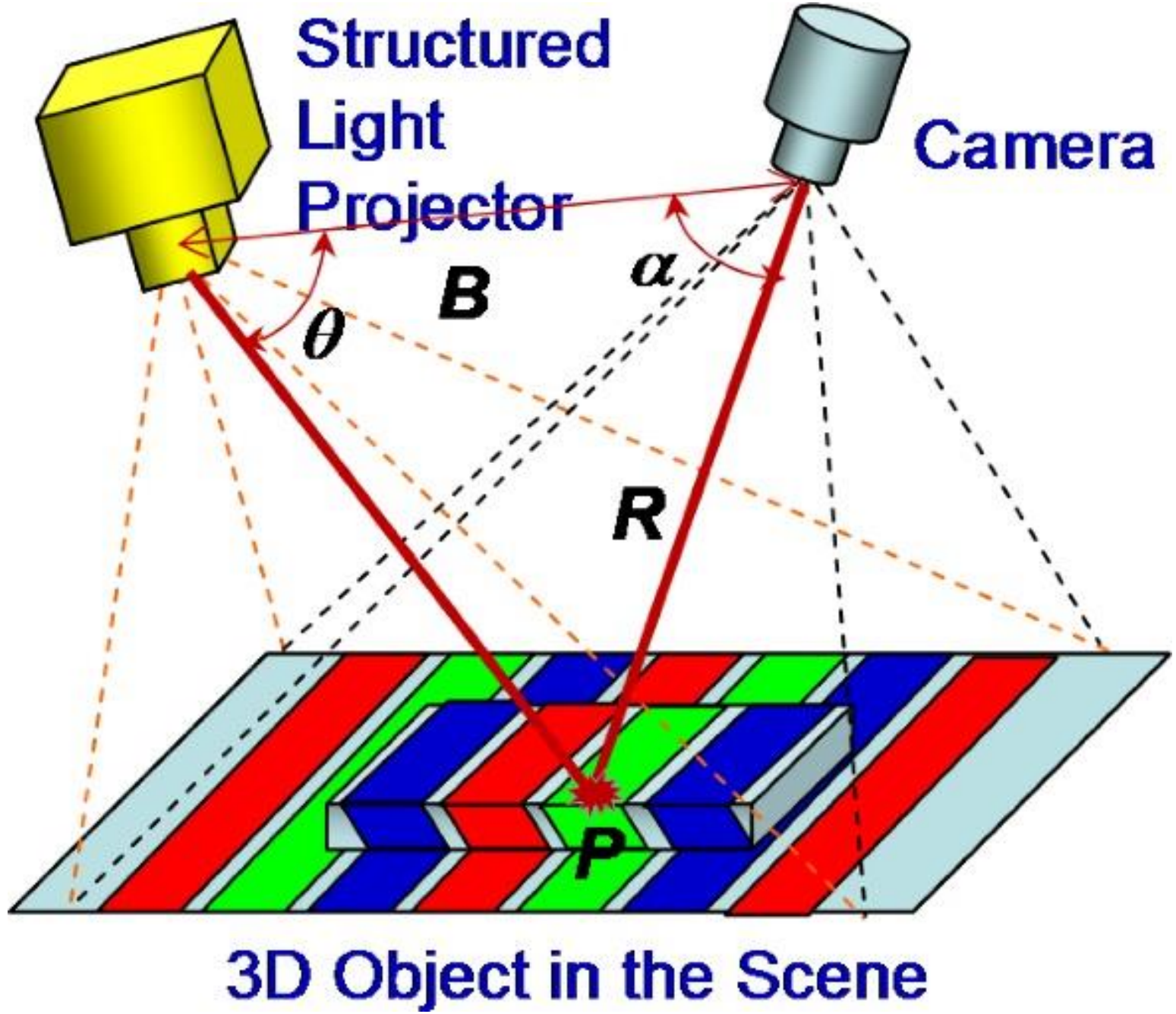
3D Reconstruction Using Structured Light Photogrammetry

