

CSE 402 - BIOMETRICS AND PATTERN
RECOGNITION

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THANKS TO: THOMAS SWEARINGEN

FACE RECOGNITION

PART 1

FACE RECOGNITION APPLICATIONS: AIRPORT



<https://www.youtube.com/watch?v=gYbNqjatGNA>

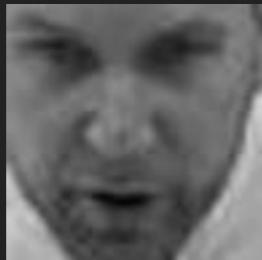
FACE INTRA-CLASS VARIATION

- ▶ Face images may vary in:
 - ▶ Pose
 - ▶ Illumination
 - ▶ Expression
 - ▶ Age
- ▶ Appearance may also change due to:
 - ▶ Makeup
 - ▶ Facial Hair
 - ▶ Accessories (e.g. Sunglasses)
- ▶ **These variations make face recognition more difficult**



Images from *Introduction to Biometrics*, 2011.

FACE INTRA-CLASS VARIATION: PIXEL EXAMPLE



| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 139 | 133 | 126 | 128 | 128 | 124 | 125 | 121 | 115 | 111 | 112 | 109 | 107 | 107 | 106 | 108 | 112 | 118 | 126 | 131 | 130 | 125 | 121 | 123 | 123 | 126 | 126 | 102 | 89 | | |
| 131 | 111 | 97 | 94 | 106 | 119 | 122 | 119 | 110 | 104 | 107 | 104 | 101 | 99 | 100 | 104 | 107 | 109 | 109 | 117 | 122 | 114 | 106 | 114 | 124 | 129 | 129 | 127 | 109 | 82 | |
| 120 | 105 | 92 | 79 | 78 | 85 | 95 | 101 | 102 | 103 | 103 | 100 | 97 | 95 | 97 | 101 | 101 | 99 | 104 | 97 | 84 | 78 | 81 | 91 | 98 | 111 | 125 | 124 | 122 | 89 | |
| 130 | 120 | 110 | 96 | 85 | 72 | 68 | 73 | 82 | 95 | 97 | 98 | 96 | 96 | 100 | 97 | 90 | 77 | 65 | 59 | 57 | 69 | 77 | 83 | 85 | 99 | 120 | 125 | 122 | 103 | |
| 126 | 104 | 86 | 66 | 55 | 44 | 40 | 52 | 62 | 78 | 89 | 96 | 95 | 95 | 93 | 84 | 68 | 53 | 44 | 38 | 37 | 53 | 62 | 70 | 79 | 107 | 129 | 127 | 116 | 115 | |
| 124 | 100 | 85 | 75 | 64 | 47 | 41 | 48 | 42 | 48 | 73 | 92 | 94 | 94 | 87 | 69 | 51 | 40 | 42 | 39 | 36 | 49 | 59 | 67 | 80 | 111 | 124 | 123 | 115 | 115 | |
| 127 | 115 | 110 | 107 | 92 | 64 | 49 | 52 | 43 | 45 | 58 | 84 | 95 | 97 | 84 | 65 | 50 | 42 | 42 | 48 | 56 | 76 | 92 | 104 | 107 | 122 | 128 | 120 | 109 | 107 | |
| 134 | 129 | 122 | 115 | 105 | 83 | 68 | 59 | 50 | 53 | 63 | 92 | 111 | 108 | 95 | 74 | 60 | 54 | 53 | 62 | 74 | 88 | 103 | 114 | 122 | 124 | 129 | 124 | 101 | 105 | |
| 135 | 135 | 129 | 116 | 101 | 86 | 74 | 65 | 69 | 86 | 101 | 114 | 124 | 124 | 120 | 100 | 84 | 76 | 71 | 71 | 78 | 92 | 109 | 119 | 128 | 127 | 126 | 115 | 107 | 110 | |
| 134 | 132 | 130 | 116 | 100 | 88 | 84 | 90 | 99 | 113 | 115 | 123 | 136 | 136 | 127 | 111 | 107 | 103 | 95 | 86 | 85 | 97 | 109 | 116 | 124 | 125 | 121 | 118 | 97 | 105 | |
| 132 | 125 | 122 | 115 | 107 | 101 | 101 | 116 | 119 | 116 | 115 | 121 | 133 | 132 | 126 | 112 | 115 | 119 | 118 | 110 | 103 | 108 | 111 | 110 | 117 | 119 | 113 | 111 | 100 | 156 | |
| 130 | 123 | 117 | 112 | 114 | 117 | 117 | 119 | 117 | 117 | 122 | 123 | 122 | 128 | 121 | 122 | 115 | 115 | 116 | 117 | 119 | 115 | 116 | 115 | 115 | 110 | 112 | 110 | 104 | 117 | 204 |
| 133 | 126 | 119 | 119 | 122 | 126 | 118 | 113 | 107 | 103 | 108 | 129 | 133 | 120 | 119 | 114 | 109 | 96 | 101 | 109 | 113 | 114 | 116 | 114 | 111 | 107 | 116 | 98 | 139 | 207 | |
| 138 | 132 | 124 | 123 | 119 | 118 | 114 | 105 | 81 | 76 | 107 | 127 | 135 | 127 | 122 | 113 | 103 | 77 | 82 | 97 | 106 | 107 | 111 | 115 | 113 | 112 | 114 | 100 | 162 | 200 | |
