Media

#WWDC17

Vision Framework

Building on Core ML

Session 506

Brett Keating, Apple Manager
Frank Doepke, He who wires things together

What Can Vision Do

Vision Concepts

The Code

What Can Vision Do

Vision Concepts

The Code

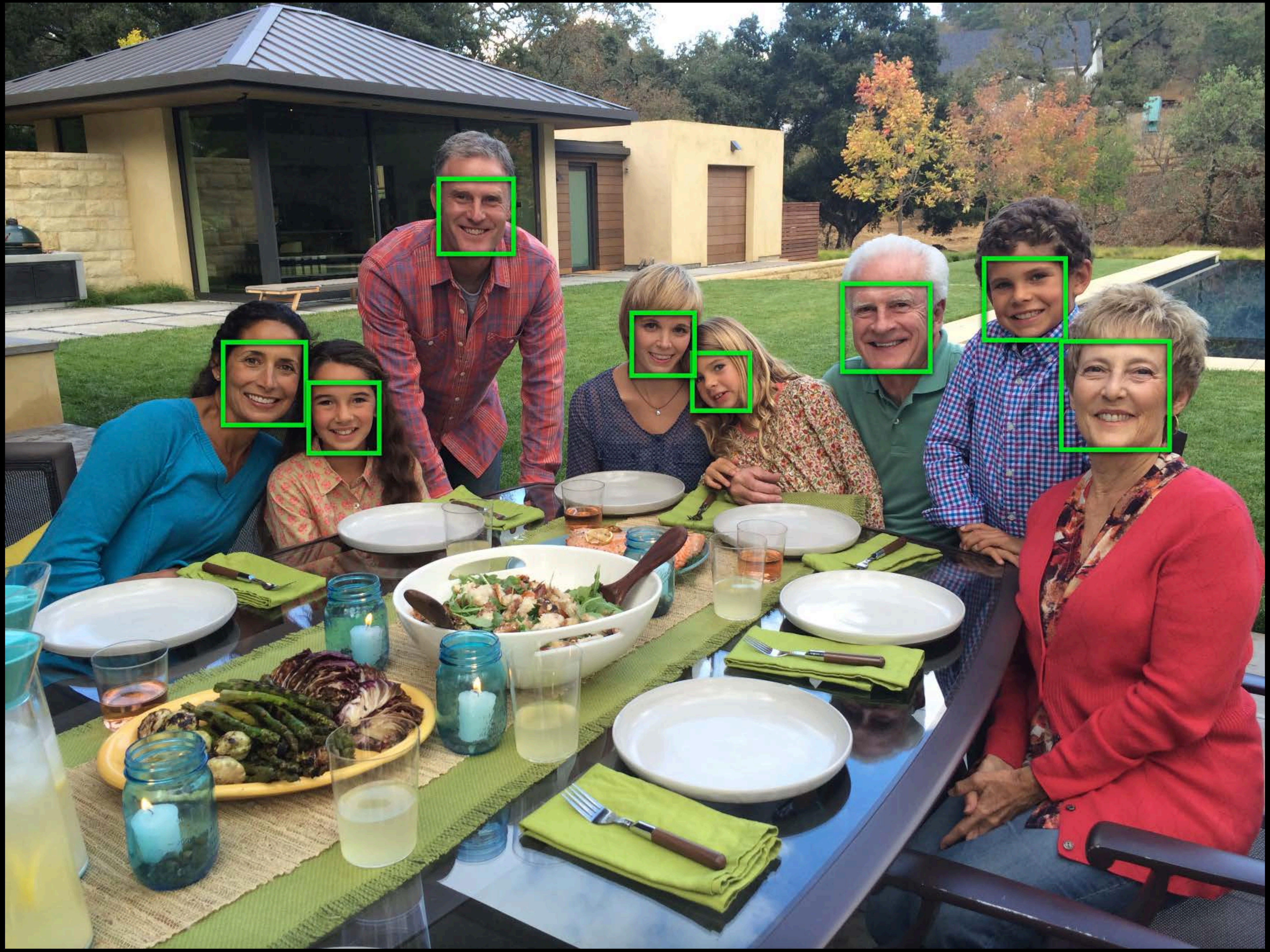
What Can Vision Do

Vision Concepts

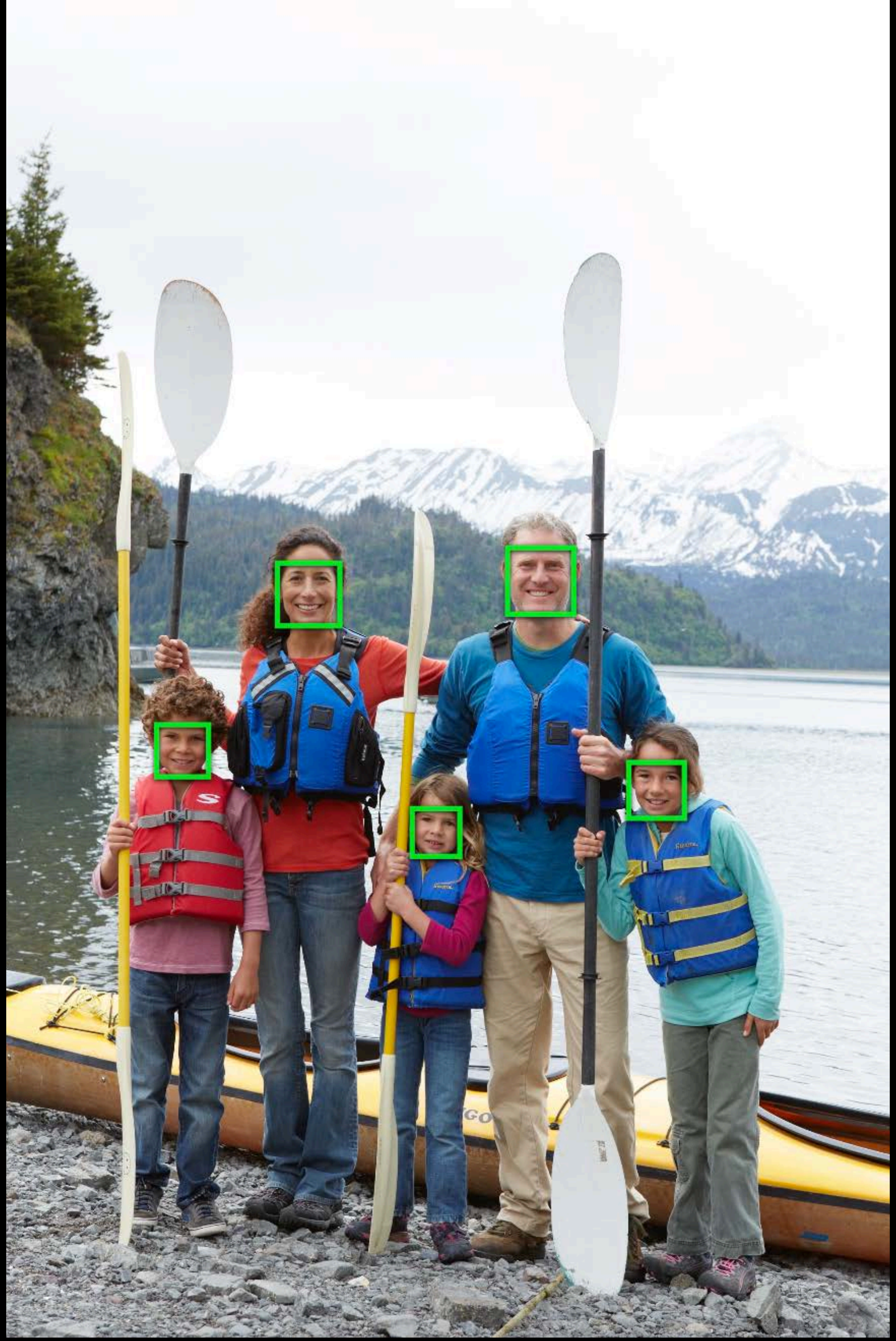
The Code

What You Can Do with Vision

