

Computer Vision

Kumar Bipin

BE, MS, PhD (MMTU, IISc, IIIT-Hyderabad) (Robotics Control and Computer Vision)

Motorola, STMicroelectronics, Tata Elxsi (Technical Manager)

Computer Vision

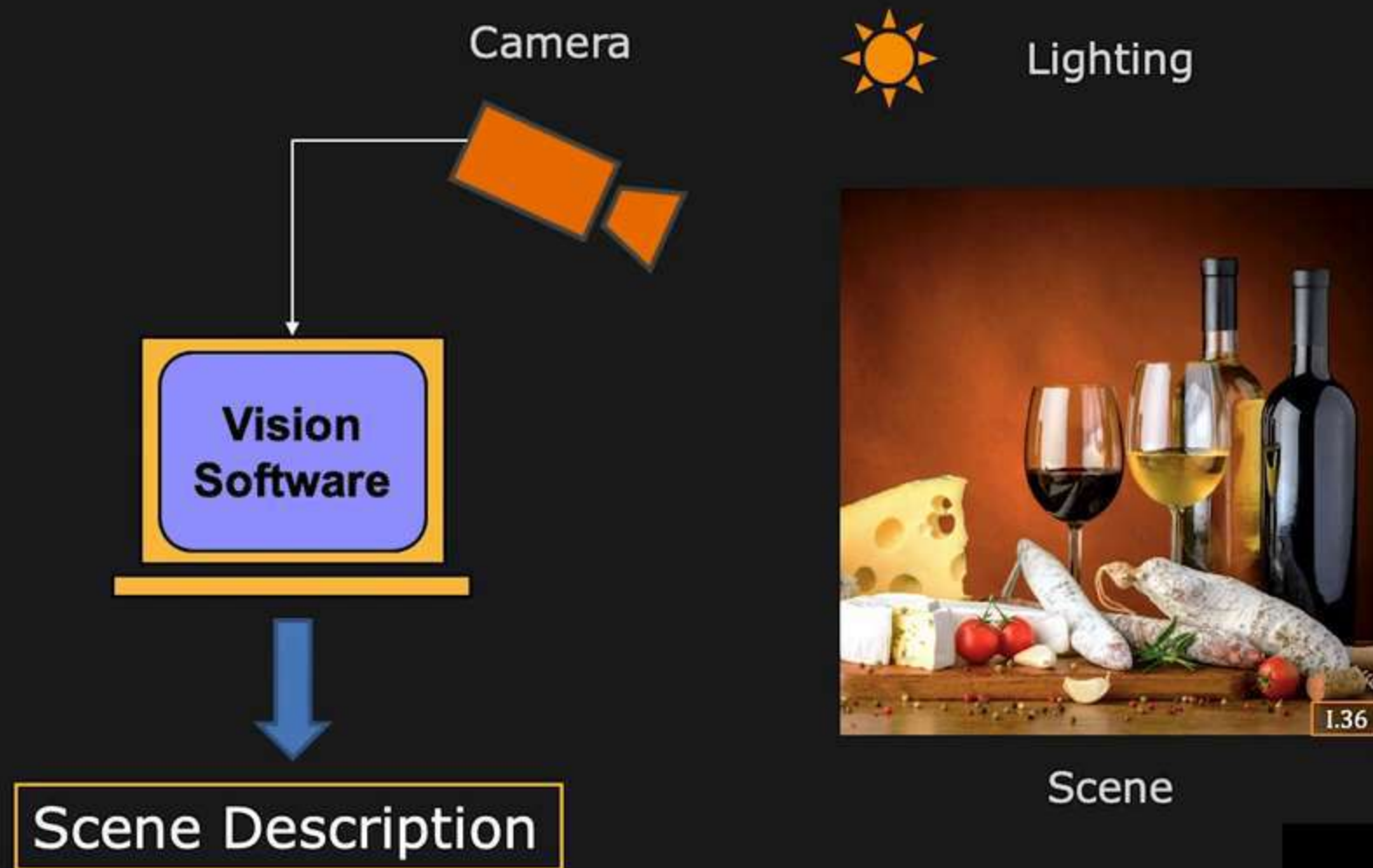
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What is Computer Vision?



But, What Really is Computer Vision?

Vision is

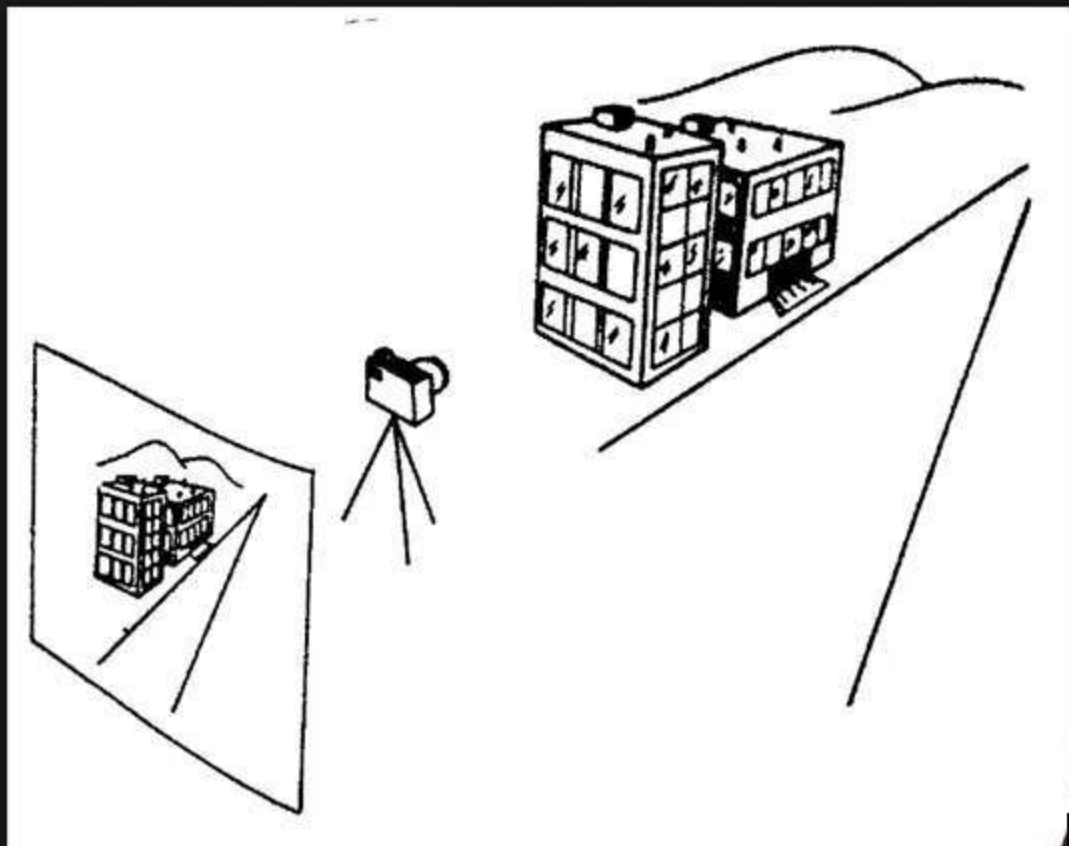
- ... automating human visual processes
- ... an information processing task
- ... inverting image formation
- ... inverse graphics

Vision Deals with Images

An Image is an **Array of Pixels**

A Pixel has Values:

- Brightness
- Color
- Distance
- Material
- ...



Images Are Interesting



But When You Look Close...

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 157 | 159 | 159 | 104 | 104 | 115 | 128 | 131 | 133 | 133 | 132 | 131 | 132 | 130 | 129 | 118 | 132 | 158 | 156 | 153 | 190 | 144 | 117 | 126 | 120 | 81 |
| 159 | 165 | 153 | 101 | 103 | 113 | 126 | 129 | 130 | 130 | 126 | 124 | 127 | 128 | 127 | 120 | 122 | 158 | 159 | 154 | 160 | 190 | 121 | 118 | 67 | 47 |
| 162 | 154 | 154 | 98 | 101 | 114 | 124 | 127 | 130 | 132 | 144 | 159 | 155 | 132 | 123 | 119 | 119 | 148 | 154 | 150 | 140 | 185 | 161 | 60 | 48 | 45 |
| 141 | 132 | 158 | 93 | 98 | 110 | 121 | 125 | 122 | 129 | 143 | 172 | 191 | 188 | 143 | 105 | 117 | 148 | 140 | 145 | 142 | 153 | 105 | 44 | 49 | 71 |
| 100 | 130 | 157 | 93 | 99 | 110 | 120 | 116 | 116 | 129 | 138 | 163 | 191 | 205 | 211 | 130 | 107 | 153 | 98 | 133 | 147 | 107 | 44 | 47 | 81 | 151 |
| 87 | 130 | 157 | 92 | 97 | 109 | 124 | 111 | 123 | 134 | 139 | 175 | 194 | 201 | 207 | 205 | 126 | 151 | 74 | 114 | 160 | 57 | 49 | 63 | 141 | 163 |
| 93 | 131 | 159 | 92 | 98 | 112 | 132 | 108 | 123 | 133 | 162 | 180 | 183 | 192 | 196 | 205 | 184 | 151 | 138 | 199 | 195 | 54 | 47 | 119 | 161 | 156 |
| 96 | 134 | 164 | 95 | 97 | 113 | 147 | 108 | 125 | 142 | 156 | 171 | 173 | 178 | 184 | 181 | 186 | 191 | 206 | 203 | 161 | 44 | 84 | 158 | 159 | 155 |
| 95 | 137 | 165 | 95 | 95 | 111 | 168 | 122 | 130 | 137 | 145 | 139 | 144 | 139 | 145 | 179 | 193 | 203 | 194 | 158 | 95 | 49 | 135 | 160 | 157 | 155 |
| 101 | 139 | 166 | 94 | 96 | 104 | 172 | 130 | 126 | 130 | 108 | 77 | 85 | 80 | 153 | 191 | 188 | 161 | 144 | 113 | 48 | 83 | 161 | 160 | 156 | 153 |
| 101 | 133 | 167 | 94 | 96 | 100 | 154 | 137 | 123 | 92 | 67 | 57 | 72 | 153 | 182 | 184 | 175 | 101 | 116 | 53 | 48 | 119 | 166 | 163 | 159 | 152 |
| 99 | 130 | 169 | 97 | 99 | 109 | 131 | 128 | 84 | 55 | 60 | 75 | 149 | 176 | 170 | 194 | 209 | 99 | 79 | 51 | 67 | 150 | 158 | 155 | 154 | 151 |
| 97 | 129 | 170 | 97 | 98 | 118 | 122 | 94 | 66 | 56 | 56 | 140 | 161 | 114 | 136 | 187 | 163 | 81 | 85 | 52 | 98 | 161 | 159 | 154 | 148 | 137 |
| 92 | 123 | 173 | 101 | 98 | 129 | 95 | 74 | 74 | 45 | 94 | 174 | 106 | 115 | 126 | 168 | 108 | 60 | 92 | 55 | 128 | 157 | 153 | 148 | 145 | 157 |
| 81 | 115 | 175 | 104 | 116 | 87 | 78 | 69 | 84 | 56 | 140 | 124 | 158 | 170 | 143 | 173 | 150 | 76 | 90 | 68 | 148 | 153 | 146 | 148 | 186 | 196 |
| 69 | 108 | 172 | 107 | 103 | 87 | 82 | 54 | 83 | 105 | 93 | 107 | 153 | 166 | 132 | 162 | 153 | 68 | 87 | 97 | 157 | 149 | 141 | 179 | 204 | 206 |
| 71 | 119 | 172 | 106 | 91 | 78 | 97 | 70 | 99 | 104 | 59 | 116 | 142 | 153 | 141 | 165 | 123 | 55 | 84 | 132 | 154 | 146 | 148 | 199 | 209 | 210 |
| 61 | 126 | 175 | 112 | 83 | 74 | 92 | 123 | 130 | 53 | 61 | 108 | 137 | 132 | 138 | 154 | 77 | 58 | 82 | 150 | 152 | 143 | 155 | 210 | 211 | 213 |
| 53 | 128 | 175 | 105 | 71 | 82 | 109 | 127 | 75 | 50 | 57 | 74 | 115 | 139 | 151 | 117 | 47 | 67 | 89 | 154 | 154 | 143 | 159 | 218 | 214 | 199 |
| 56 | 115 | 173 | 105 | 61 | 76 | 106 | 114 | 70 | 54 | 52 | 60 | 102 | 137 | 160 | 146 | 78 | 67 | 96 | 135 | 130 | 125 | 165 | 215 | 142 | 81 |
| 117 | 106 | 176 | 101 | 55 | 71 | 81 | 112 | 101 | 57 | 55 | 70 | 117 | 139 | 152 | 188 | 198 | 112 | 87 | 146 | 131 | 112 | 178 | 164 | 81 | 91 |
| 107 | 121 | 177 | 89 | 50 | 64 | 60 | 103 | 114 | 66 | 56 | 90 | 120 | 140 | 149 | 169 | 201 | 194 | 100 | 148 | 134 | 155 | 208 | 120 | 99 | 99 |

Vision Research

- Vision is a Hard Problem
- Vision is Multi-Disciplinary
- Considerable Progress Has Been Made
- Many Successful Real-World Applications

What is Vision Used For?