| 139 | 135 | 129 | 123 | 114 | 108 | 105 | 90 | 71 | 101 | 139 | 129 | 130 | 118 | 115 | 120 | 121 | 83 | 72 | 88 | 101 | 106 | 106 | 111 | 114 | 115 | 110 | 108 | 180 | 192 | |
| 132 | 134 | 131 | 123 | 111 | 106 | 95 | 82 | 73 | 111 | 143 | 126 | 112 | 96 | 109 | 122 | 131 | 99 | 74 | 79 | 95 | 103 | 105 | 110 | 113 | 113 | 106 | 113 | 185 | 185 | |
| 126 | 133 | 134 | 125 | 111 | 104 | 90 | 81 | 75 | 87 | 114 | 119 | 109 | 100 | 110 | 112 | 110 | 96 | 82 | 75 | 88 | 97 | 103 | 111 | 114 | 112 | 99 | 127 | 187 | 177 | |
| 117 | 130 | 138 | 129 | 110 | 103 | 82 | 82 | 87 | 84 | 89 | 101 | 102 | 96 | 90 | 93 | 93 | 91 | 93 | 85 | 86 | 92 | 100 | 111 | 116 | 109 | 93 | 151 | 189 | 172 | |
| 123 | 125 | 135 | 122 | 107 | 93 | 81 | 88 | 93 | 91 | 89 | 81 | 79 | 76 | 75 | 80 | 89 | 97 | 96 | 93 | 89 | 95 | 99 | 106 | 109 | 96 | 107 | 175 | 185 | 173 | |
| 156 | 115 | 125 | 117 | 111 | 89 | 92 | 96 | 91 | 91 | 85 | 76 | 77 | 73 | 72 | 76 | 83 | 91 | 93 | 92 | 89 | 97 | 105 | 106 | 96 | 90 | 140 | 186 | 178 | 165 | |
| 183 | 116 | 110 | 114 | 105 | 87 | 90 | 96 | 102 | 108 | 98 | 82 | 69 | 63 | 74 | 80 | 83 | 85 | 84 | 82 | 81 | 92 | 104 | 98 | 82 | 95 | 166 | 189 | 171 | 162 | |
| 194 | 141 | 96 | 101 | 98 | 87 | 70 | 67 | 82 | 86 | 79 | 72 | 75 | 77 | 84 | 83 | 85 | 87 | 78 | 67 | 65 | 83 | 90 | 75 | 70 | 124 | 176 | 177 | 166 | 167 | |
| 191 | 169 | 101 | 89 | 102 | 85 | 59 | 51 | 71 | 69 | 38 | 20 | 28 | 34 | 29 | 28 | 45 | 67 | 73 | 61 | 58 | 74 | 76 | 61 | 84 | 165 | 177 | 169 | 165 | 170 | |
| 187 | 193 | 152 | 93 | 86 | 76 | 63 | 68 | 86 | 96 | 74 | 43 | 26 | 20 | 21 | 31 | 52 | 76 | 81 | 62 | 52 | 65 | 69 | 68 | 140 | 178 | 167 | 166 | 165 | | |
| 198 | 193 | 192 | 146 | 82 | 79 | 61 | 75 | 83 | 91 | 93 | 76 | 58 | 60 | 61 | 63 | 74 | 81 | 74 | 62 | 54 | 60 | 71 | 109 | 180 | 170 | 167 | 167 | 163 | 164 | |
| 201 | 186 | 191 | 181 | 121 | 73 | 69 | 67 | 66 | 82 | 92 | 84 | 67 | 69 | 69 | 74 | 84 | 82 | 69 | 60 | 59 | 64 | 99 | 152 | 170 | 164 | 167 | 167 | 163 | 159 | 161 |
| 198 | 190 | 179 | 177 | 156 | 89 | 66 | 64 | 63 | 62 | 69 | 64 | 52 | 52 | 54 | 66 | 77 | 80 | 74 | 68 | 59 | 81 | 131 | 156 | 163 | 165 | 157 | 157 | 158 | 161 | |
| 192 | 186 | 182 | 177 | 166 | 131 | 84 | 73 | 60 | 60 | 64 | 53 | 49 | 44 | 50 | 64 | 68 | 74 | 76 | 72 | 74 | 119 | 146 | 155 | 165 | 148 | 155 | 161 | 164 | | |
| 185 | 176 | 179 | 182 | 175 | 165 | 115 | 70 | 74 | 76 | 67 | 71 | 71 | 66 | 68 | 73 | 74 | 78 | 66 | 72 | 104 | 141 | 148 | 158 | 153 | 147 | 151 | 161 | 165 | 164 | |
| 181 | 172 | 173 | 177 | 177 | 178 | 155 | 98 | 73 | 74 | 68 | 71 | 72 | 70 | 69 | 69 | 74 | 79 | 57 | 78 | 144 | 143 | 146 | 153 | 141 | 152 | 166 | 167 | 166 | 163 | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|----|
| 207 | 188 | 170 | 179 | 186 | 185 | 186 | 176 | 160 | 146 | 147 | 138 | 130 | 130 | 135 | 134 | 143 | 160 | 173 | 192 | 212 | 208 | 182 | 164 | 162 | 166 | 176 | 175 | 115 | 86 |
| 185 | 121 | 83 | 86 | 125 | 166 | 177 | 169 | 144 | 123 | 131 | 123 | 109 | 105 | 110 | 125 | 139 | 146 | 147 | 168 | 185 | 159 | 132 | 146 | 170 | 183 | 187 | 180 | 133 | 66 |
| 154 | 106 | 74 | 56 | 63 | 89 | | | | | | | | | | | | | | | | | | | | | | | | |