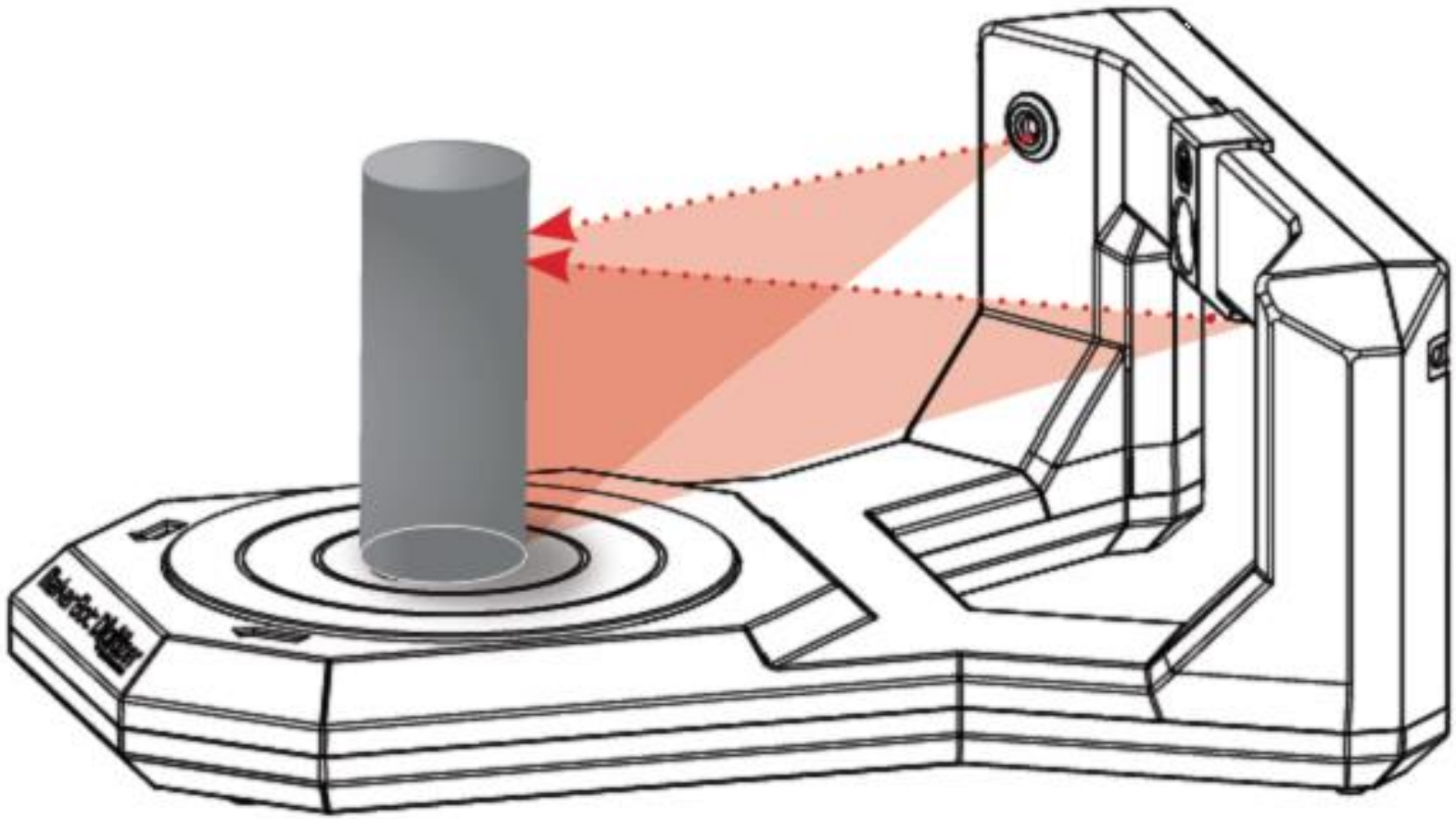
Jim Bethel

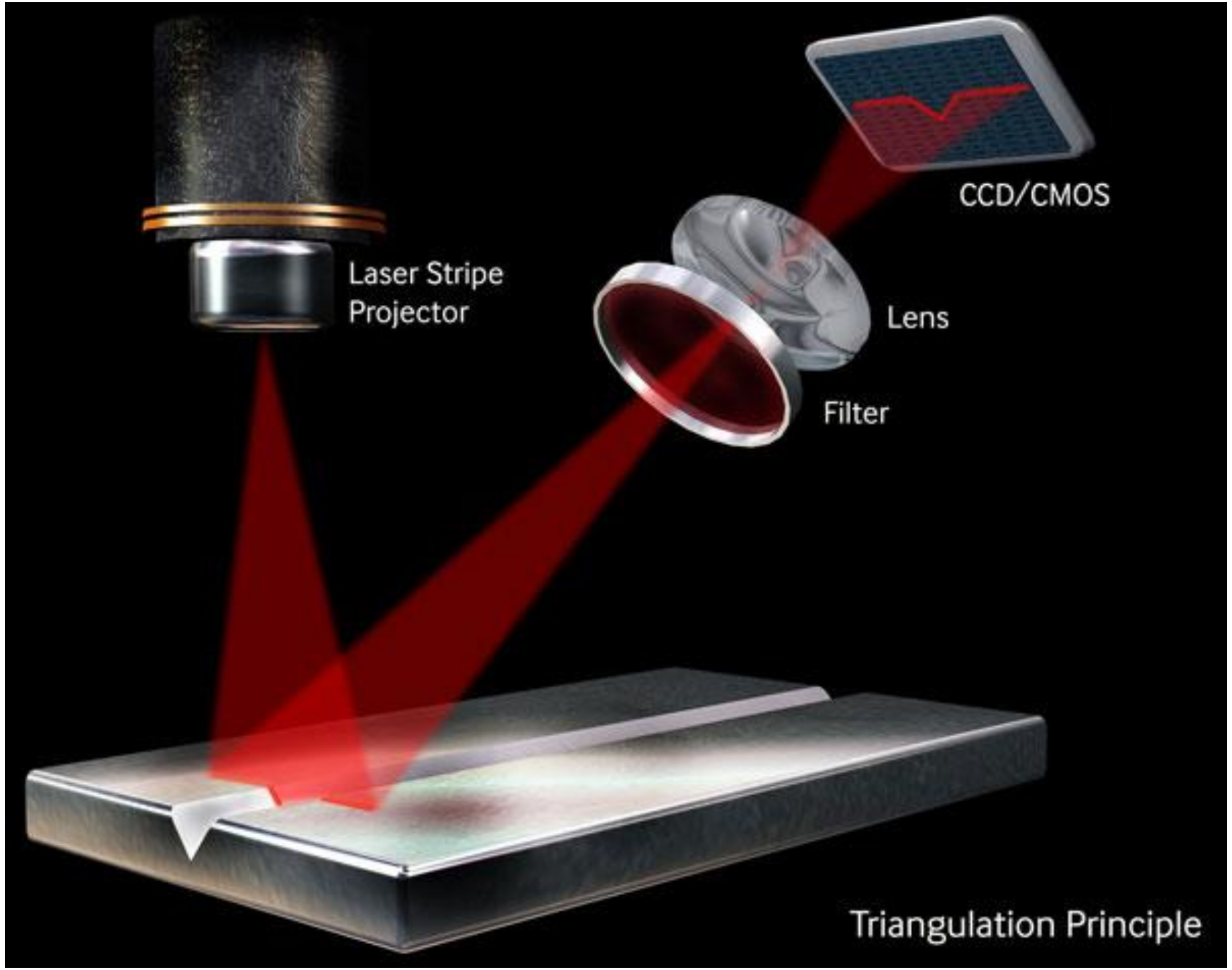

Structured
Light
Projector
Camera
B
θ
α
R
P
3D Object in the Scene

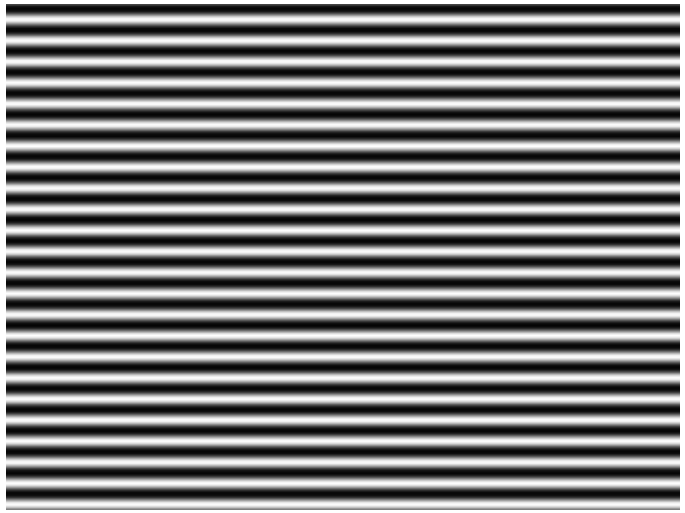

DAVID
DAVID

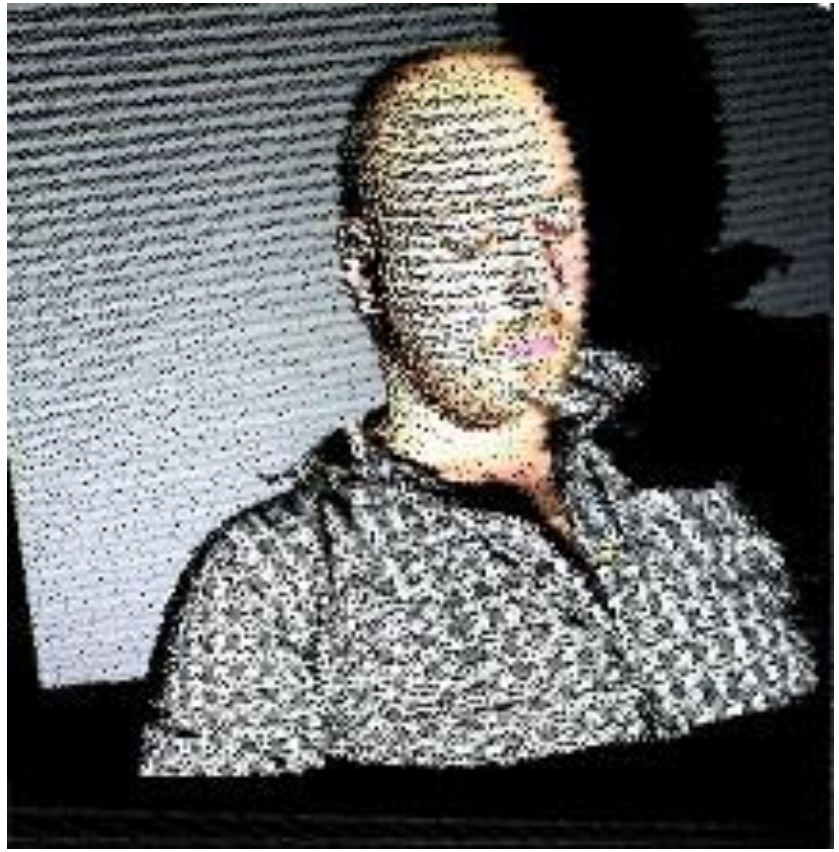

IR Projector
RGB Camera
IR Camera
XBOX 360


MakerBot Digitizer
DESKTOP 3D SCANNER



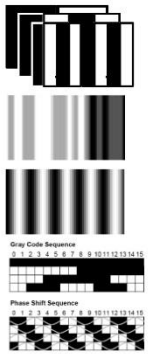

CCD/CMOS
Laser Stripe
Projector
Lens
Filter
Triangulation Principle



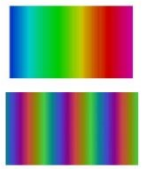


Structured Light 3D Surface Imaging Techniques

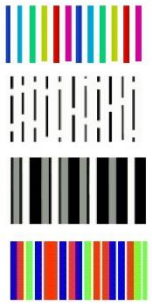
- Sequential Projections (Multi-Shots)
  - Binary Code
  - Gray Code
  - Phase Shift
  - Hybrid: Gray code + Phase Shift



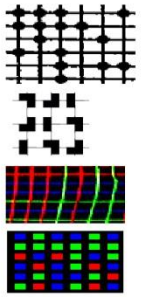
- Continuous Varying Pattern (Single Shot)
  - Rainbow 3D Camera
  - Continuously Varying Color Code