Factory Automation: Vision-Guided Robotics

What is Vision Used For?



Factory Automation: Visual Inspection

What is Vision Used For?



Optical Character Recognition (OCR): Reading License Plates

What is Vision Used For?



1.2

Optical Character Recognition (OCR): Book Digitization

What is Vision Used For?



Biometrics: Iris Recognition

What is Vision Used For?



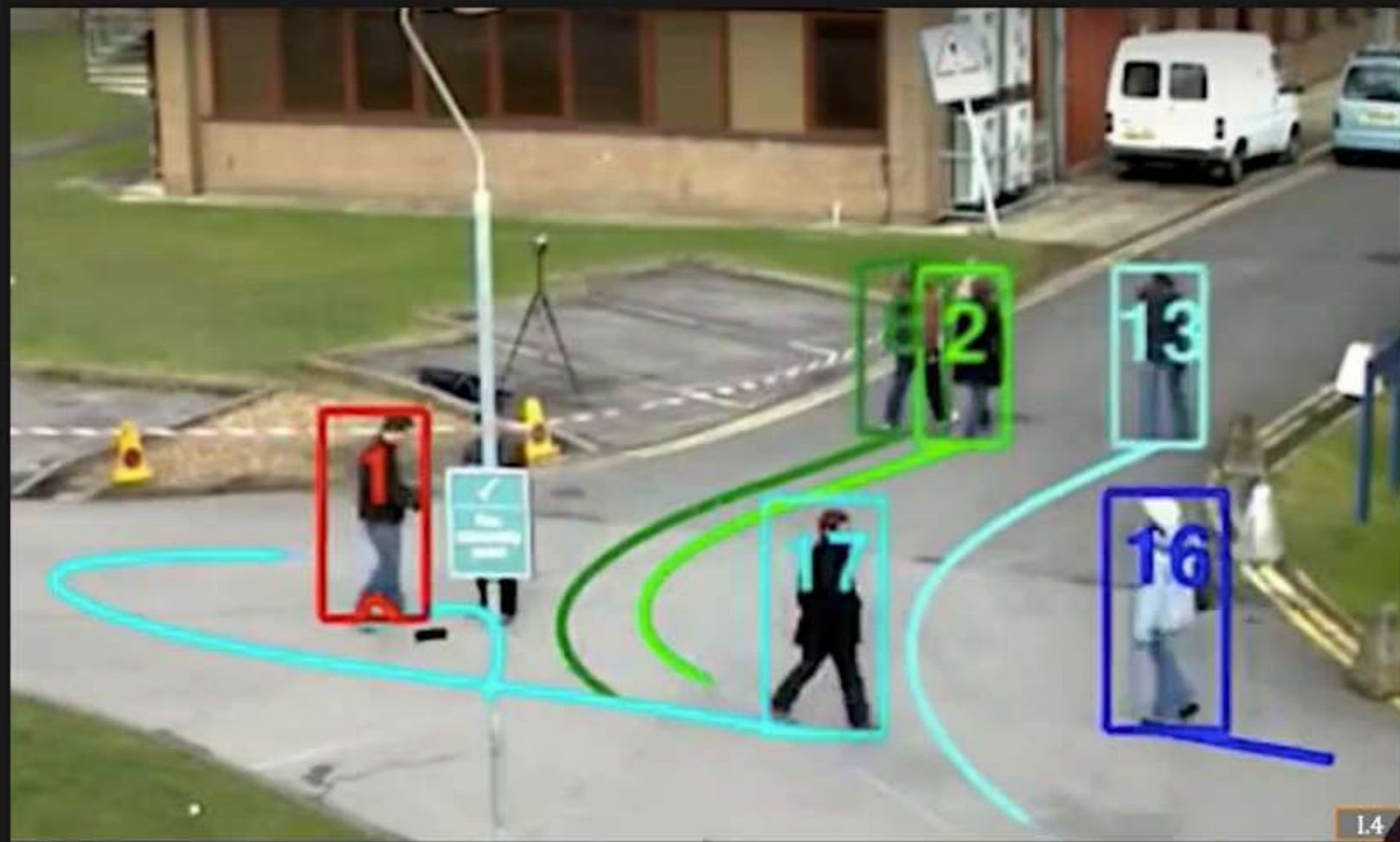
Biometrics: Face Detection and Recognition

What is Vision Used For?



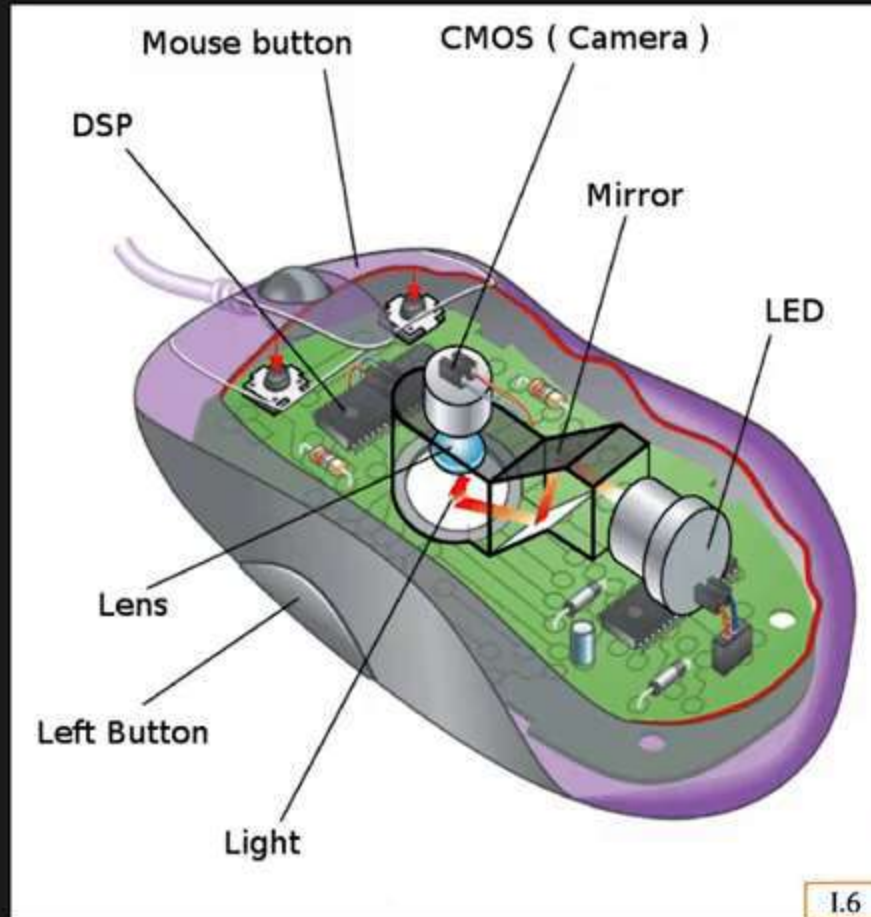
Intelligent Marketing: Vending Machine with Face Detection

What is Vision Used For?



Security: Object Detection and Tracking

What is Vision Used For?



Human Computer Interaction: Optical Mouse

What is Vision Used For?



Entertainment and Gaming: Kinect

What is Vision Used For?

Doug

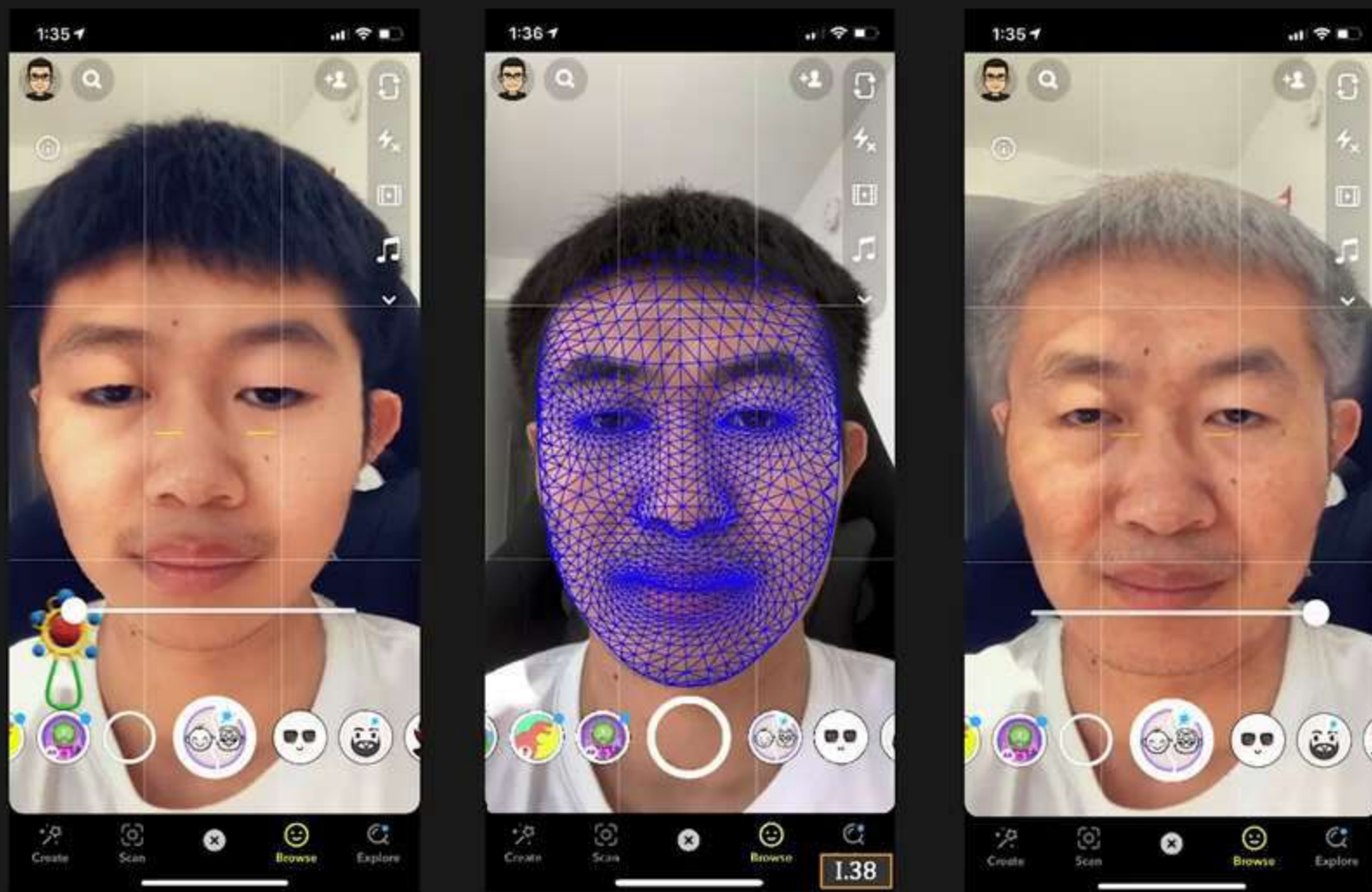


Elbor



Visual Effects: Motion and Performance Capture

What is Vision Used For?



Augmented Reality: Face Manipulation

What is Vision Used For?



Visual Search: Landmark Recognition

What is Vision Used For?