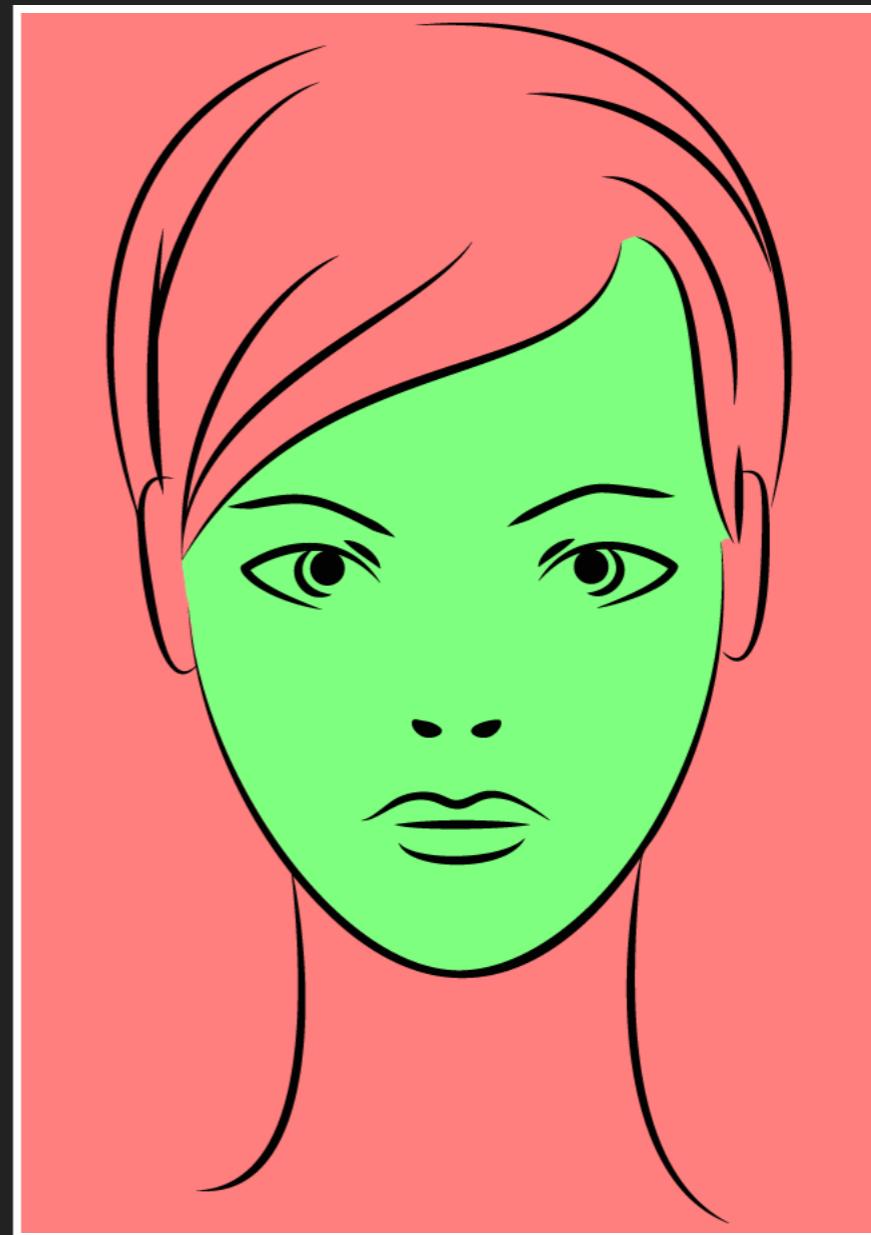
FACE RECOGNITION APPLICATION: APPLE IPHONE