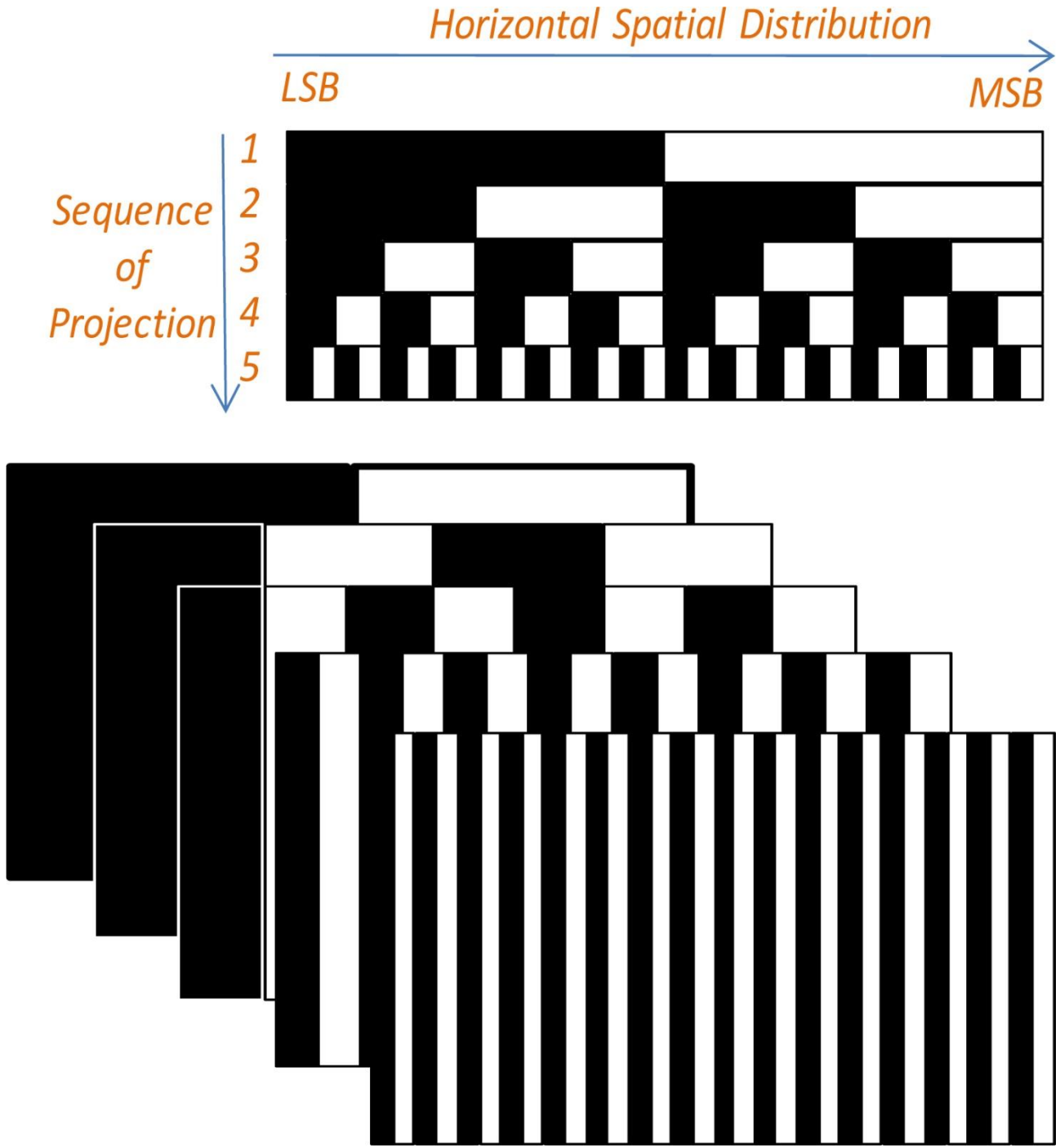
- Stripe Indexing (Single Shot)
  - Color Coded Stripes
  - Segmented Stripes
  - Gray Scale Coded Stripes
  - De Bruijn Sequence

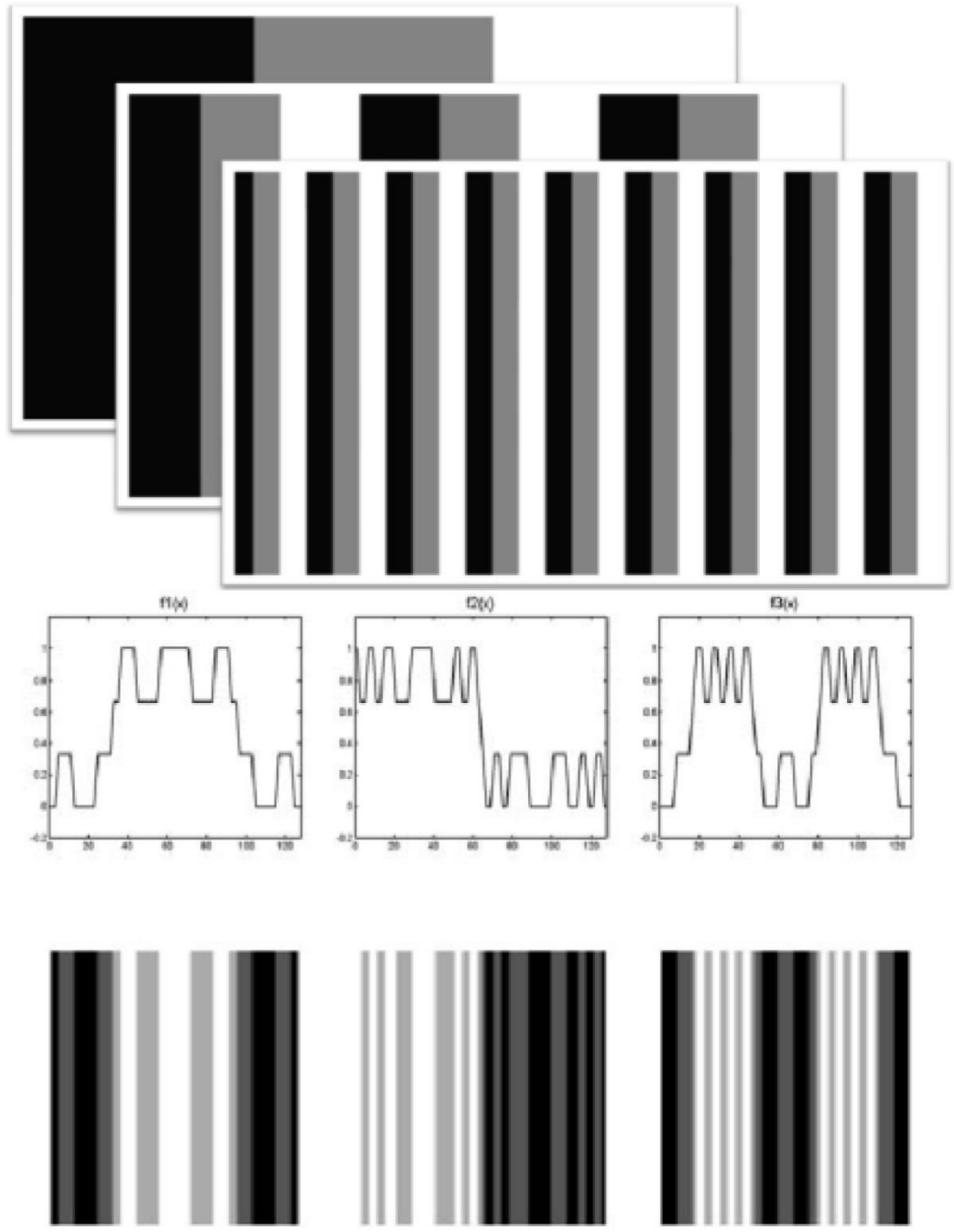


- Grid Indexing (Single Shot)
  - Pseudo Random Binary-Dots
  - Mini-Patterns as Codewords
  - Color Coded Grid
  - 2D Color Coded Dot Array