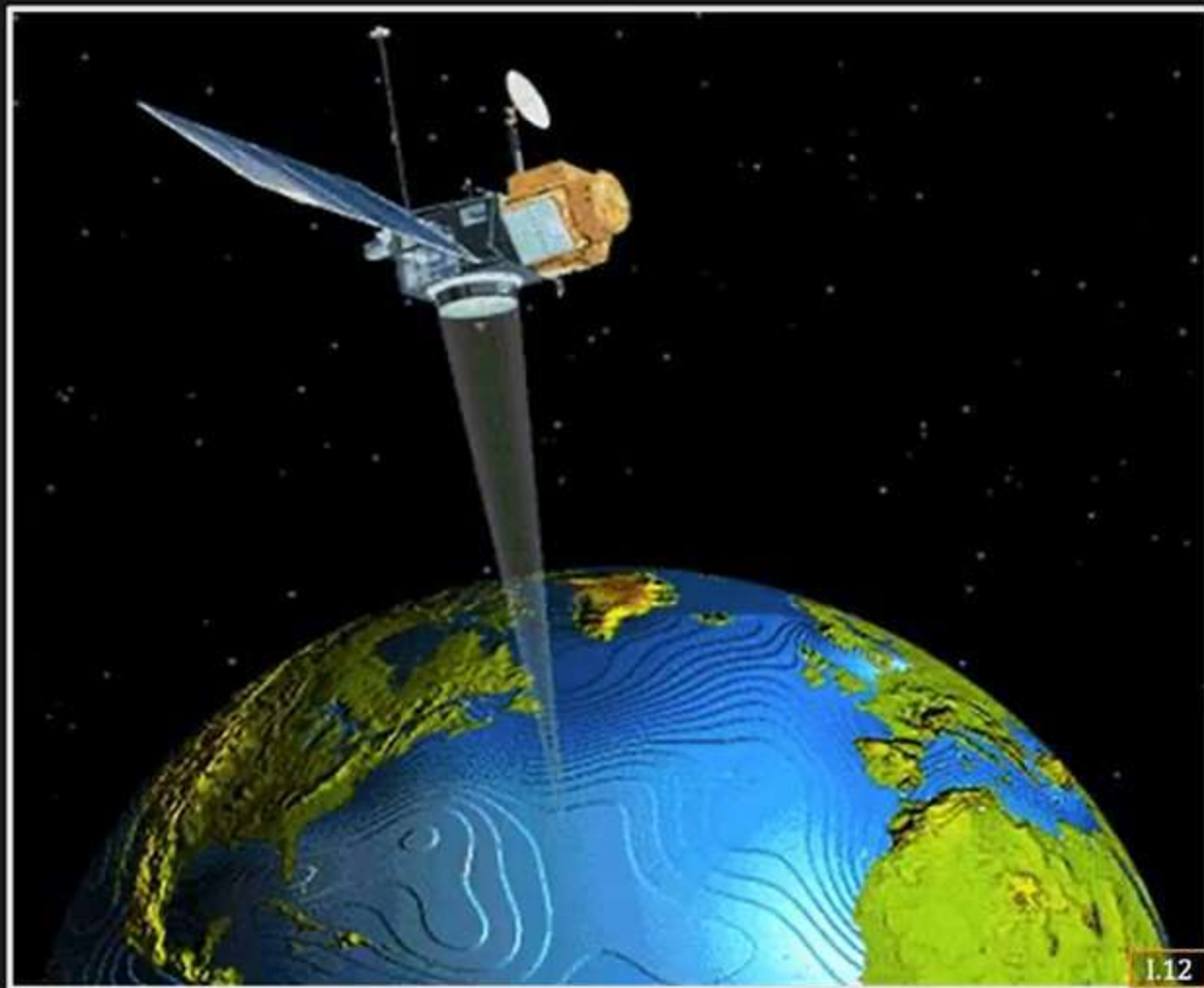
Autonomous Navigation: Space Exploration

What is Vision Used For?



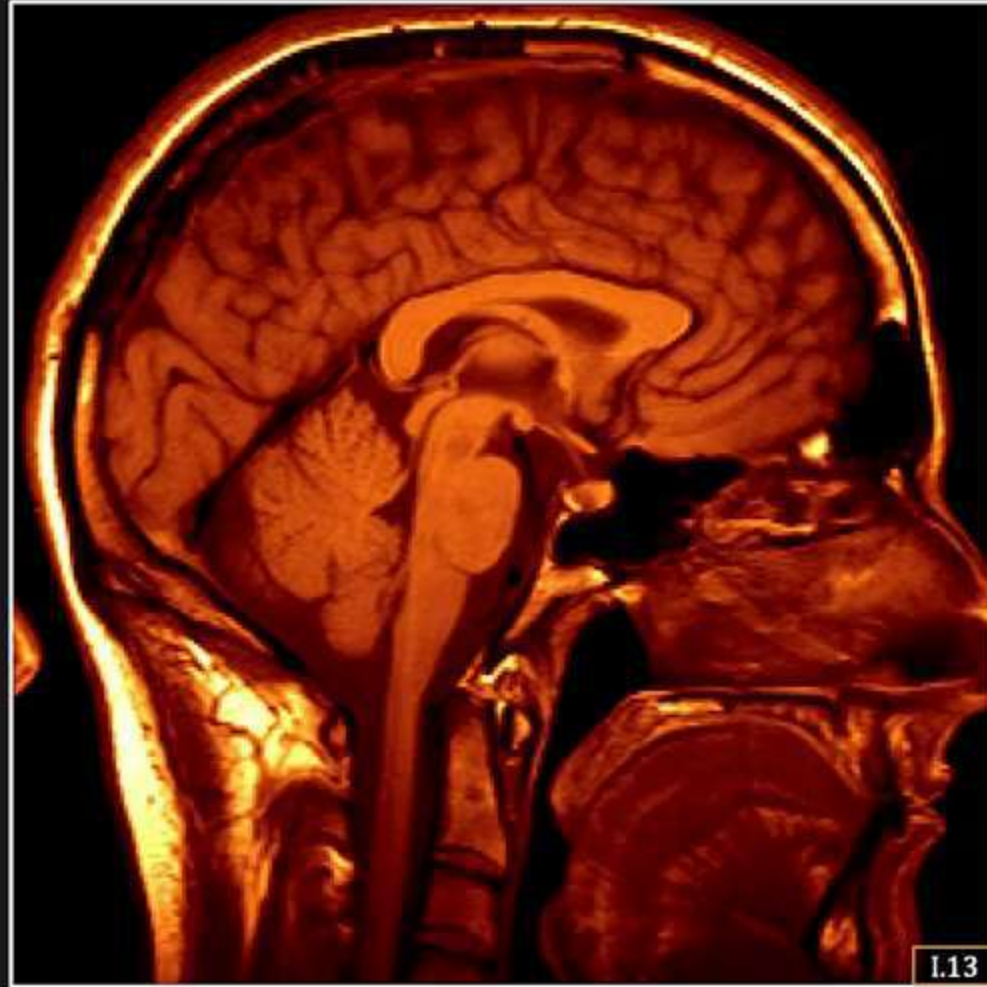
Autonomous Navigation: Driverless Car

What is Vision Used For?



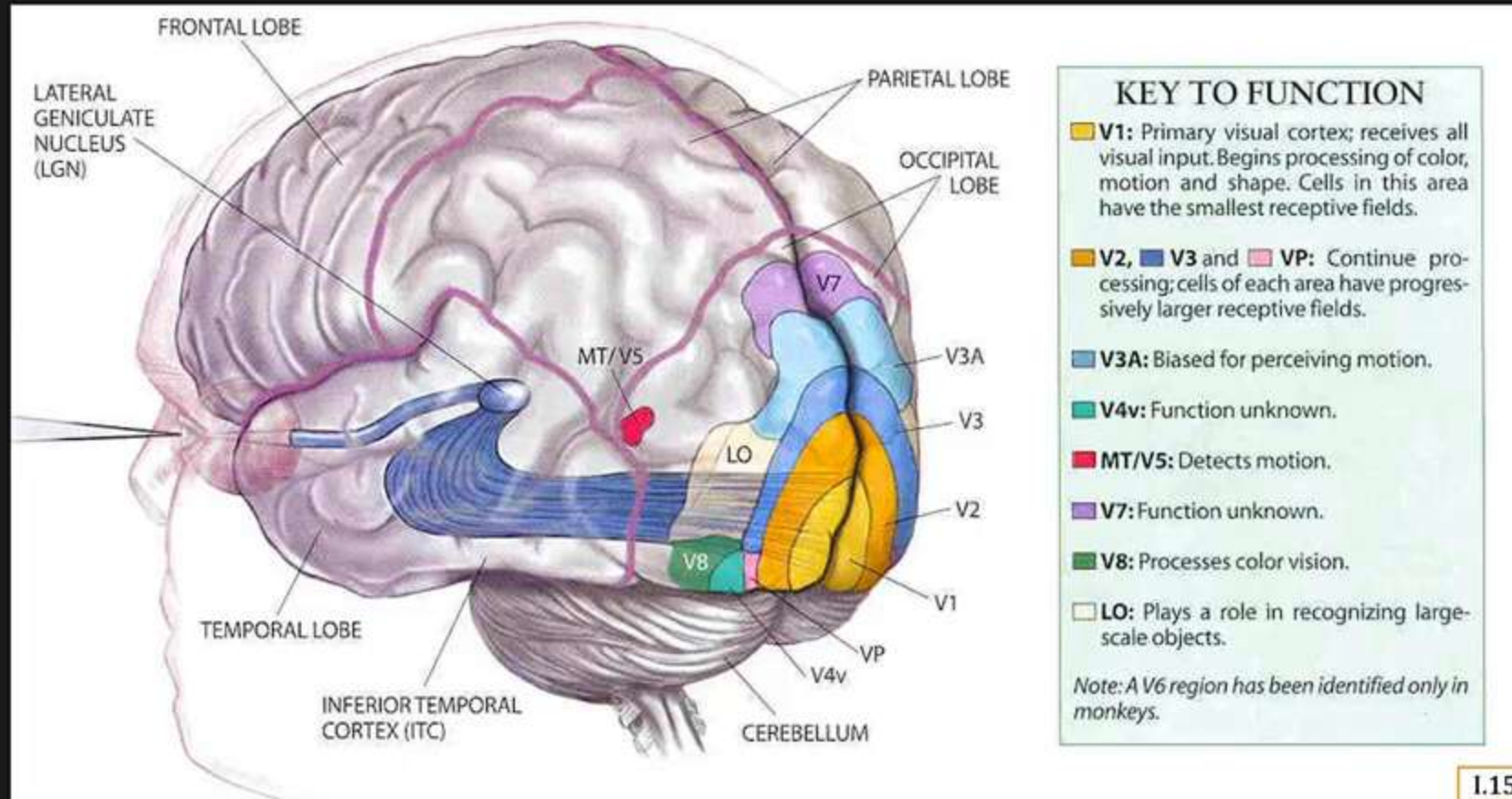
Remote Sensing

What is Vision Used For?



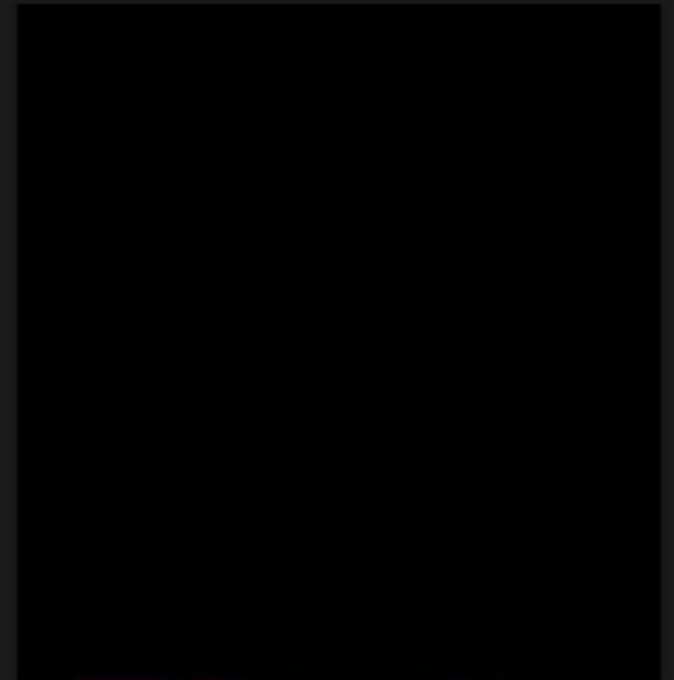
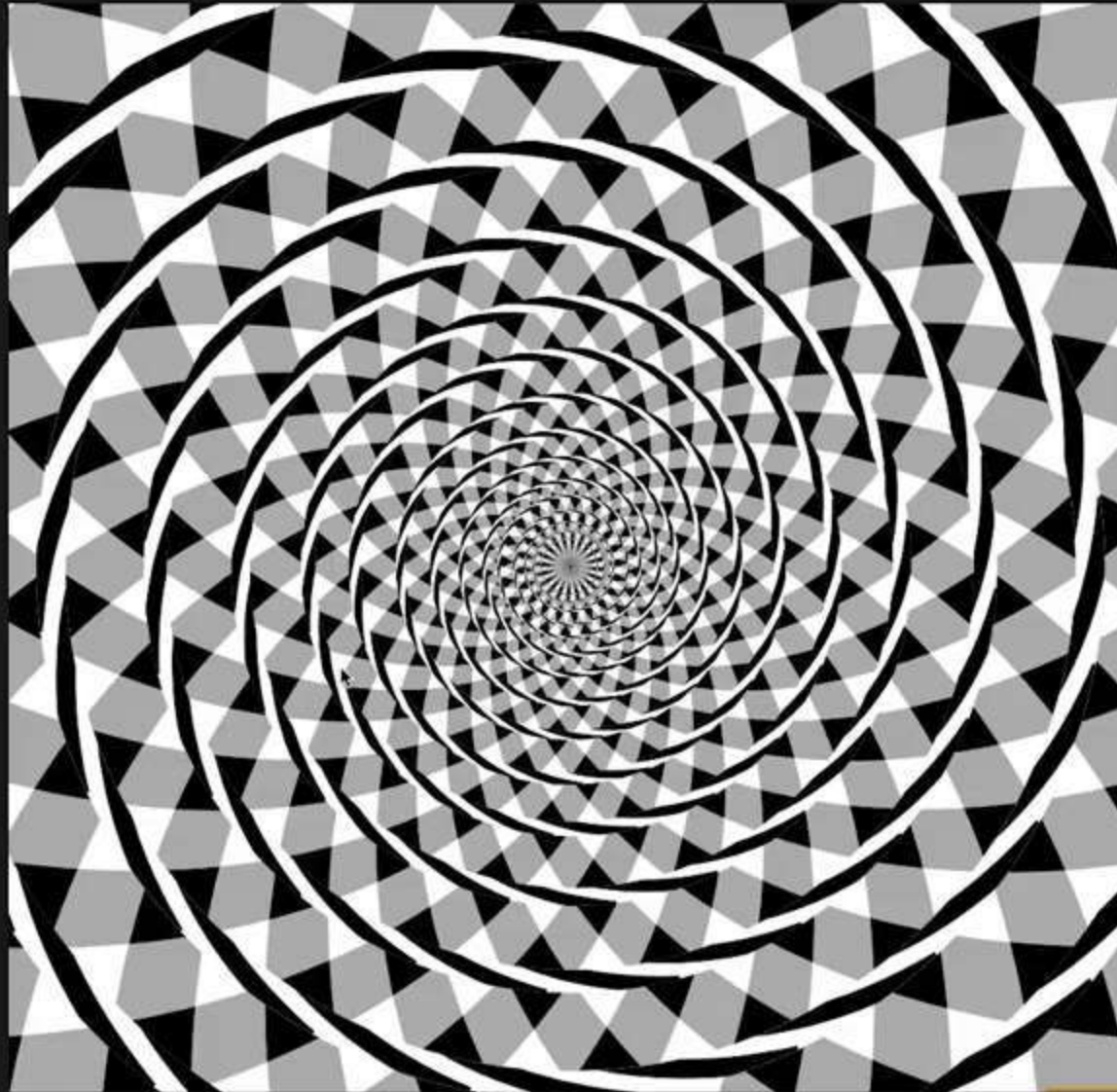
Medical Image Analysis