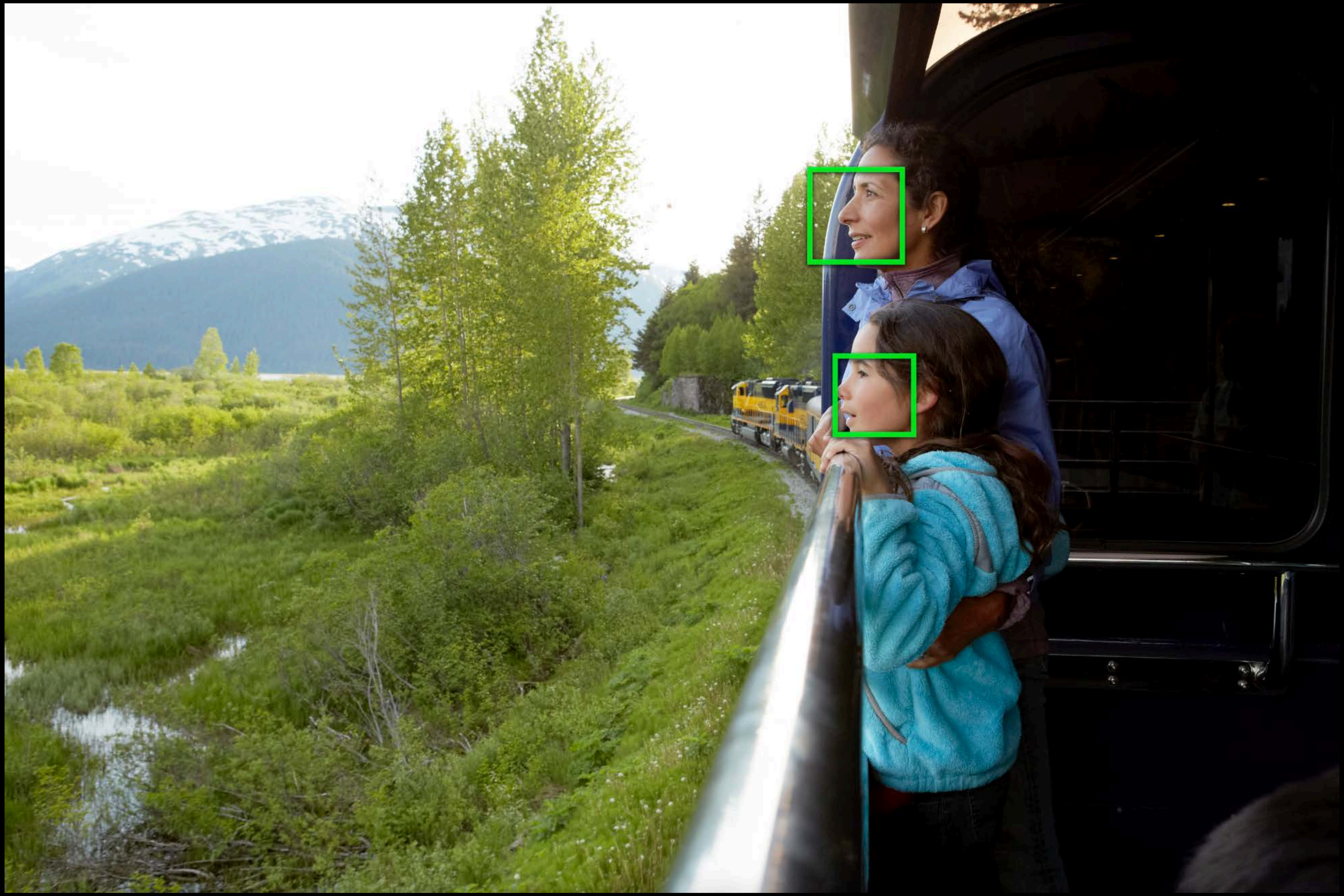
Face Detection



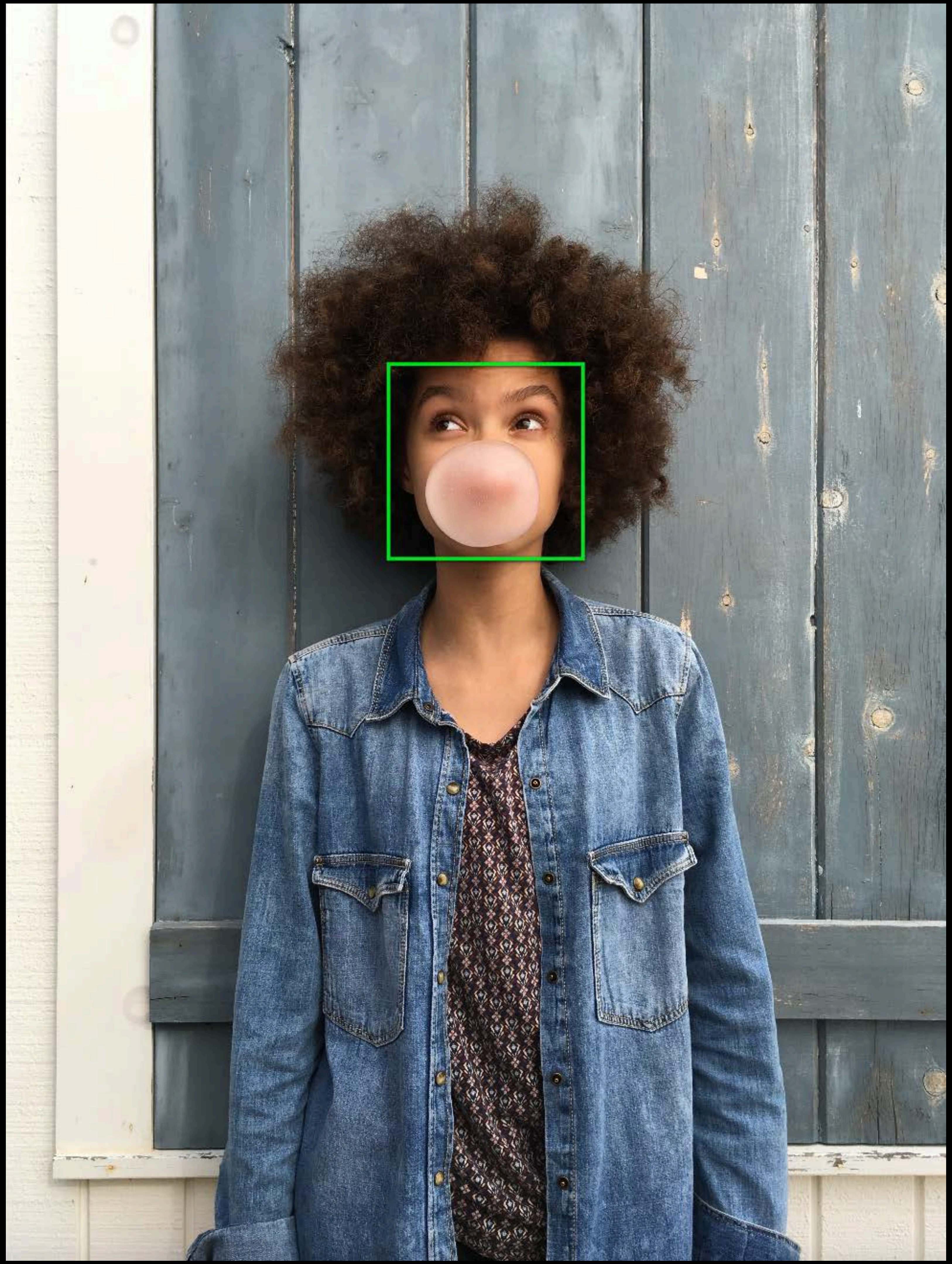
Face Detection: Small Faces