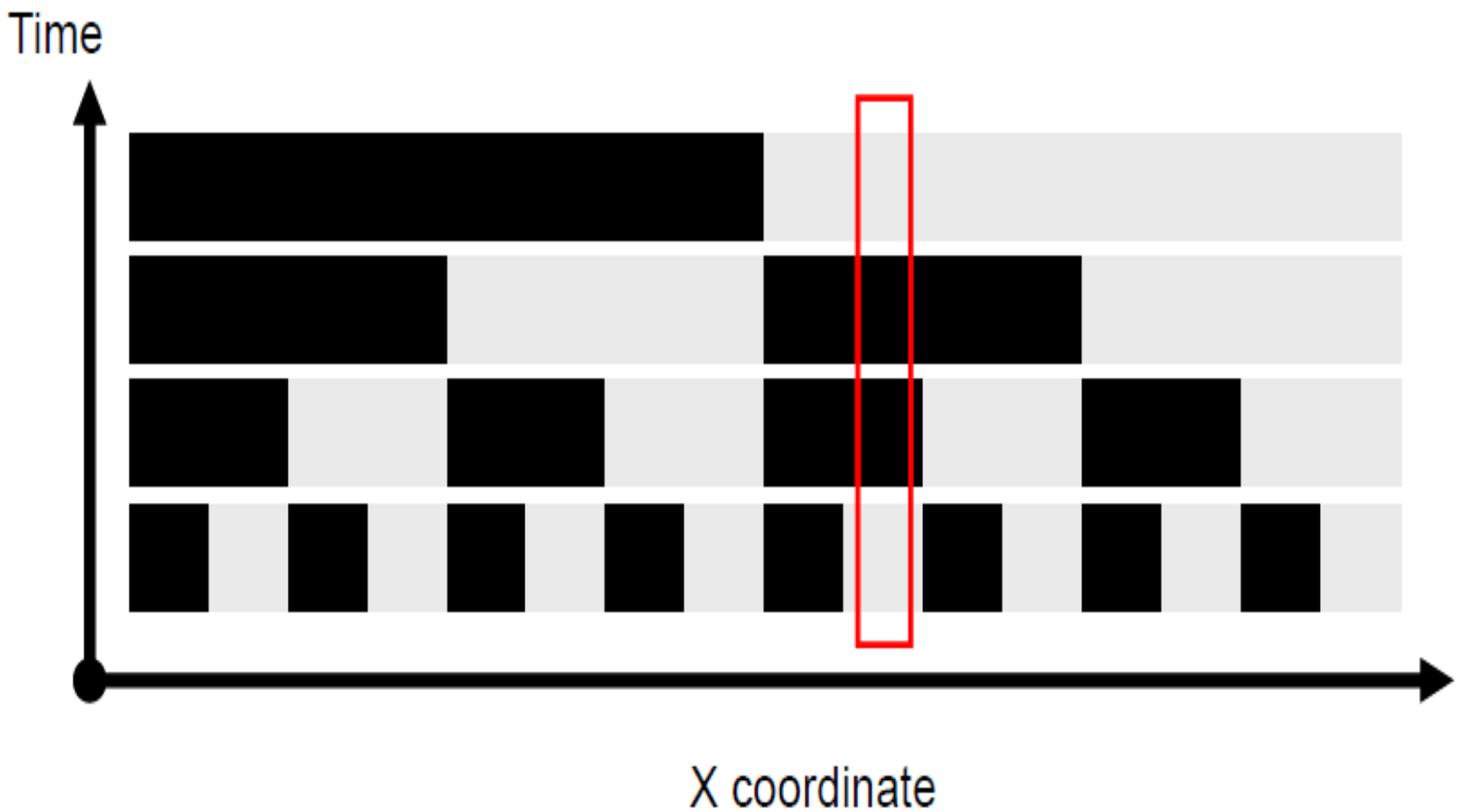


- Hybrid Methods

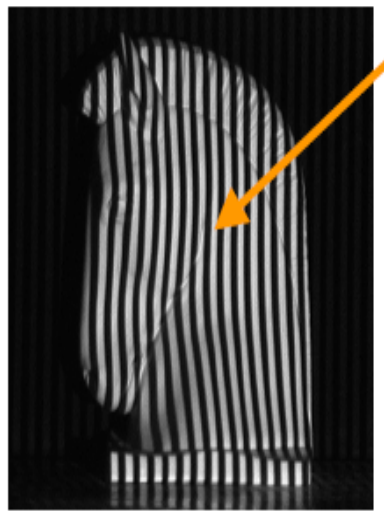

Horizontal Spatial Distribution
LSB
MSB
Sequence of Projection
1
2
3
4
5

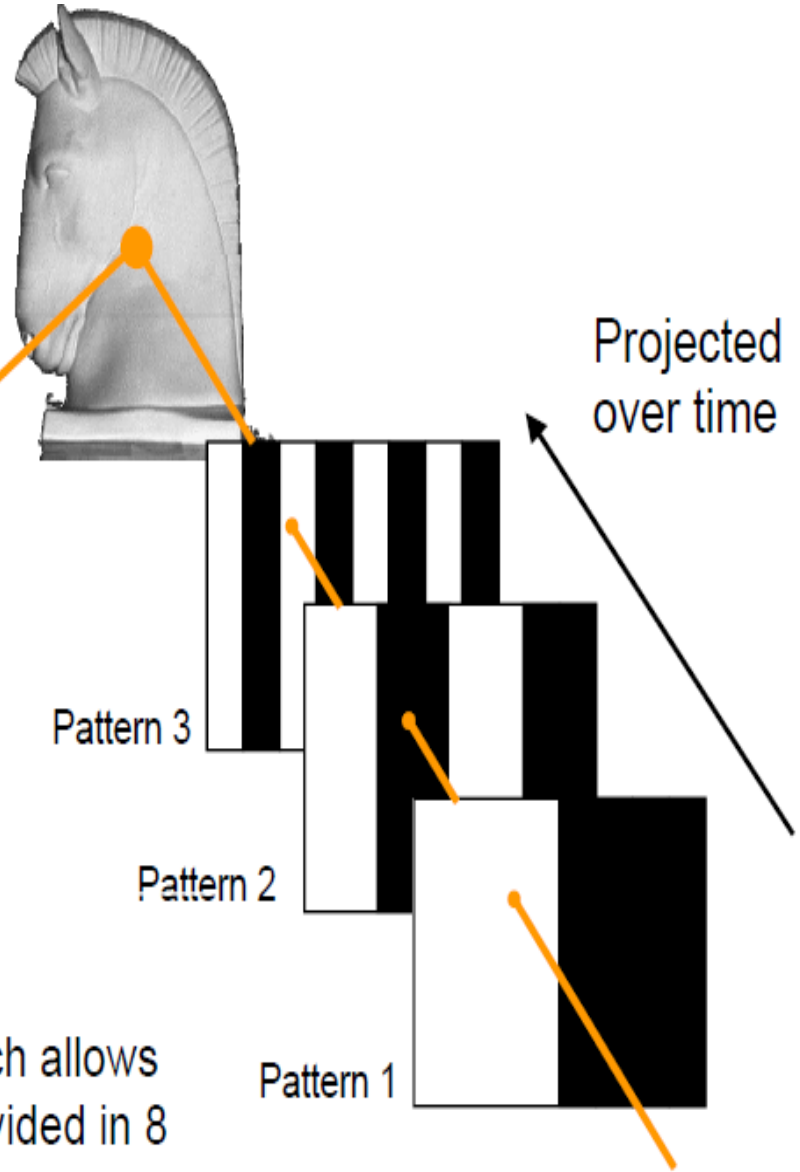