Human Eye and Visual Cortex

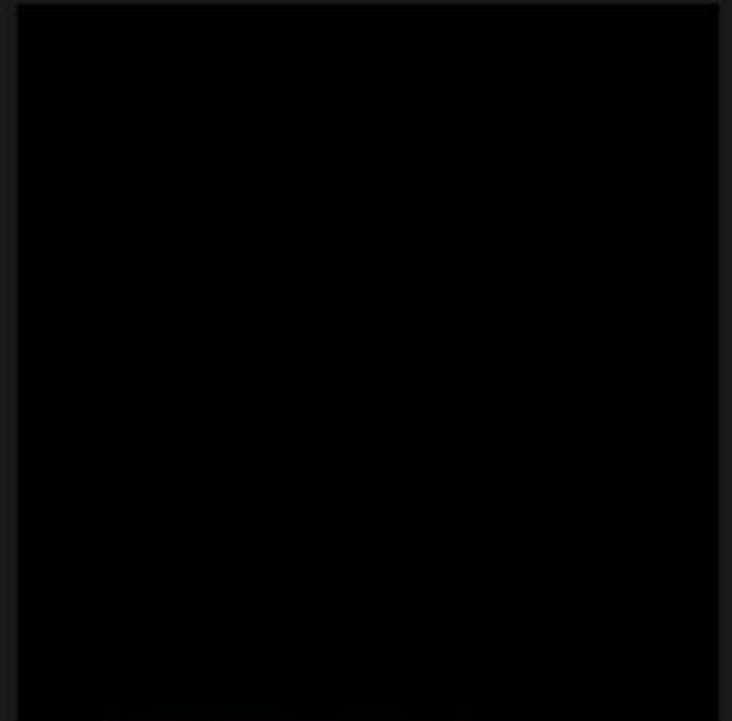
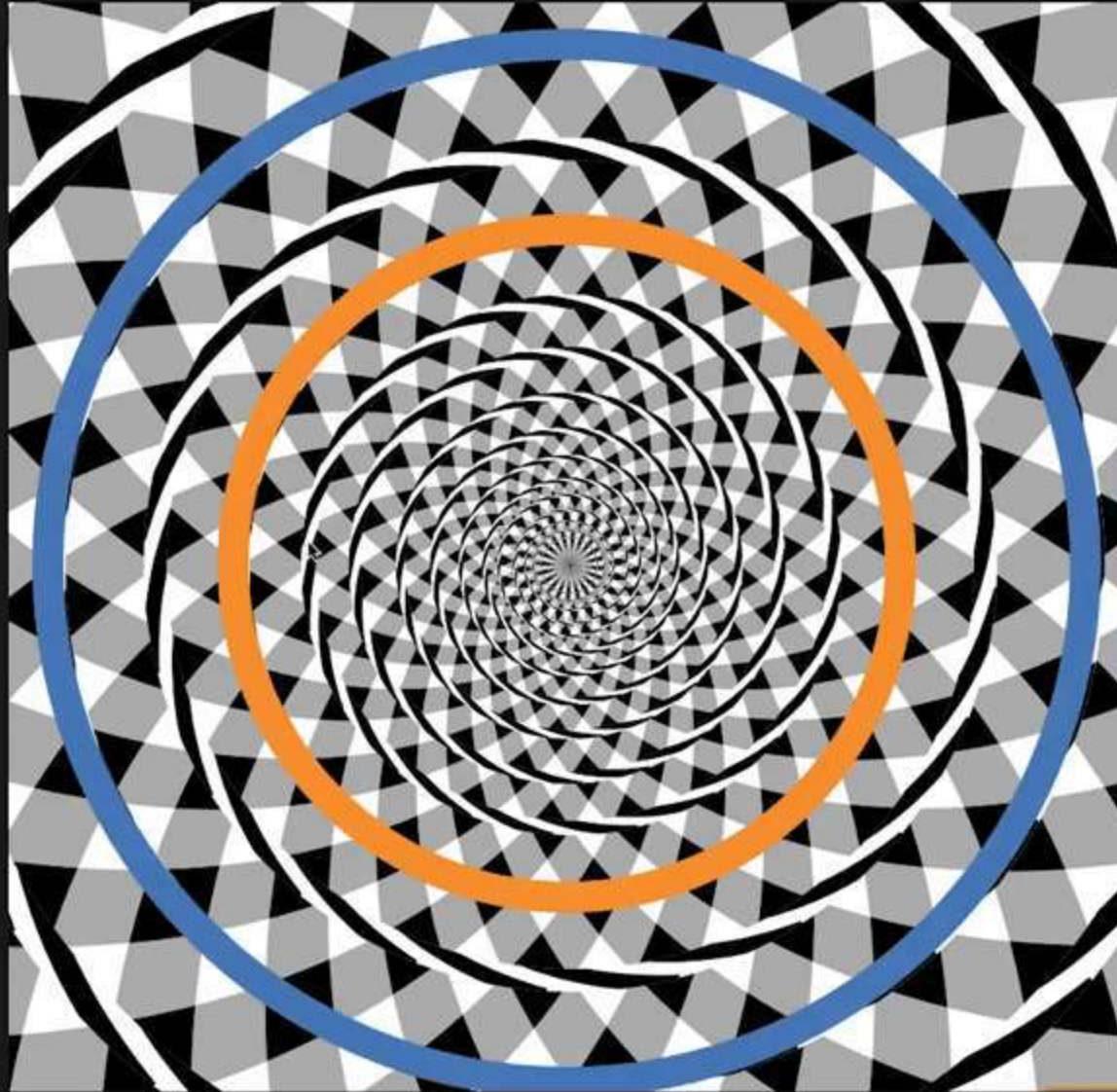