<https://www.youtube.com/watch?v=z-t1h0Y8vuM>

WHAT IS THE FACE?

- ▶ Front portion of the human head
- ▶ Ranges from the forehead to the chin
- ▶ Includes mouth, nose, cheeks, and eyes



HOW DO HUMANS RECOGNIZE FACES?



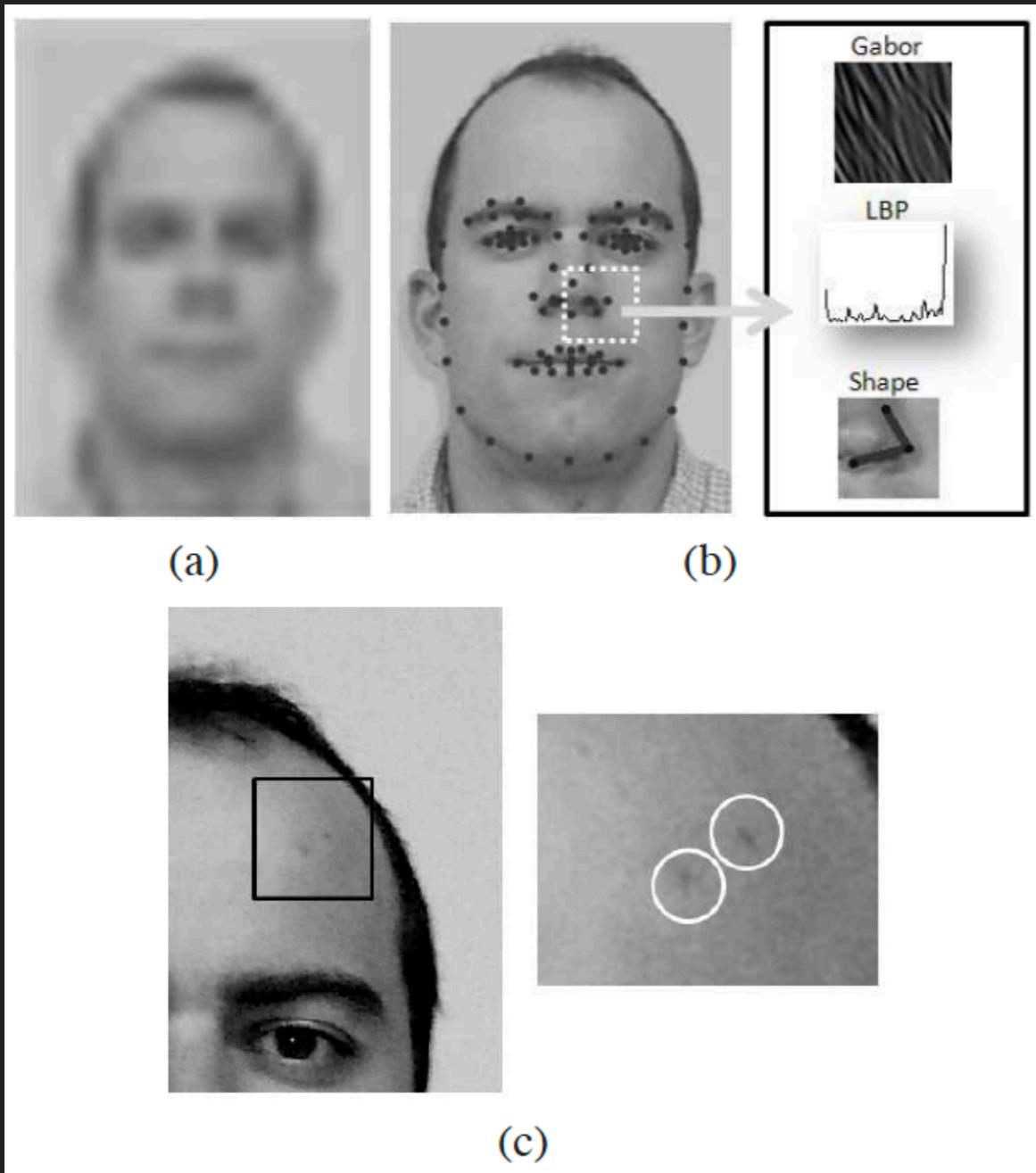
- ▶ Neuro-cognition & psychology indicates that certain parts of the human brain are geared towards perceiving the face
- ▶ Humans struggle to recognize inverted faces even though they can easily identify other inverted objects
- ▶ Humans likely perceive the face based on high-level characteristics (e.g., object with two eyes, nose, & mouth)