f1(x)
f2(x)
f3(x)

- Assign each pixel a unique illumination code over time [Posdamer 82]



$2^n - 1$ stripes in n images





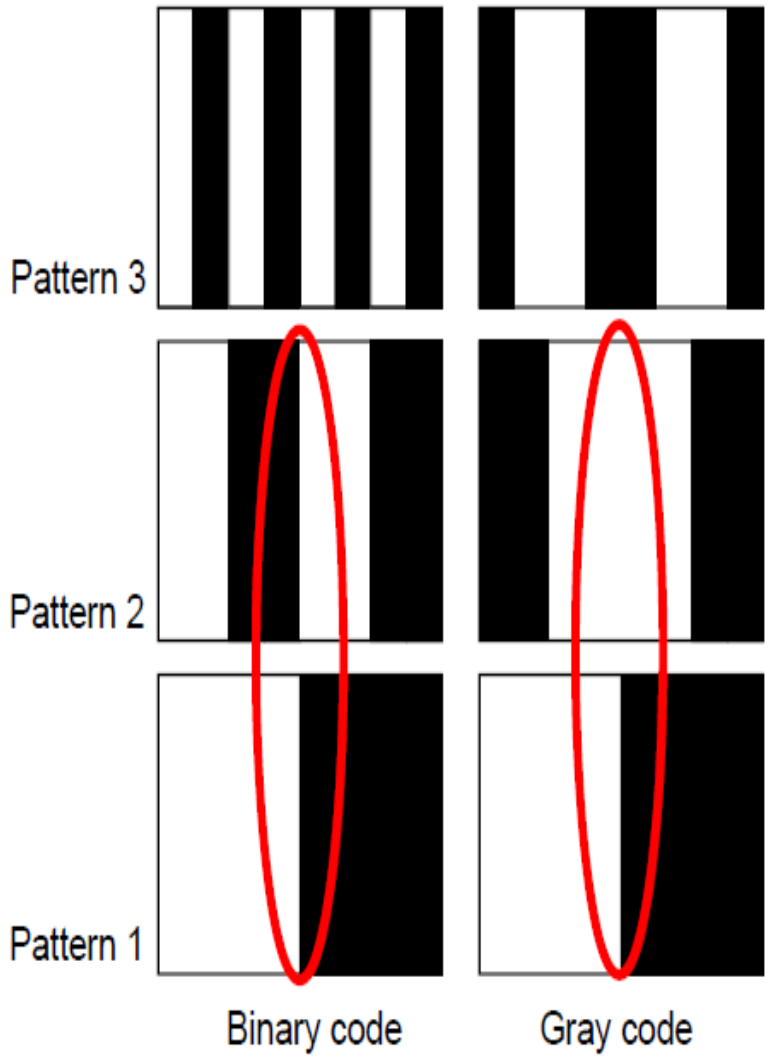
Example:

