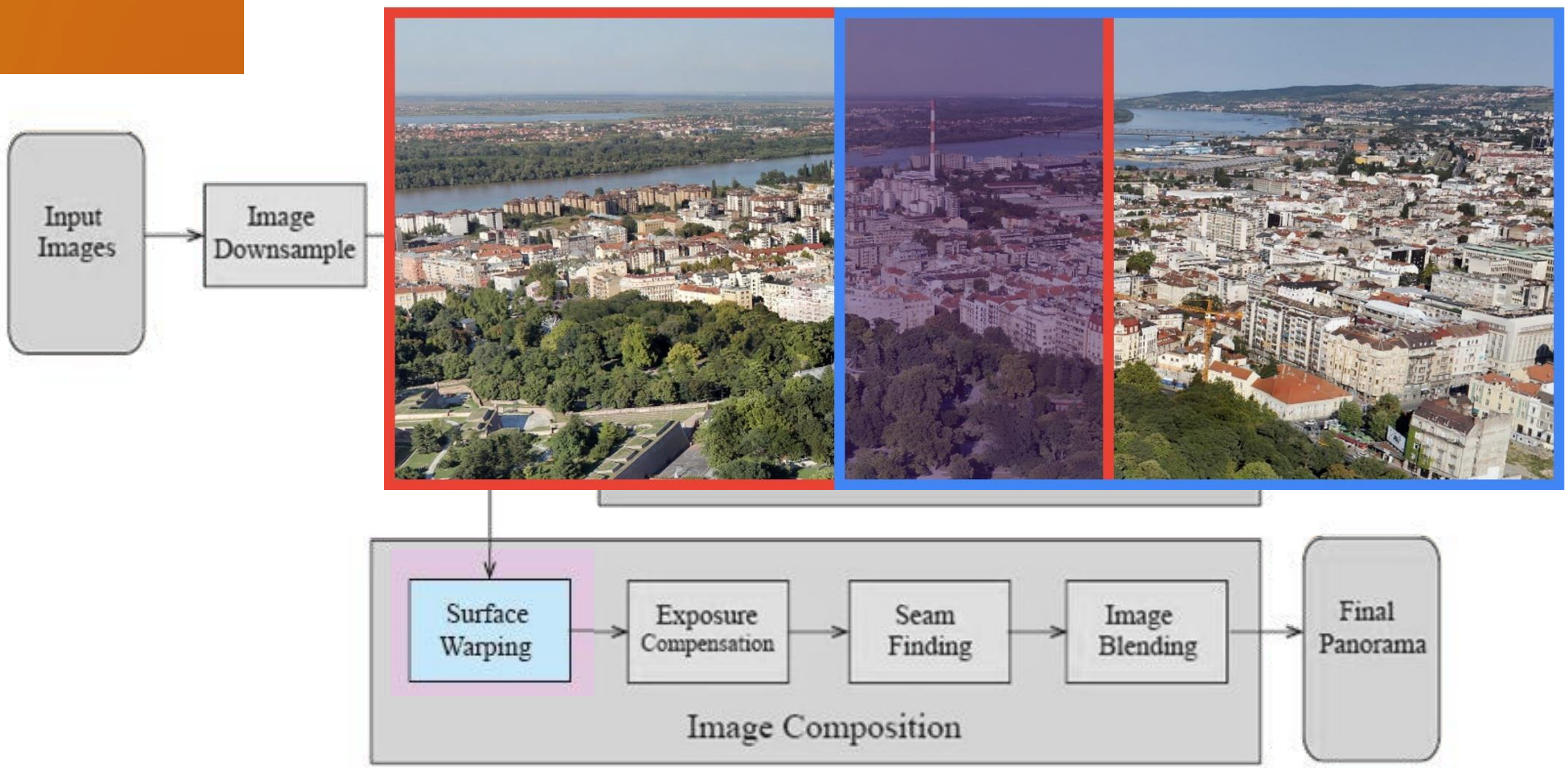
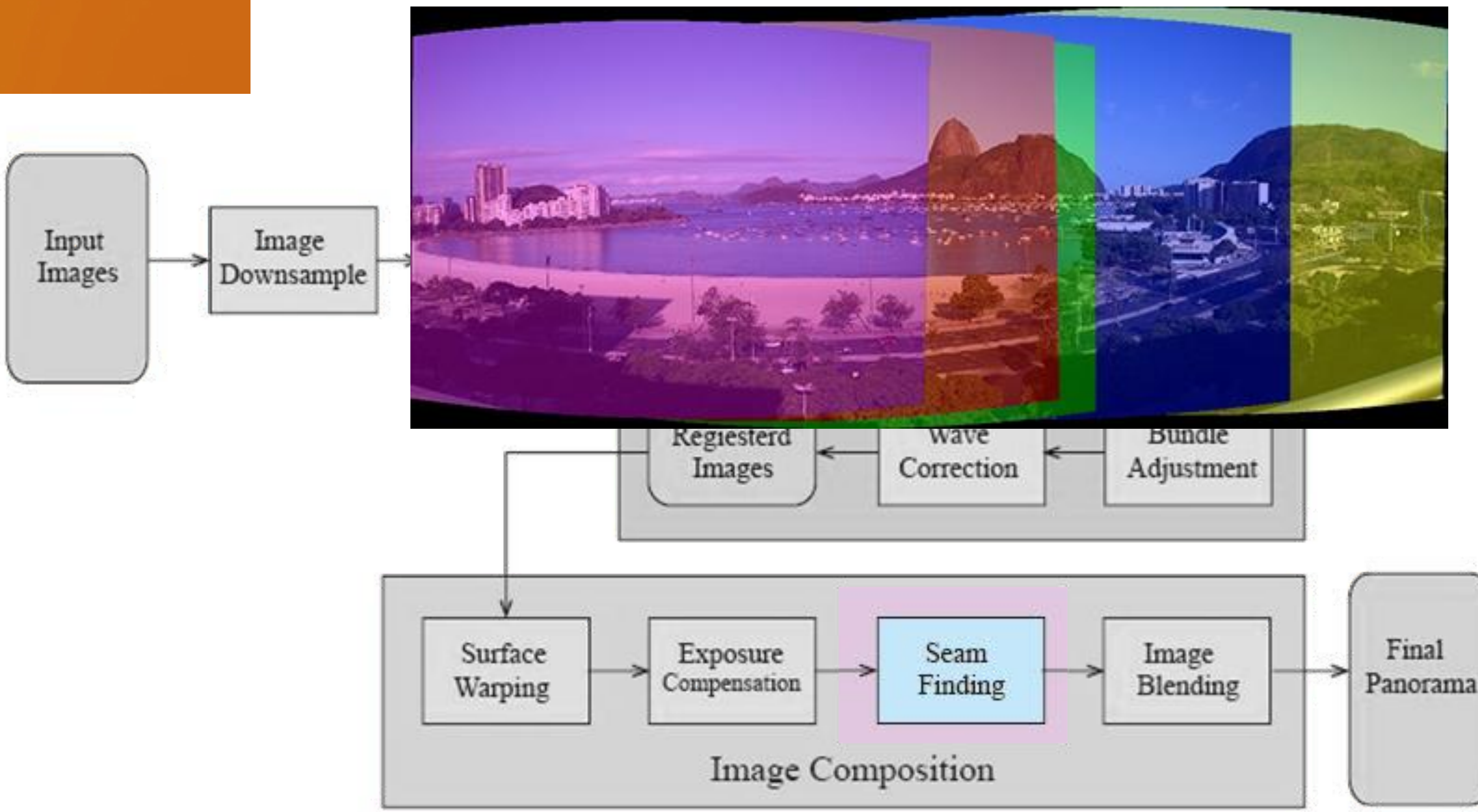


Image stitching algorithm



AI and computer vision

Ref.

- Ref.: “Introduction To Robotics”, Subir Kumar **Saha**