AUTOMATED FACE RECOGNITION SYSTEM BY MACHINES

Goal:

Create a representation that adequately distinguishes between different subjects

3 LEVELS OF DETAILS IN FACES



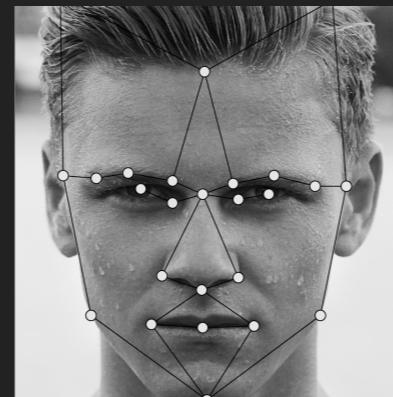
(a) Level 1 features contain appearance information that can be useful for determining ethnicity, gender, and the general shape of a face.

(b) Level 2 features require detailed processing for face recognition. Information regarding the structure and the specific shape and texture of local regions in a face is used to make an accurate determination of the subject's identity.

(c) Level 3 features include marks, moles, scars, and other irregular micro features of the face. This information is useful to resolve ambiguities when distinguishing identical twins, or to assist in forensic investigation scenarios.

WHAT IS A REPRESENTATION?

- ▶ Usually refers to a **digital** representation
- ▶ Could be an image, a graph, or a **vector**
 - ▶ Vector is the most common representation for faces over the last half decade



| |
|------|
| 3.2 |
| -1.5 |
| 9.2 |
| 4.2 |
| -4.3 |

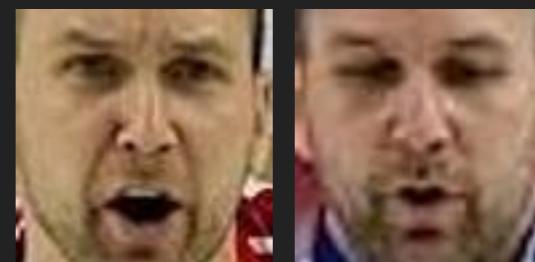
WHAT IS THE GOAL?