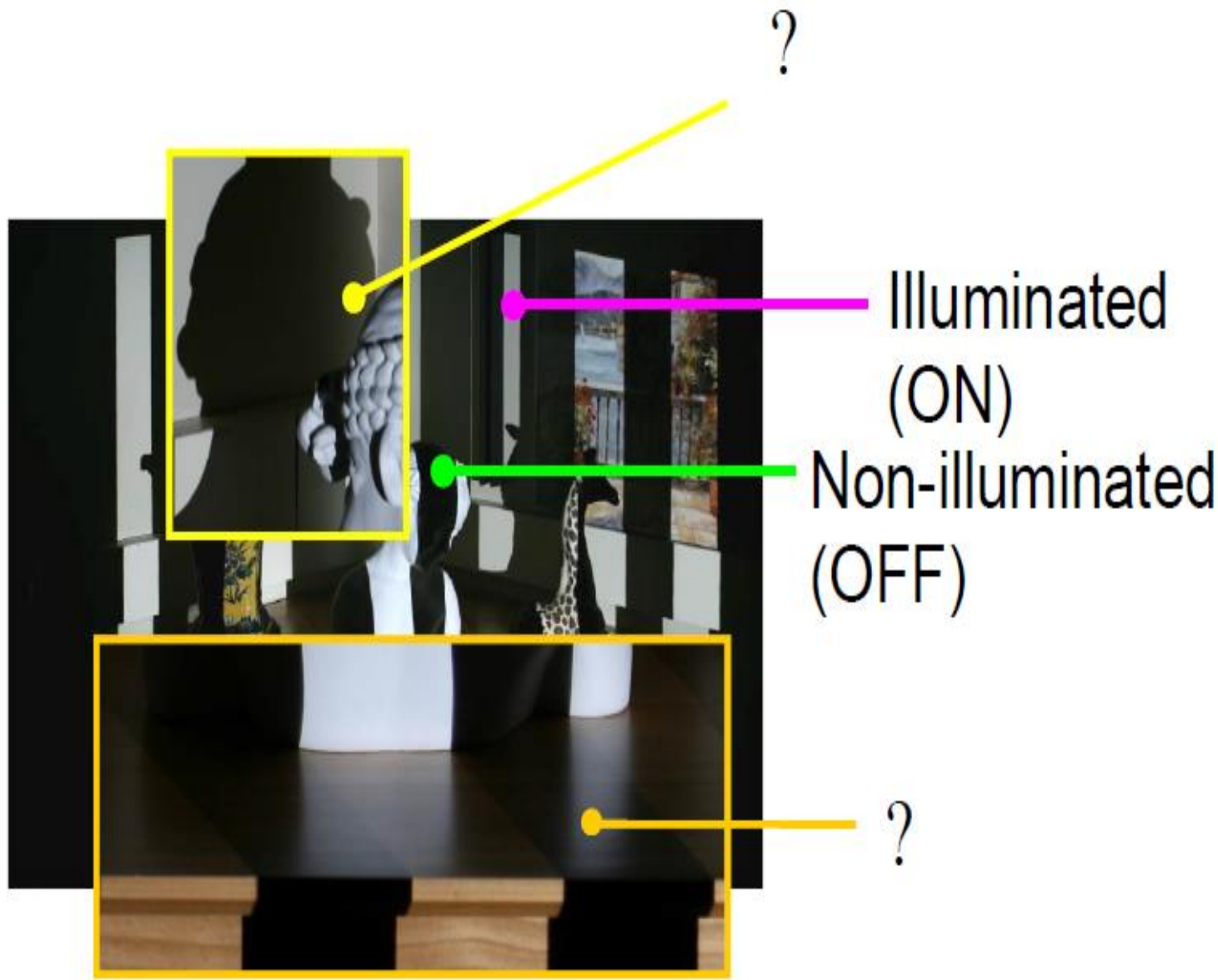
3 binary-encoded patterns which allows the measuring surface to be divided in 8 sub-regions

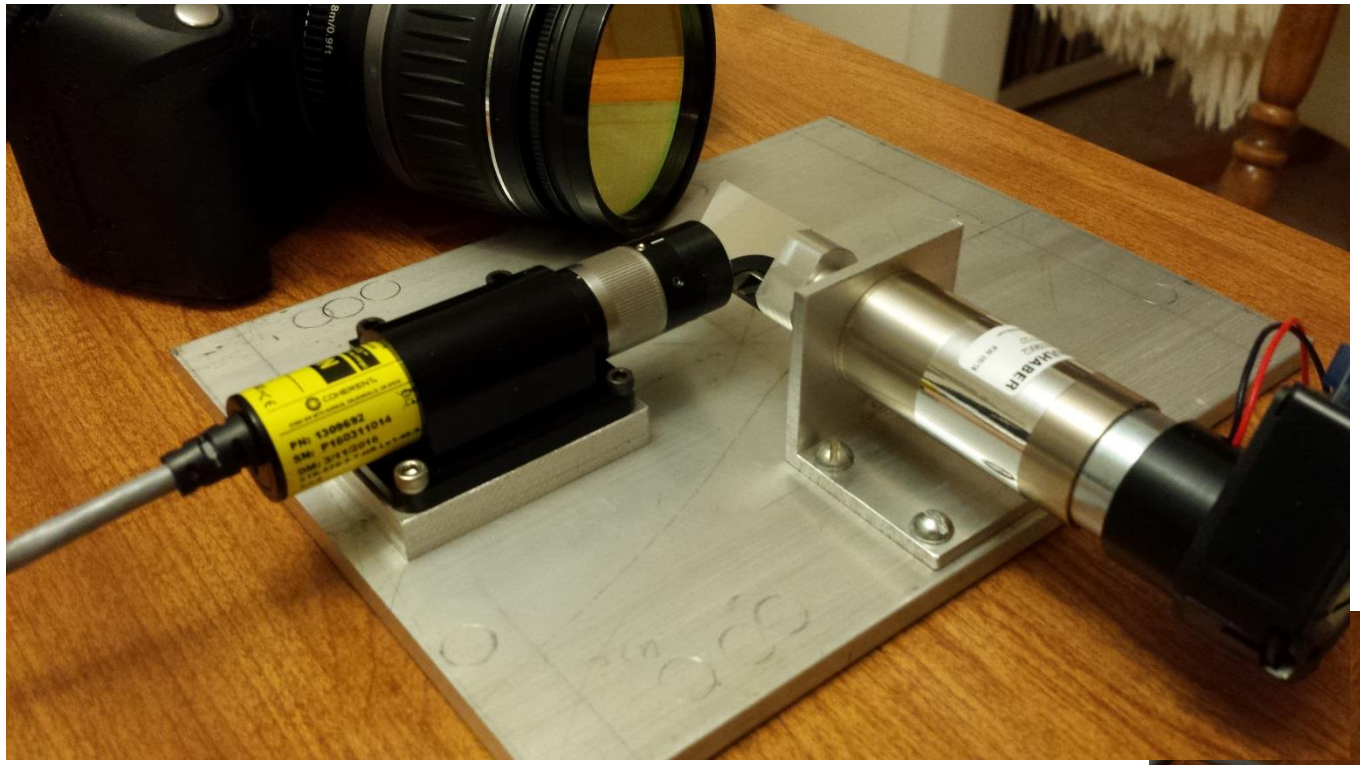
Binary vs Gray Codes

Decimal	Binary	Gray Code
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101
10	1010	1111

Binary vs Gray Codes




?
Illuminated
(ON)
Non-illuminated
(OFF)
?