Vision is easy for us

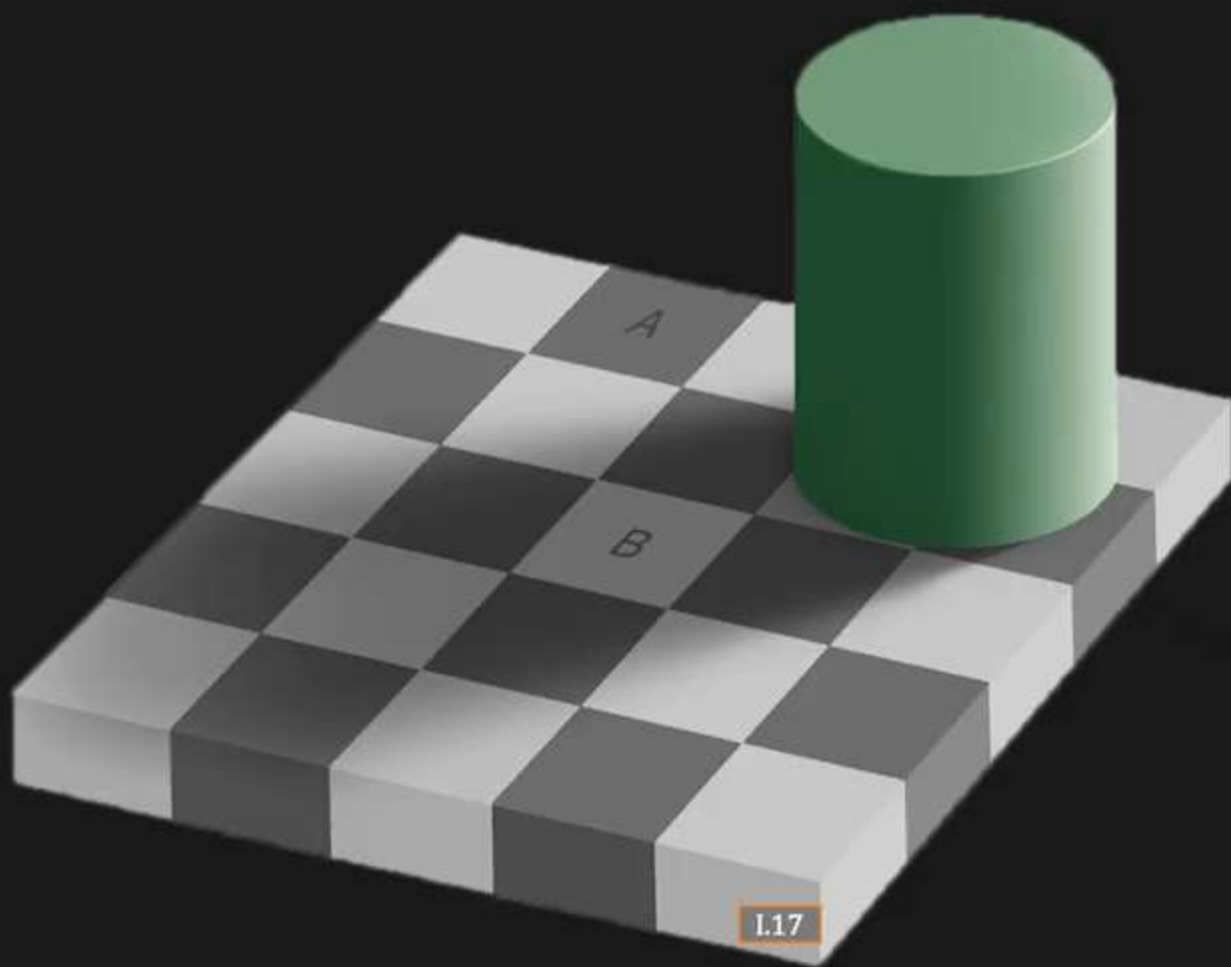
Illusions: Fraser's Spiral



Illusions: Fraser's Spiral



Illusions: Checker Shadow



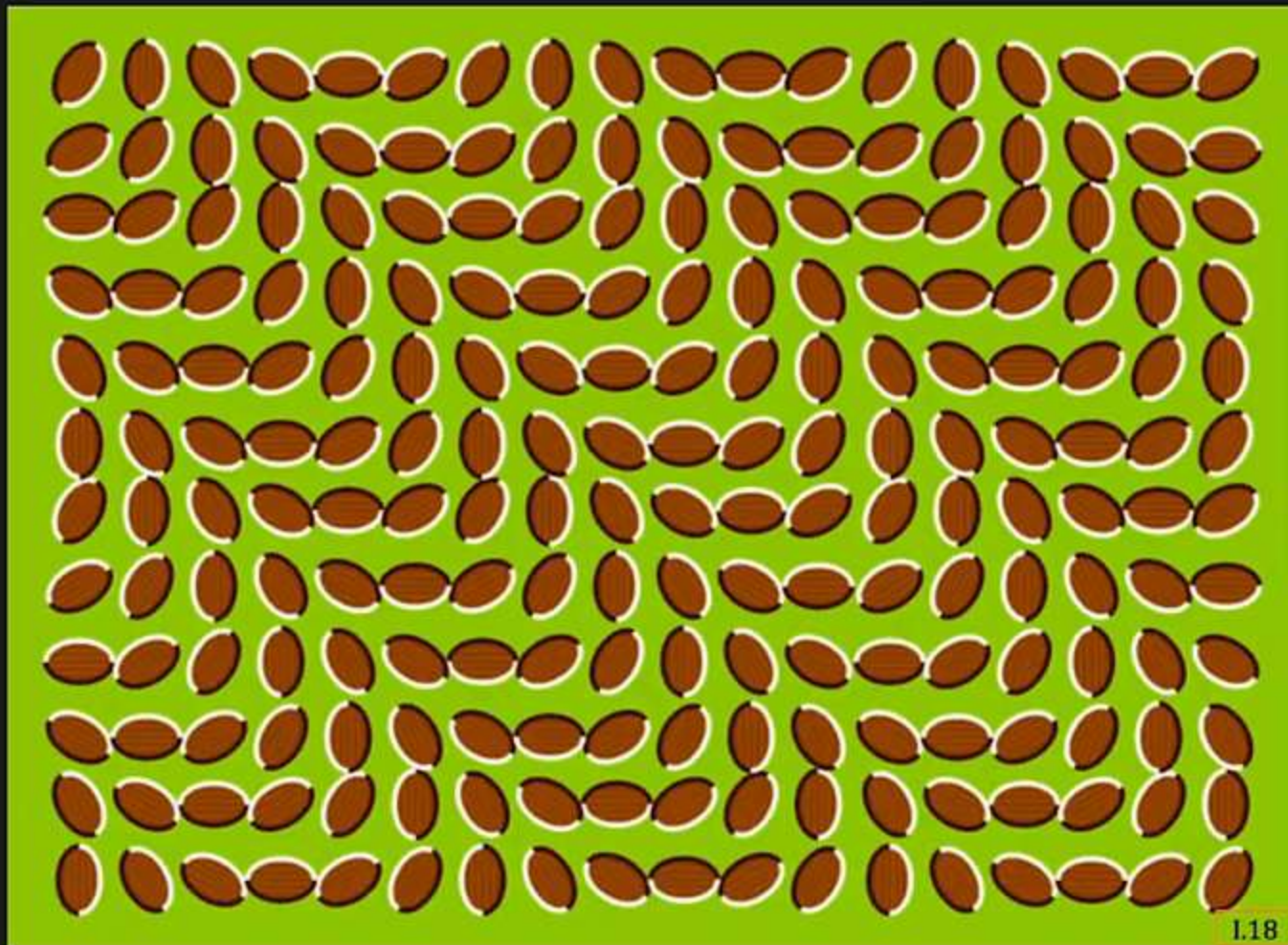
B seems Brighter than A

Illusions: Checker Shadow



...But, they have the same brightness

Illusions: Donguri Wave



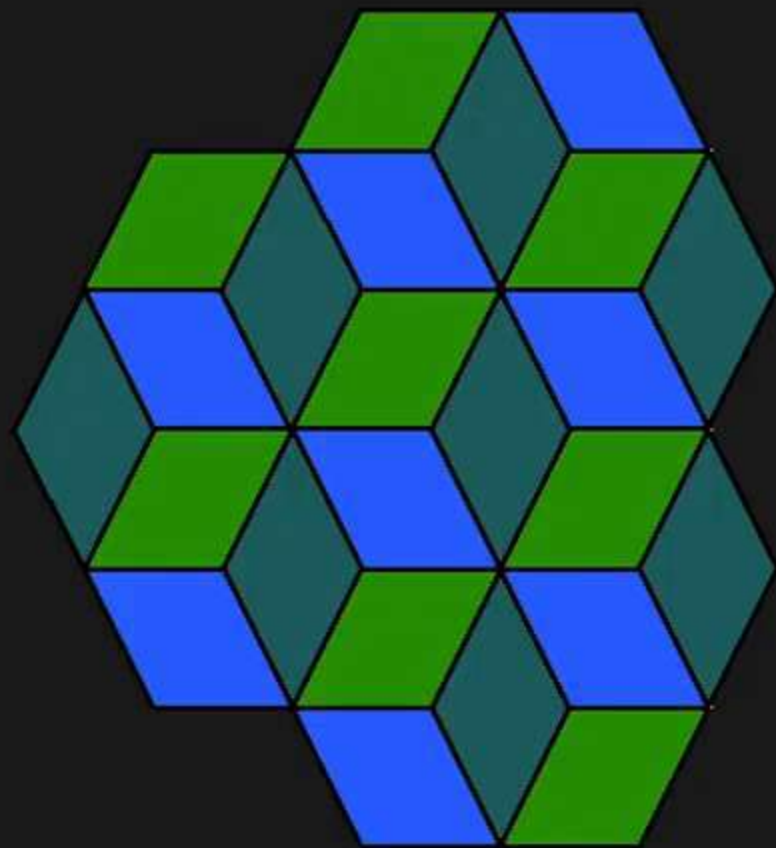
Perceived Motion Without Motion

Illusions: Forced Perspective



These two people are of the same height!

Visual Ambiguities

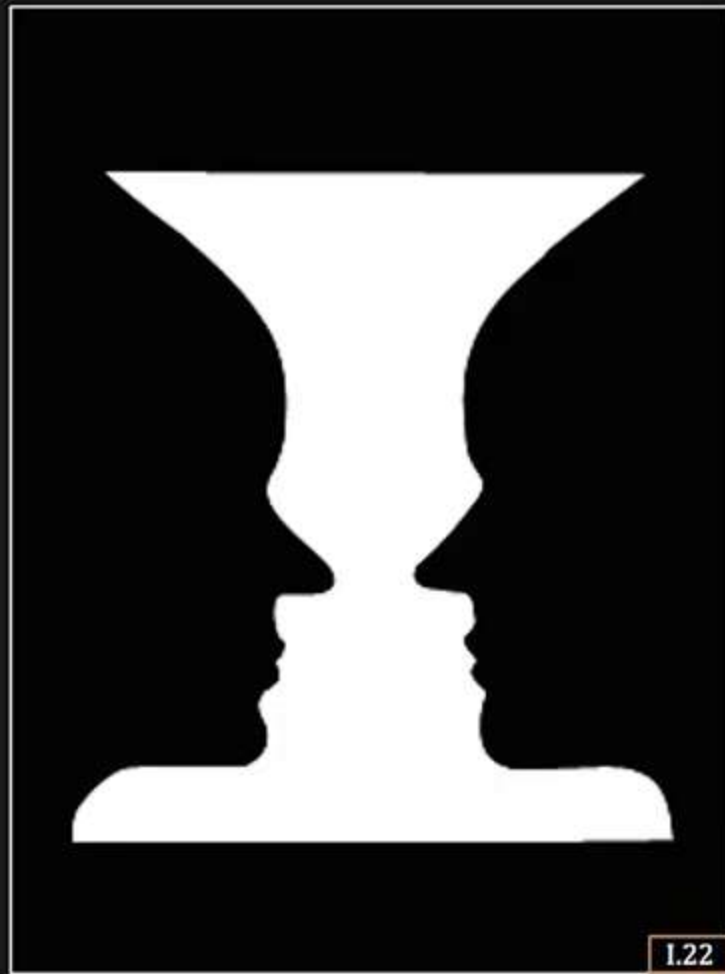


Six Cubes or Seven Cubes?