- ▶ **Input:**

- ▶ Two Face Images

- ▶ **Output:**

- ▶ Match Score



Face Matcher

Converts 2 images
into 2 representations
and compares them

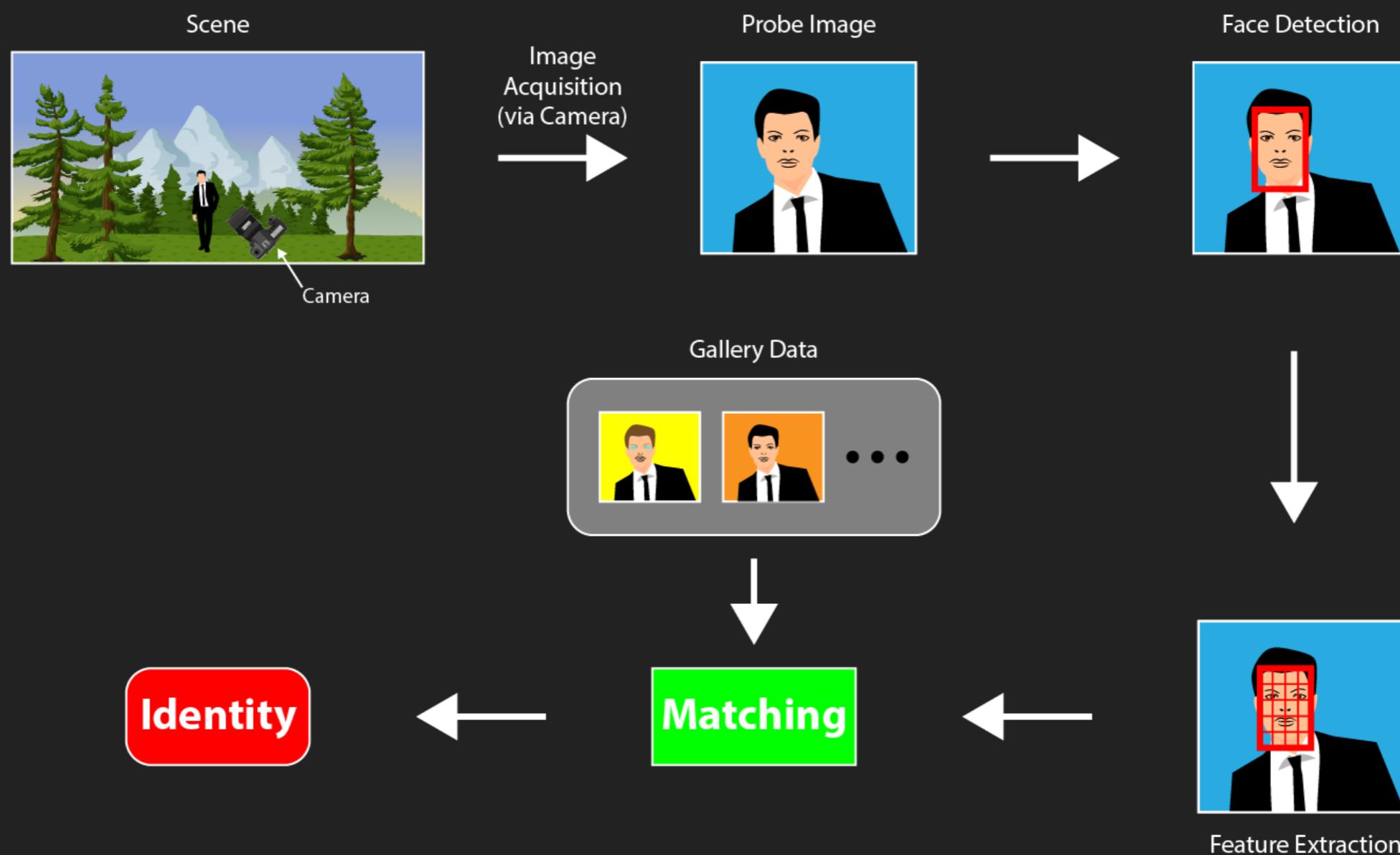


0.67

TRAINING A FACE RECOGNITION SYSTEM

- ▶ A face recognition method must be **trained**
- ▶ A *set of face images* with identity labels is input to a face recognition method
- ▶ The FR method uses training data to create a representation