Elements of System

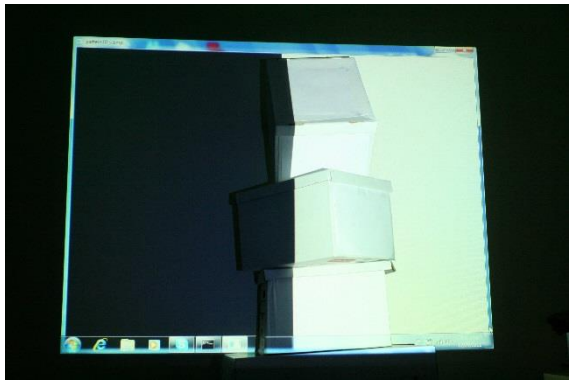
- Laser line generator (current one at 515 nm wavelength)
- Operational system will use laser in the infrared
- Ability to modulate the intensity (on / off)
- Programmable scan mirror to sweep the line across the object
- DSLR camera with narrow bandpass filter (510-520 nm)
- Rotary table to permit scanning horizontally and vertically

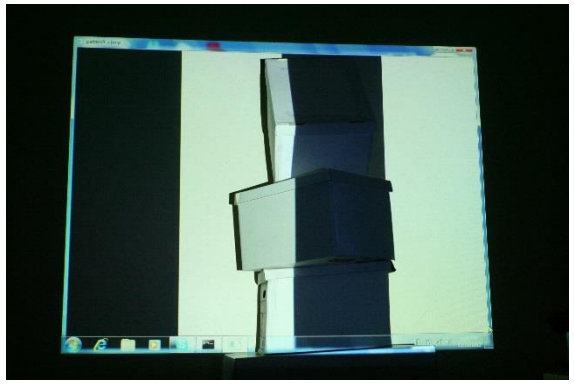
Operations

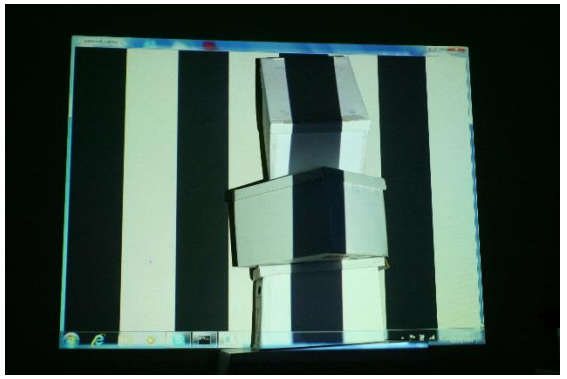
- Scan the scene multiple times
- Via the modulation generate binary patterns at increasing spatial frequency
- Record each scan using time exposure on camera and narrow band filter, short baseline to minimize shadows
- Repeat this process for both horizontal and vertical directions
- Stack of such images encodes the ray direction from the laser at any point in the scene

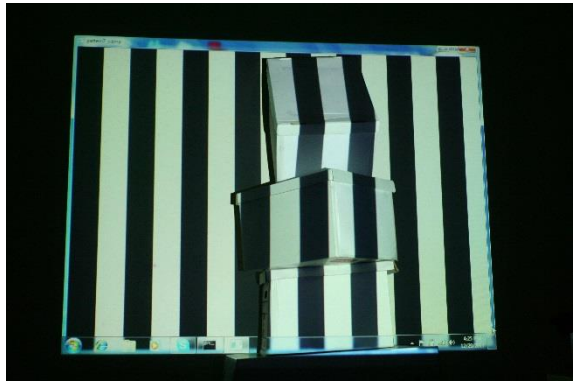
- Implicit correspondence between each camera pixel and its conjugate ray defined by the binary encoding means there is no matching or searching.
- Just have to do space intersection at each camera pixel

Previous effort unsatisfactory due to low contrast from the projector







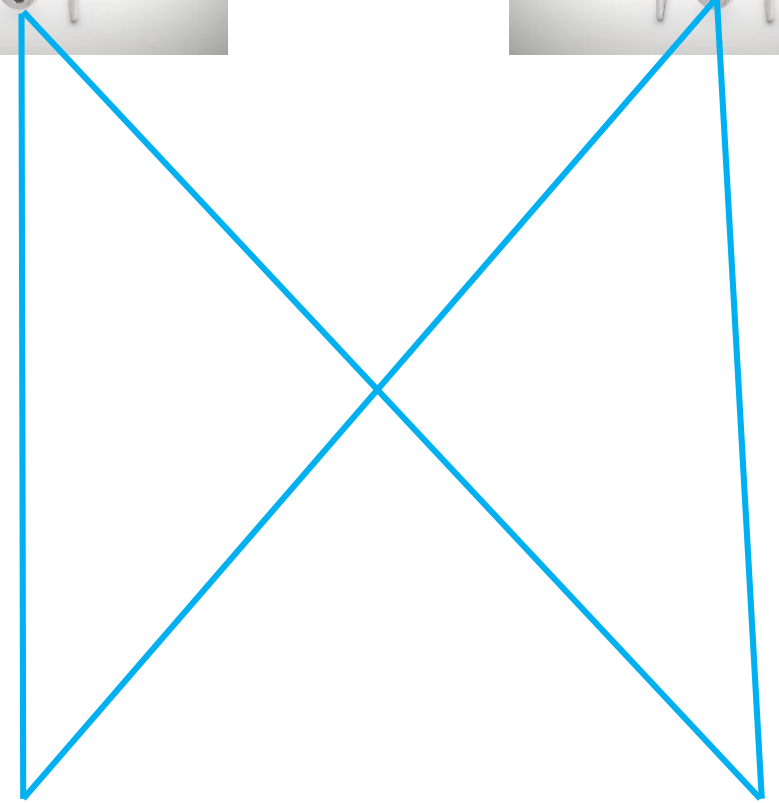


Advantages of such a system

- Low cost (we only use the laser for illumination, not ranging)
- Overcomes lack of texture in the scene
- Will work in the dark
- Get a depth for each camera pixel with no matching
- Combination of laser and narrow band filter should yield very high contrast
- Could be used for indoor mapping

Projector vehicle

Camera vehicle



Will require good position and attitude !!

Use such a system on cooperative UAV’s