Visual Ambiguities

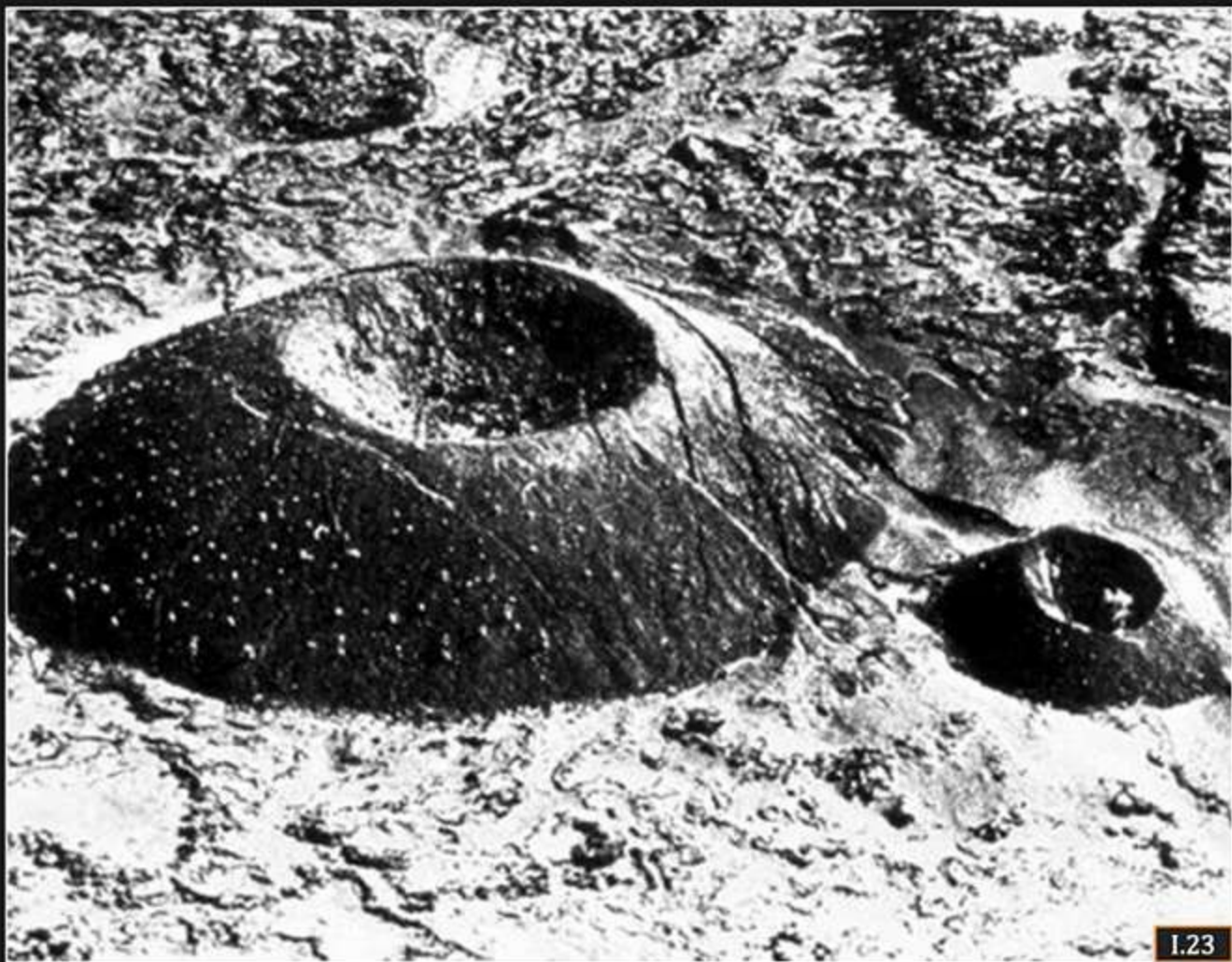


Young-Girl/Old-Woman



Face/Vase

Visual Ambiguities



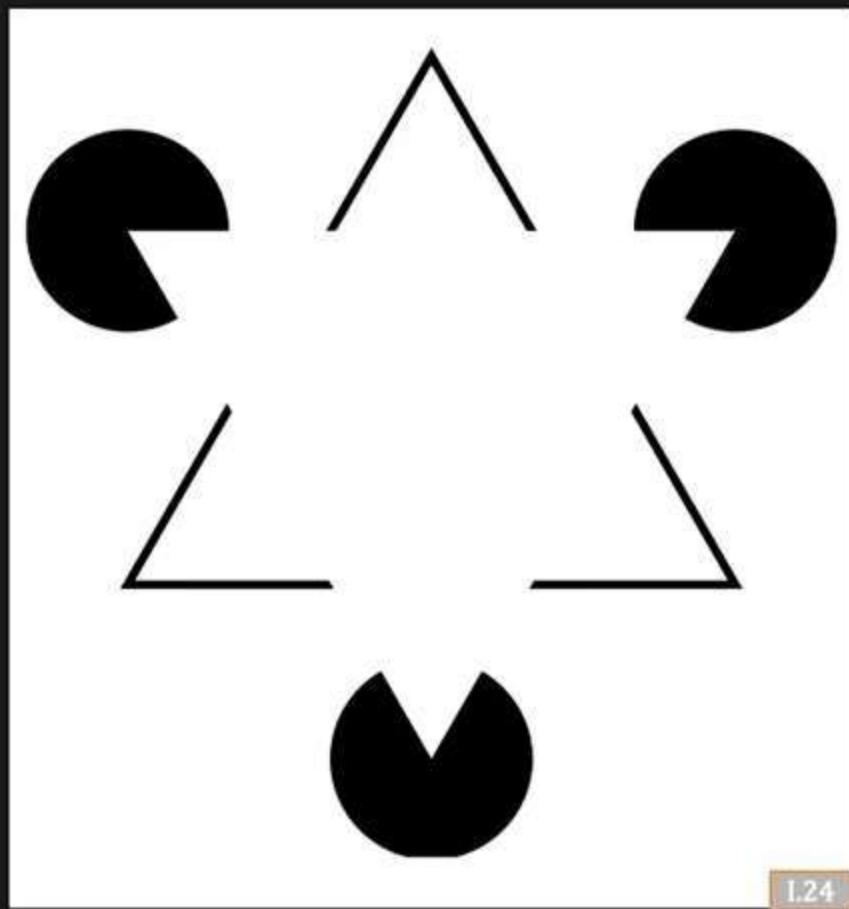
Crater on a Mound

Visual Ambiguities



Mound in a Crater

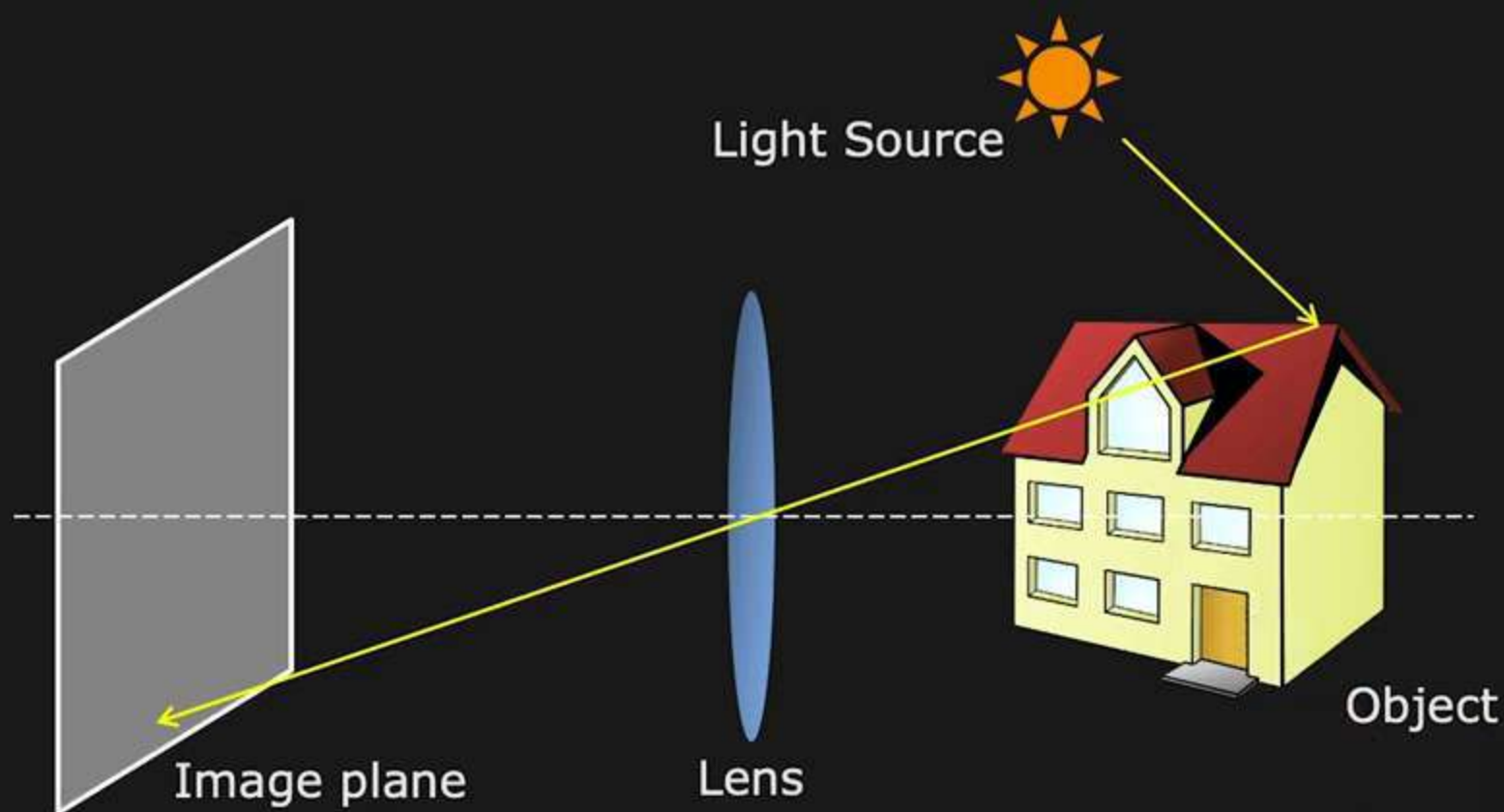
Seeing vs. Thinking



Kanizsa Triangle

Image Formation and Optics

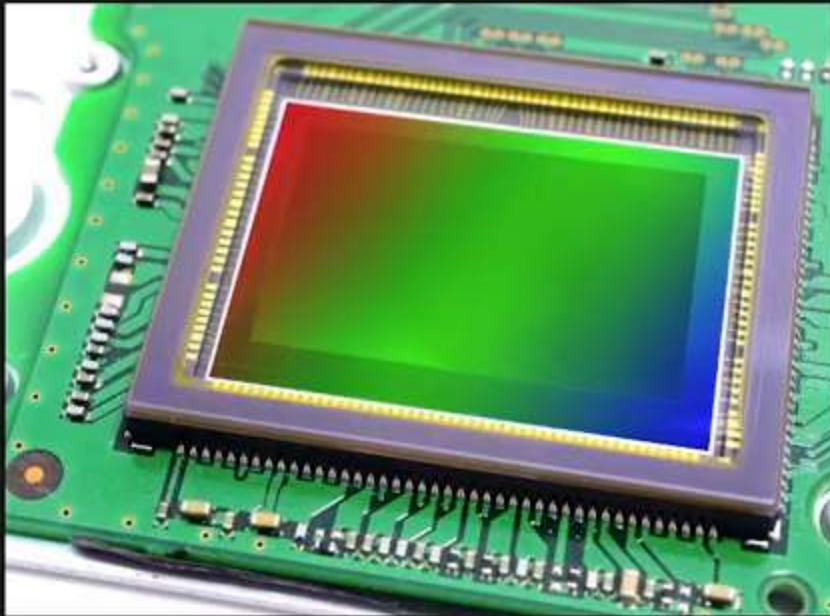
Where do Images Come From?



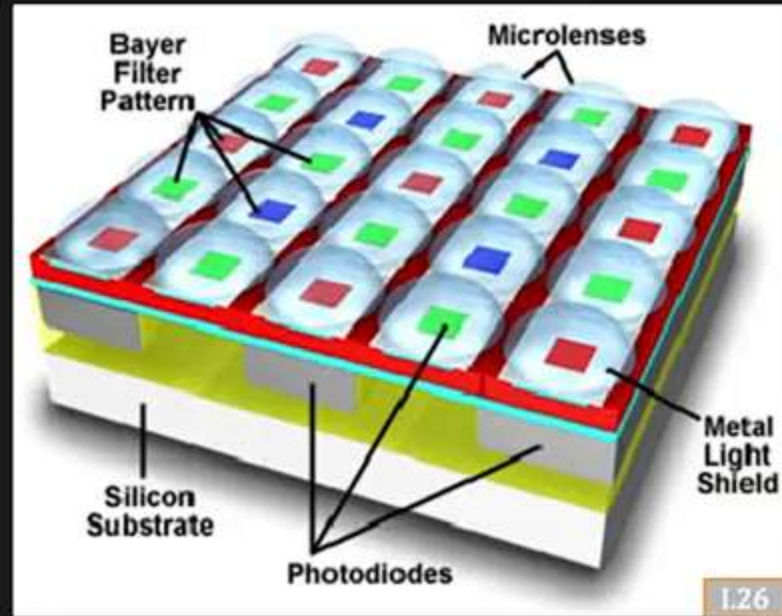
Projection of 3D world on a 2D Plane

Image Sensors

Convert Optical Images to Electrical Signals



Consumer Image Sensor



Typical Structure of Image Sensor

Binary Images

Two-Valued Images: Easy to Store and Process



Grayscale Image



Binary Image

Image Processing

Transform Image to New One that is More Useful



Input Image



Edge-Preserved Smoothing

Edge and Corner Detection

Detecting Intensity Changes in the Image



Input Image



Edges

Boundaries from Edges

Finding Continuous Lines from Edge Segments



Input Image

Edge
Detection



Edges

Boundary
Detection



Boundaries

2D Recognition using Features

Matching using "Interesting Points"



Object in Database



Input Image and Detected Object

Image Alignment and Stitching

Combine multiple photos to create a larger photo



Source Image 1

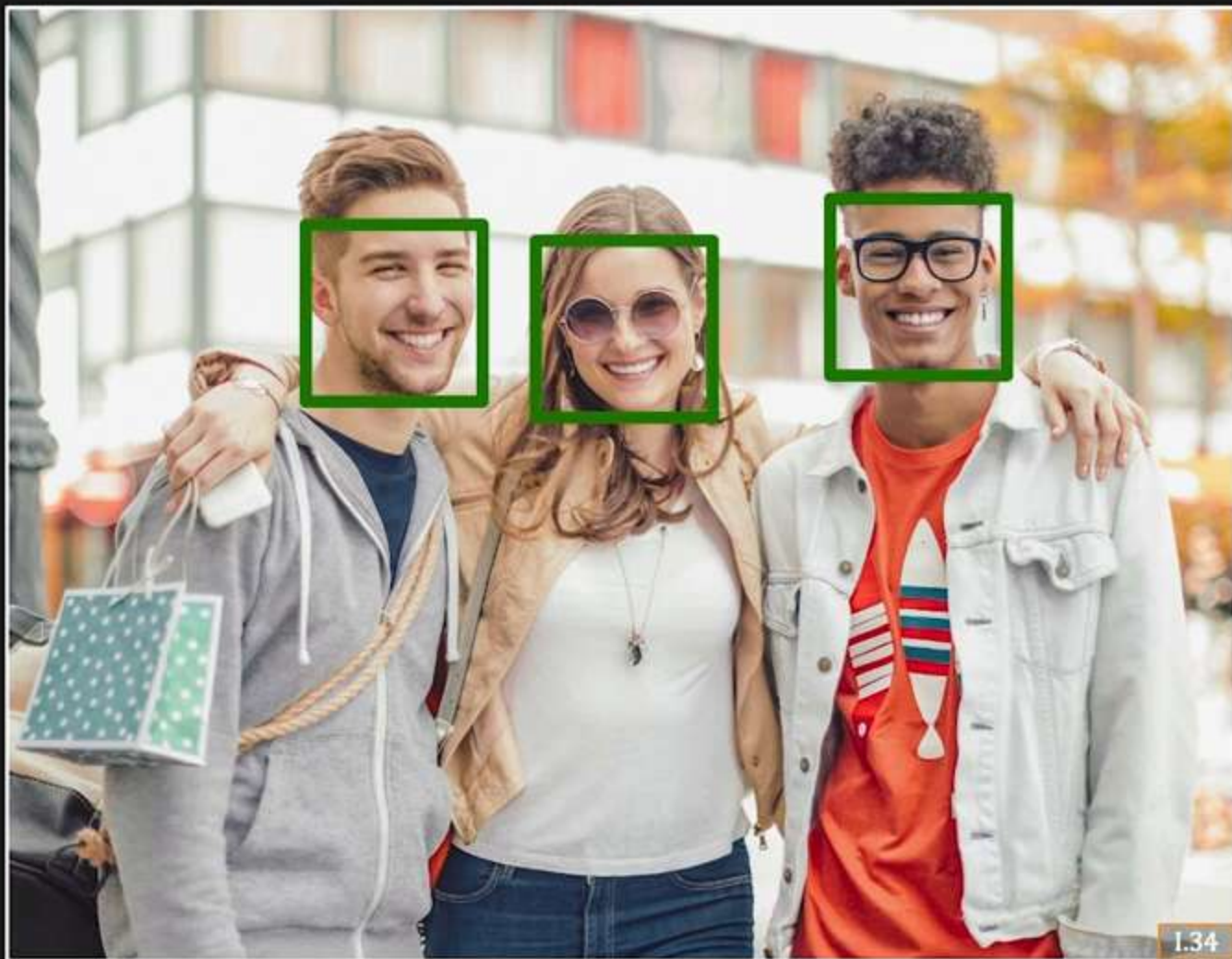
Source Image 2

Source Image 3



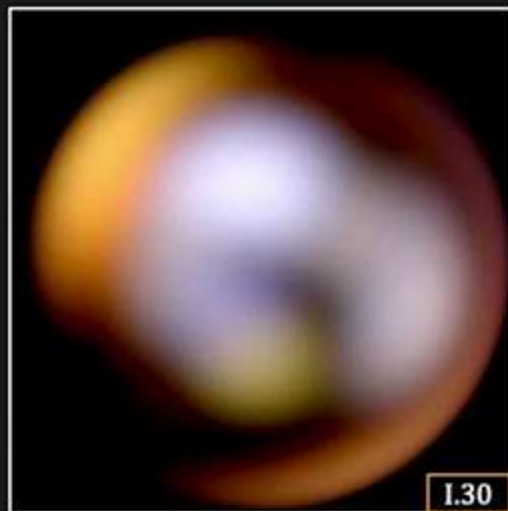
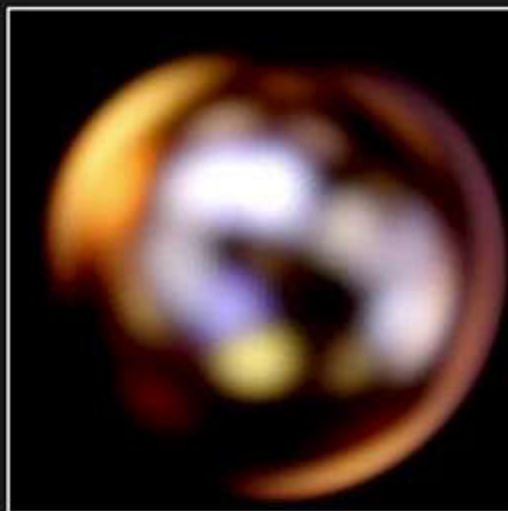
Stitched Image