TYPICAL FACE RECOGNITION PIPELINE

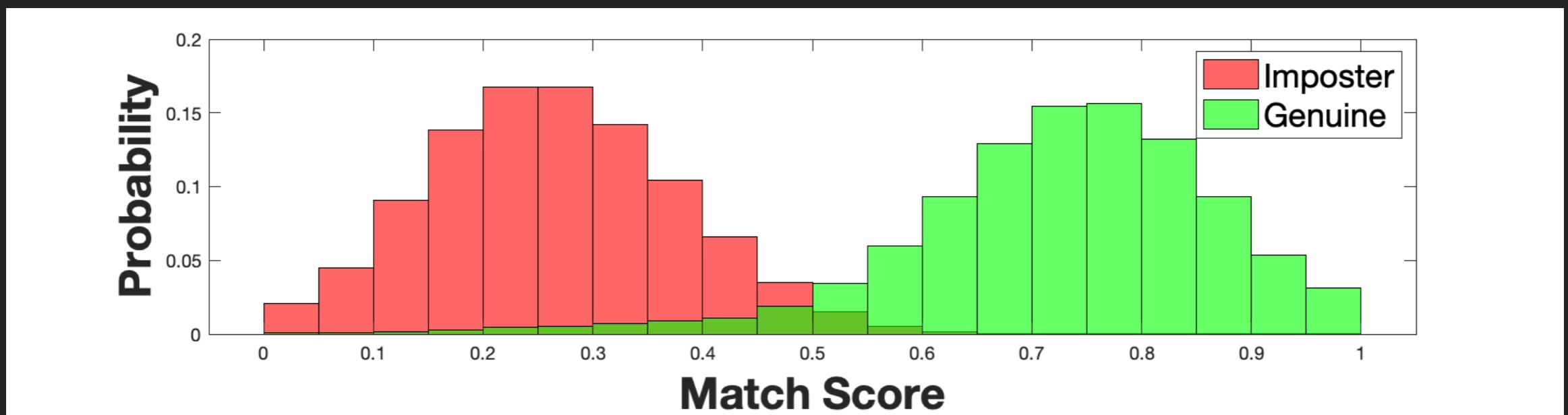


WHAT IS A MATCH SCORE?

- ▶ A numerical scalar value which indicates the **confidence** of a match
- ▶ Can be a *similarity* or *dissimilarity* score
 - ▶ **Similarity:** higher scores indicates more similarity (i.e., a match)
 - ▶ **Dissimilarity:** lower scores indicate less difference (i.e., a match)

WHAT IS A MATCH SCORE?

- ▶ We can compare match scores to analyze the performance of a matching system
- ▶ Desire **genuine** (match) and **imposter** (non-match) scores to be well-separated



TYPES OF FACE RECOGNITION

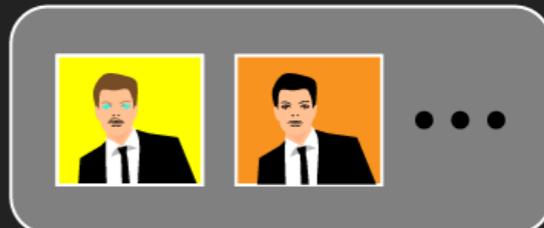
Identification (1-to-N)

- Given a probe, find a match (*if it exists*) among a set of face images

Identification



Probe



Gallery

Verification (1-to-1)

- Given a face image and a claimed identity, match the given face image to *known image* of the claimed identity

Verification

Known Face Image
for Claimed Identity

FACE SENSING SPECTRA

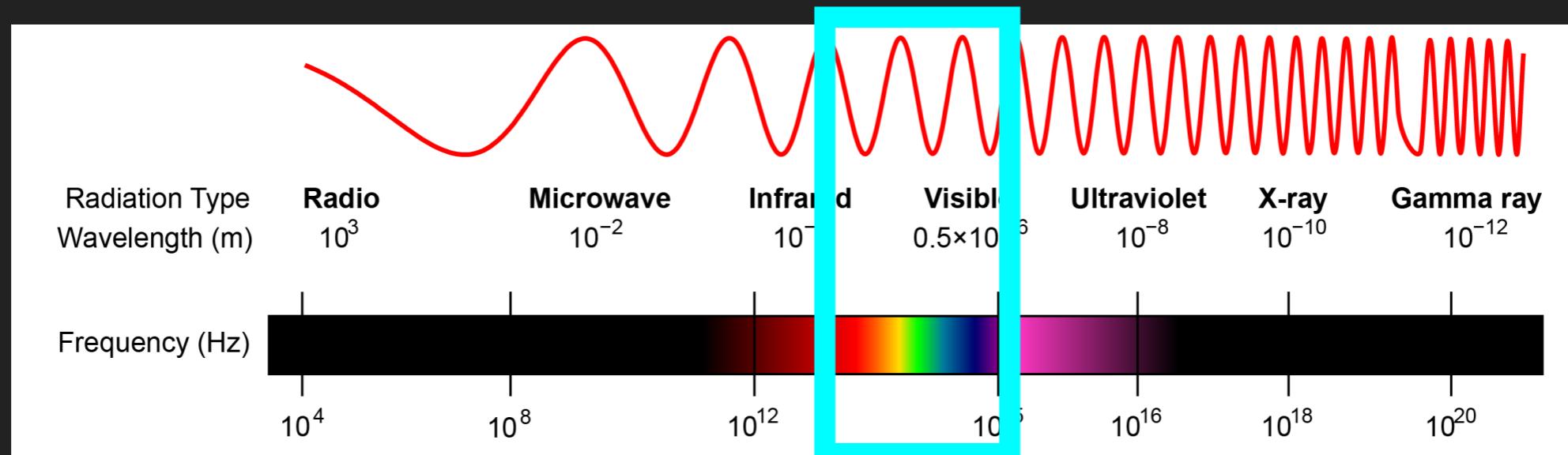


Image from "Electromagnetic Spectrum," Wikipedia.