Face Detection



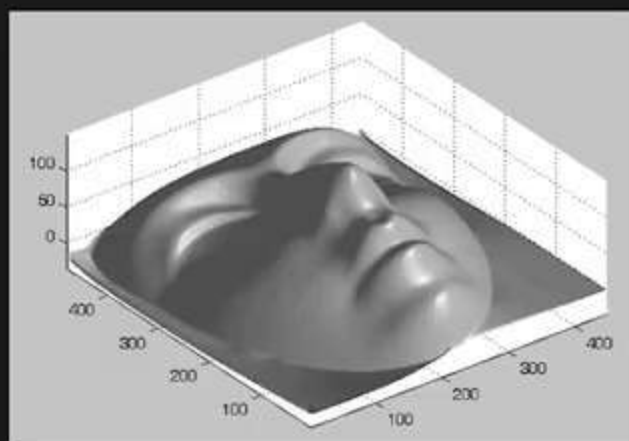
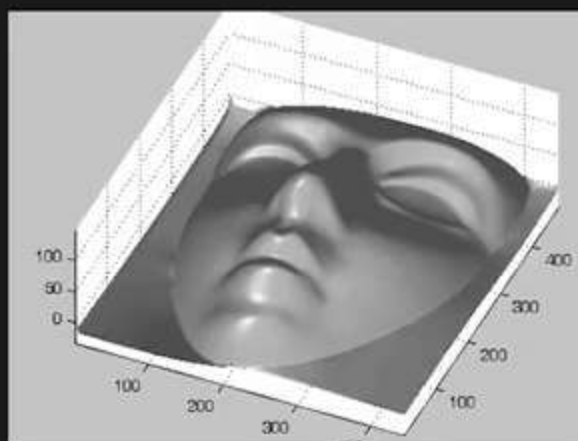
Radiometry and Reflectance

Why do these Spheres Look Different?