- ▶ Face Recognition can be performed in different spectra (e.g., Visible or Near-Infrared)
- ▶ **Visible Spectrum Face Recognition is most common**

FACE SENSING SPECTRA



Image from *Introduction to Biometrics*, 2011.

- ▶ Face Recognition can be performed in different spectrums (e.g., Visible or Near-Infrared)
- ▶ **Visible Spectrum Face Recognition is most common**

2D AND 3D

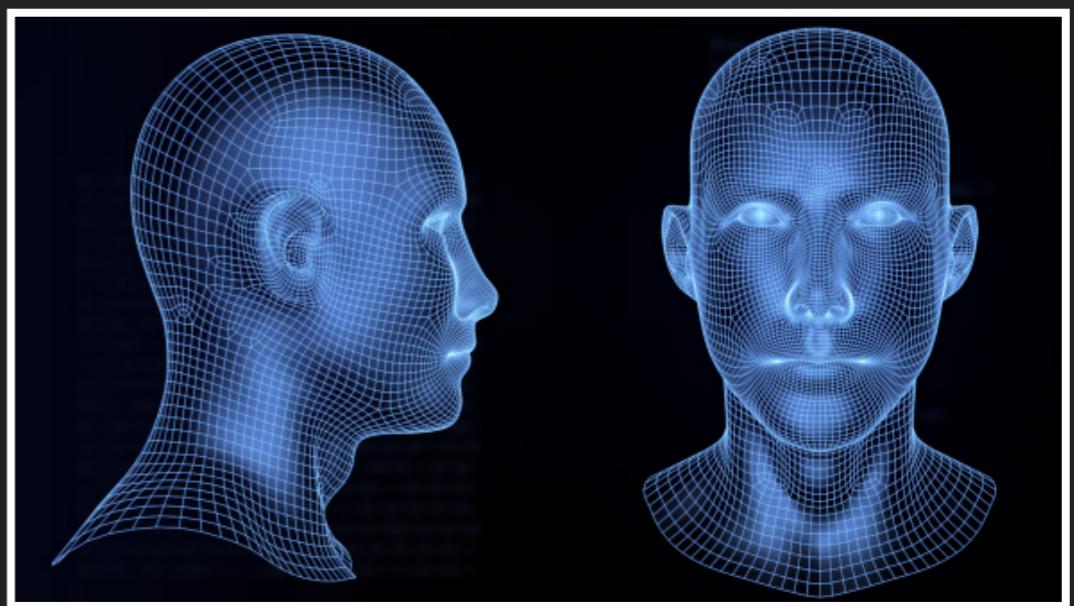
2D

- ▶ Maybe a photo obtained from a **typical camera**
- ▶ Pixel intensities in a 2D grid (X & Y)



3D

- ▶ Adds depth information (Z)
- ▶ **Requires special camera**
(or many 2D images)



FACE IMAGE SENSORS

- ▶ General purpose cameras can be used for FR
- ▶ Some cameras can be used for FR, but **typical use makes it more difficult**
 - ▶ E.G., surveillance camera captures a face at odd angle
- ▶ Some cameras designed specifically for FR
 - ▶ Apple iPhoneX
 - ▶ Bellus3D Face Camera



Bellus3D
Face Camera



General Purpose Camera



Surveillance Camera



Apple iPhoneX FaceID

FACE DATASETS

| Dataset | Num. Subjects | Num. Images |
|---------------|------------------|---------------------|
| MegaFace | 690,572 | 1,027,060 |
| MF2 | 672,057 | 4,753,320 |
| Celeb A | 10,177 | 202,599 |
| VGG Face 2 | 9,131 | 3,311,286 |
| LFW | 5,749 | 13,233 |
| IJB-C | 3,531 | 31,334 |
| Audience | 2,284 | 26,580 |
| YouTube Faces | 1,595 | 3,425 <i>videos</i> |
| PubFig | 200 | 58,797 |
| UTK Face | <i>not given</i> | 23,708 |