Photometric Stereo

3D Shape from Images under Different Lighting



Computed Shape

Shape from Shading

3D Shape from a Single Image



Input Image



Computed Shape

Depth from Focus/Defocus



Near-Focus Image



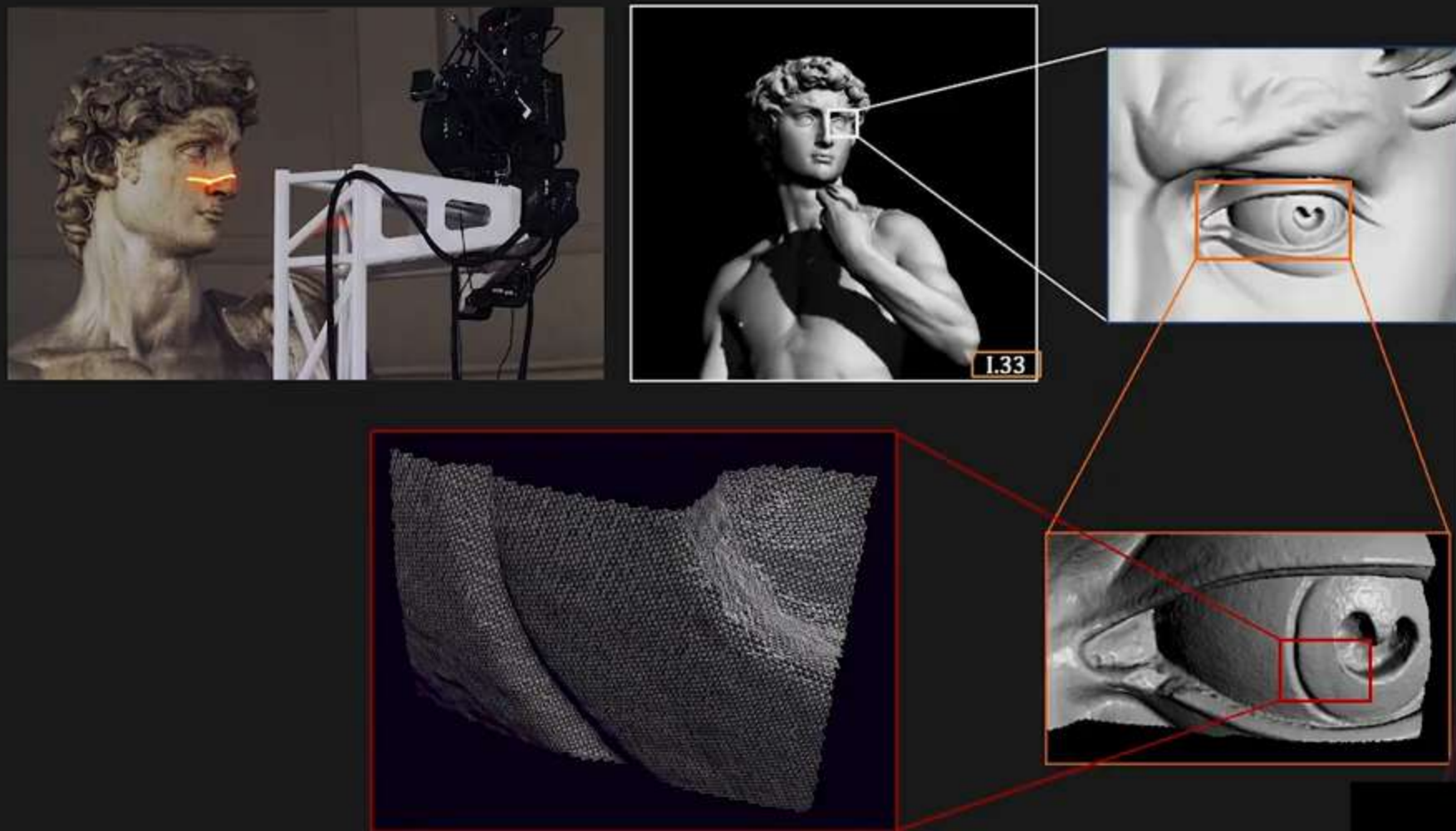
Far-Focus Image



Estimated Depth Map

Active Illumination Methods

Using Patterned Lighting to Recover Shape



Camera Calibration

Estimating Camera Parameters

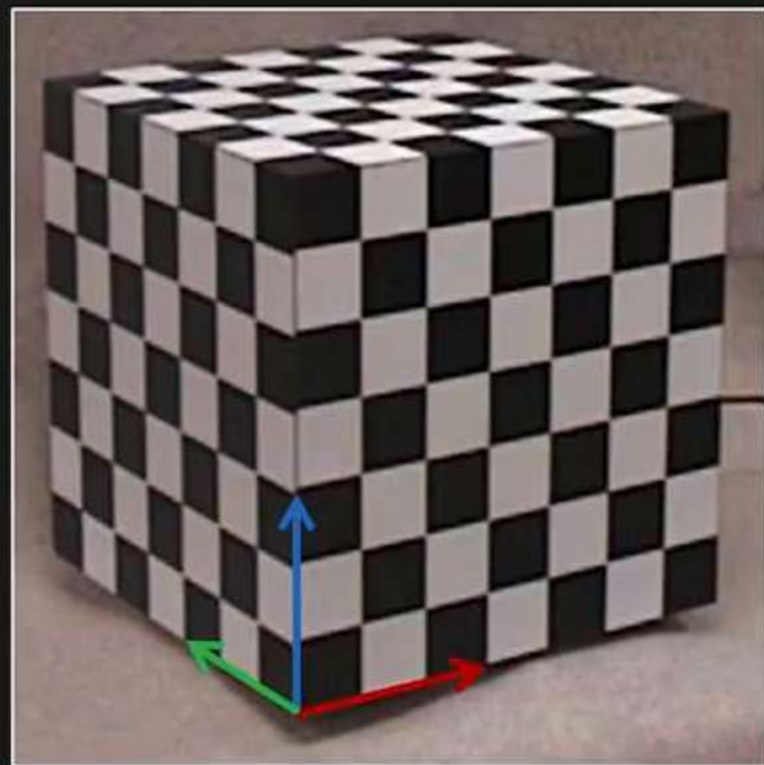


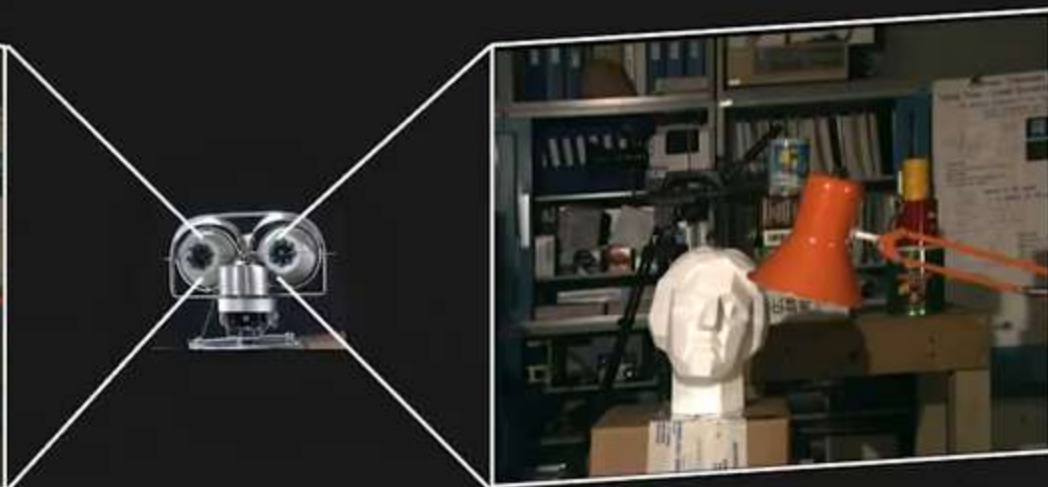
Image of object with known geometry

Binocular Stereo

Computing Depth using Two Views



Right View



Left View



Estimated Depth Map

Motion and Optical Flow

Determining the Movement of Scene Points



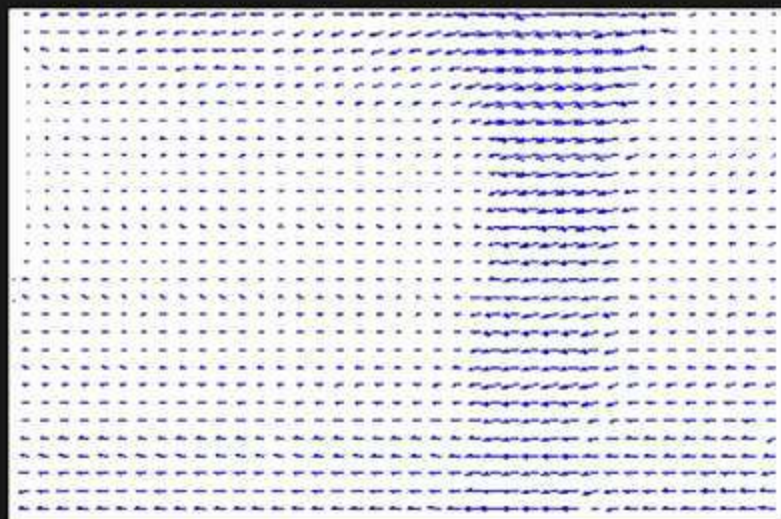
Frame 1



Frame 2



Frame 3



Estimated Motion

Structure From Motion



Casual Video

Structure From Motion



Casual Video

Structure From Motion



Casual Video

Structure From Motion

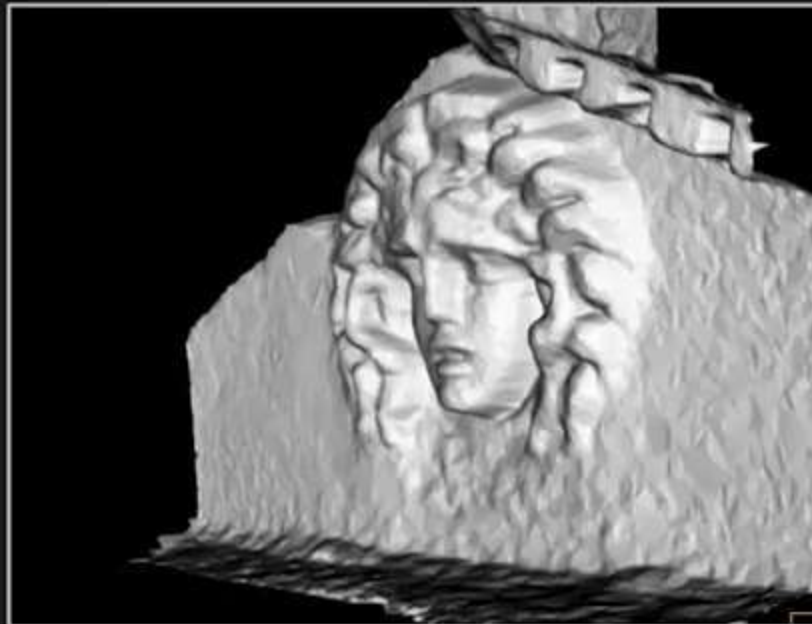


Casual Video

Structure From Motion



Casual Video



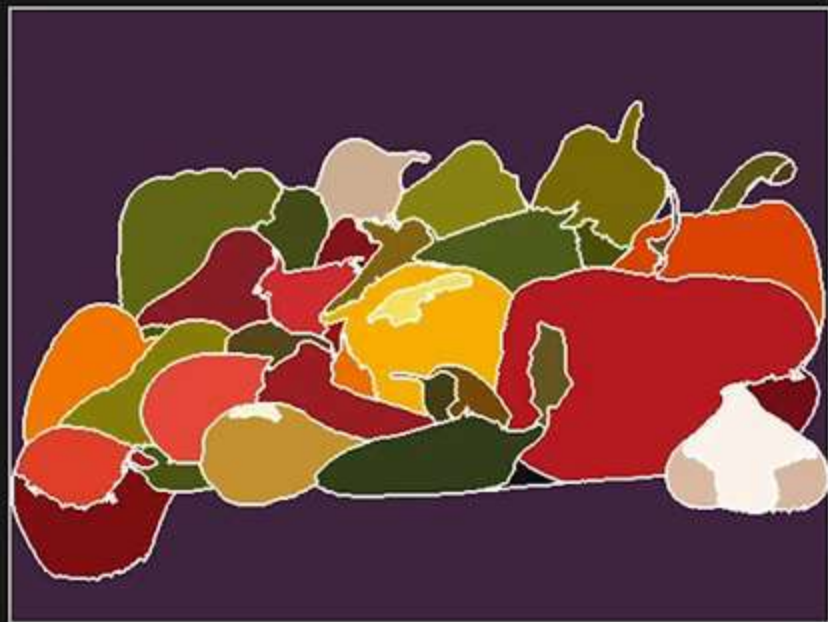
Reconstructed 3D Structure

Image Segmentation

Group pixels with similar visual characteristics.



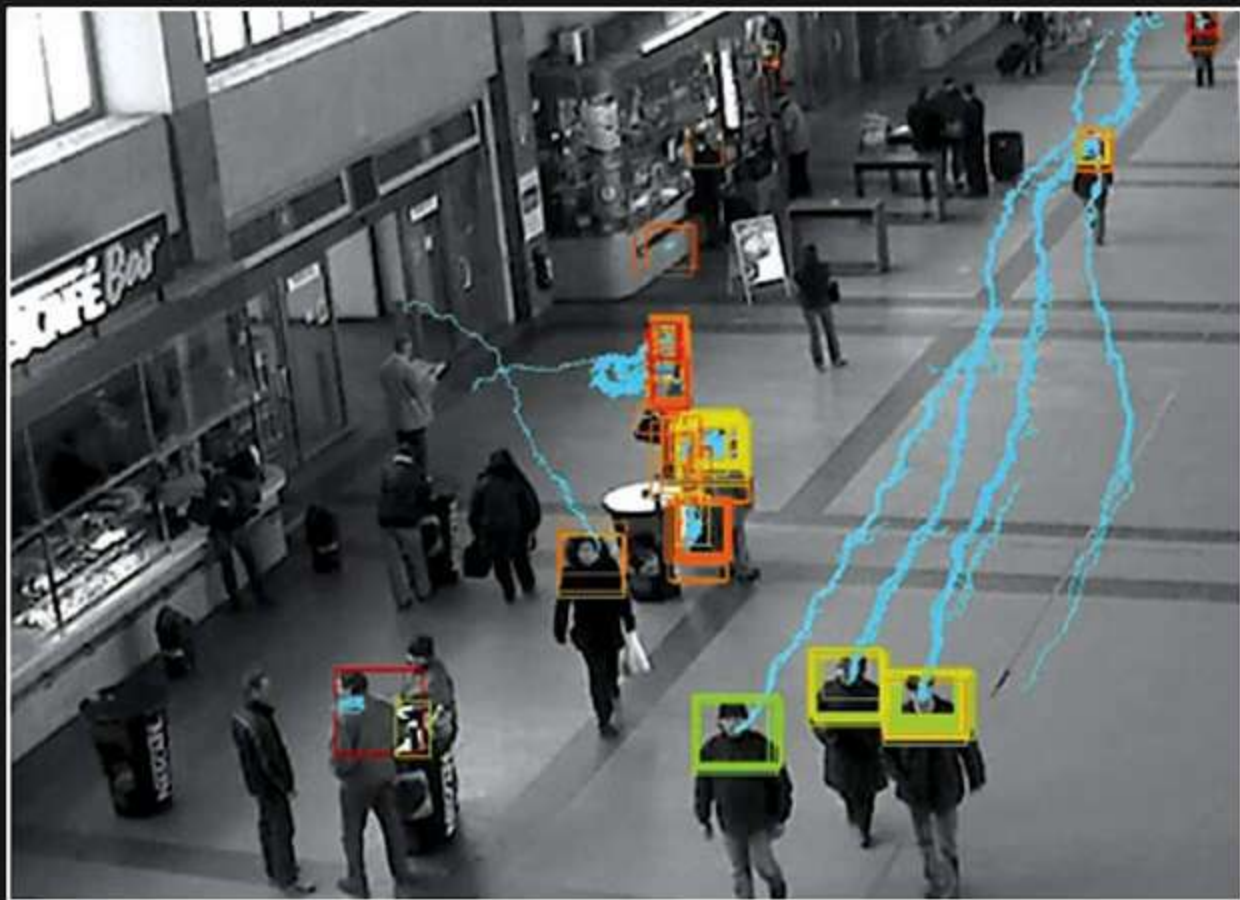
Input Image



Segmented Image

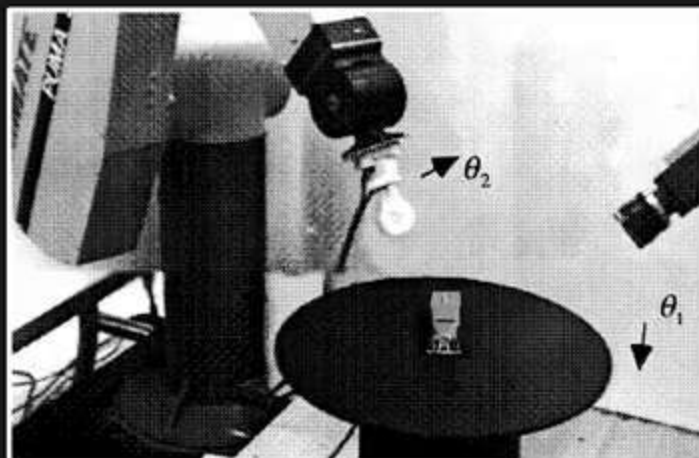
Object Tracking

Determining the Movement of Objects in Videos

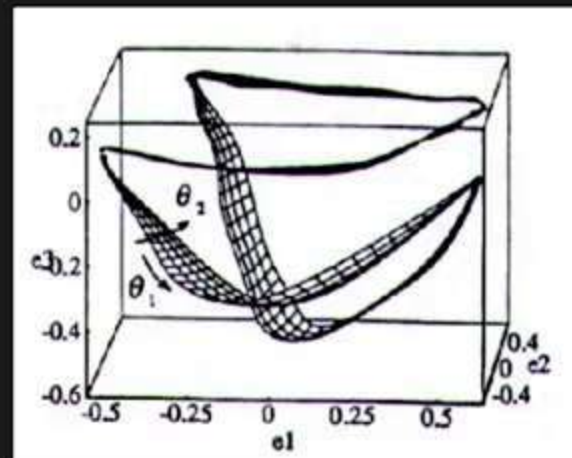


Appearance Matching

Object Recognition using Principle Component Analysis



Learning Object Appearance



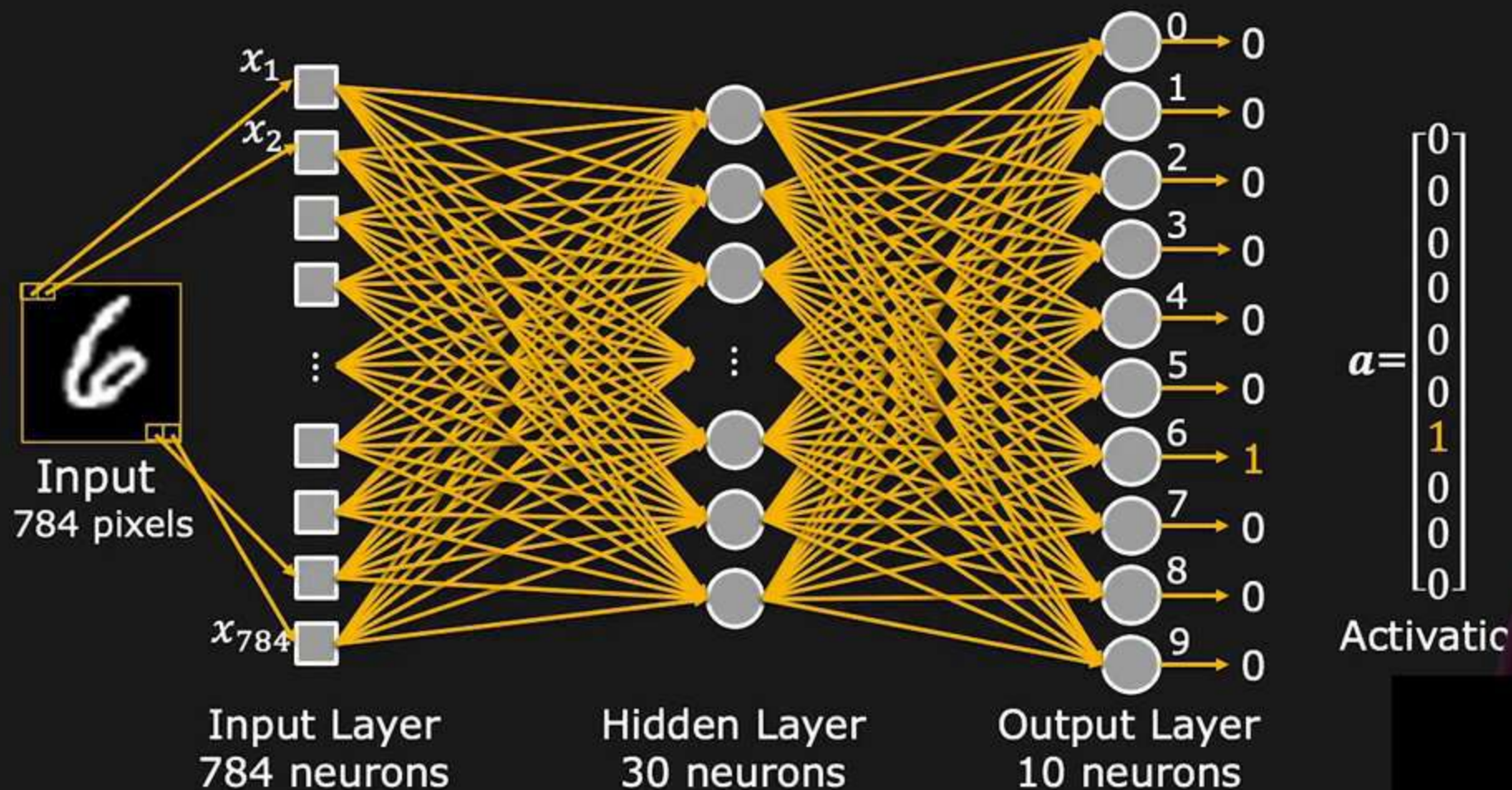
Appearance Manifold (Model)



Recognition by Matching Appearance

Artificial Neural Networks

Using Network of Neurons to Solve Complex Problems



Modules and Prerequisites

Modules:

0. **Introduction**
1. **Imaging**: Image Formation, Sensing, Processing
2. **Features**: Edges, Boundaries, SIFT, Applications
3. **Reconstruction 1**: Shading, Focus, Active Illumination
4. **Reconstruction 2**: Stereo, Optical Flow, SFM
5. **Perception**: Segmentation, Tracking, Recognition

Prerequisites:

- Fundamental of Linear Algebra
- Fundamentals of Calculus
- One Programming Language

Thank You

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