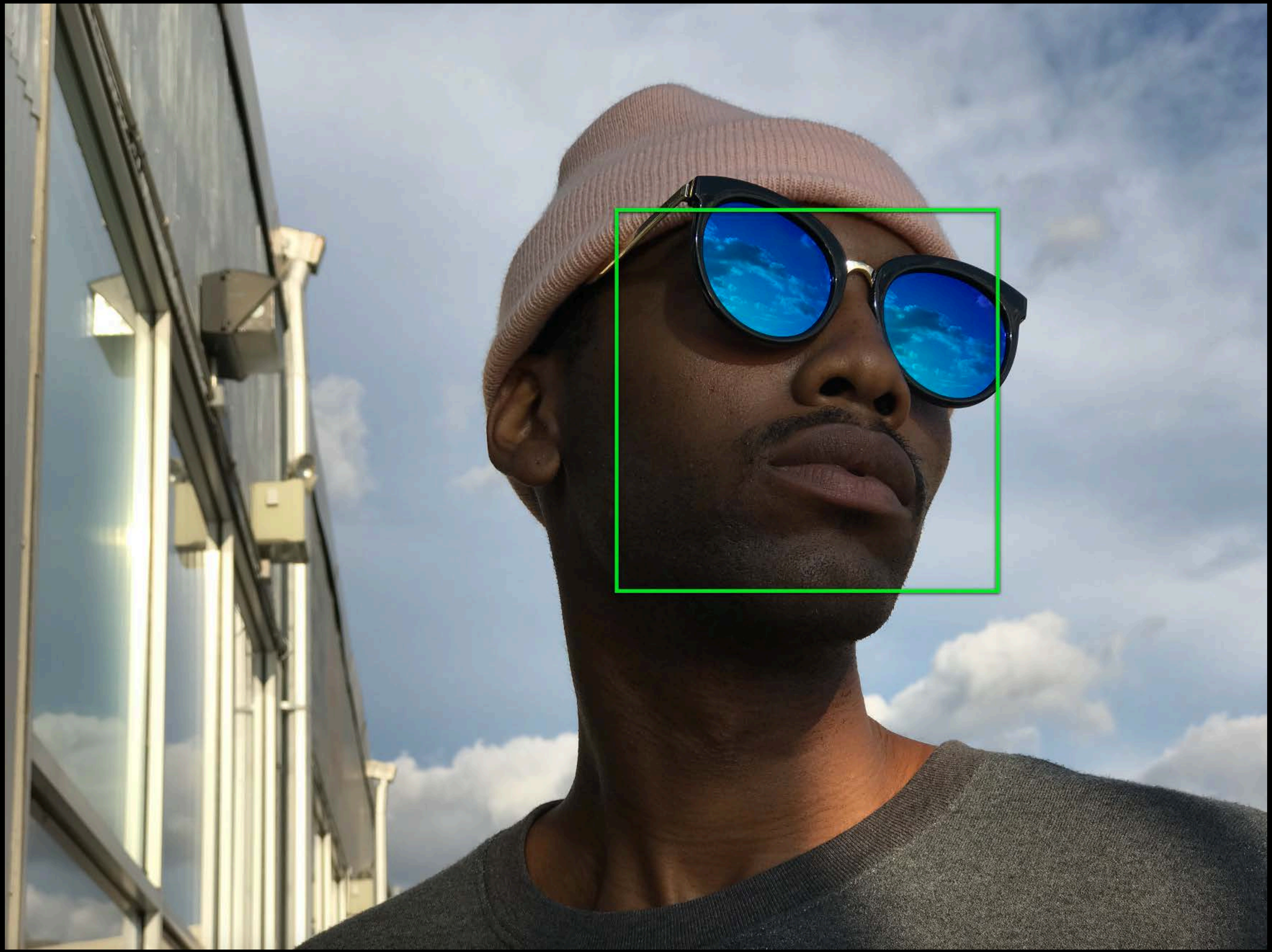
Face Detection: Strong Profiles



Face Detection: Partially Occluded

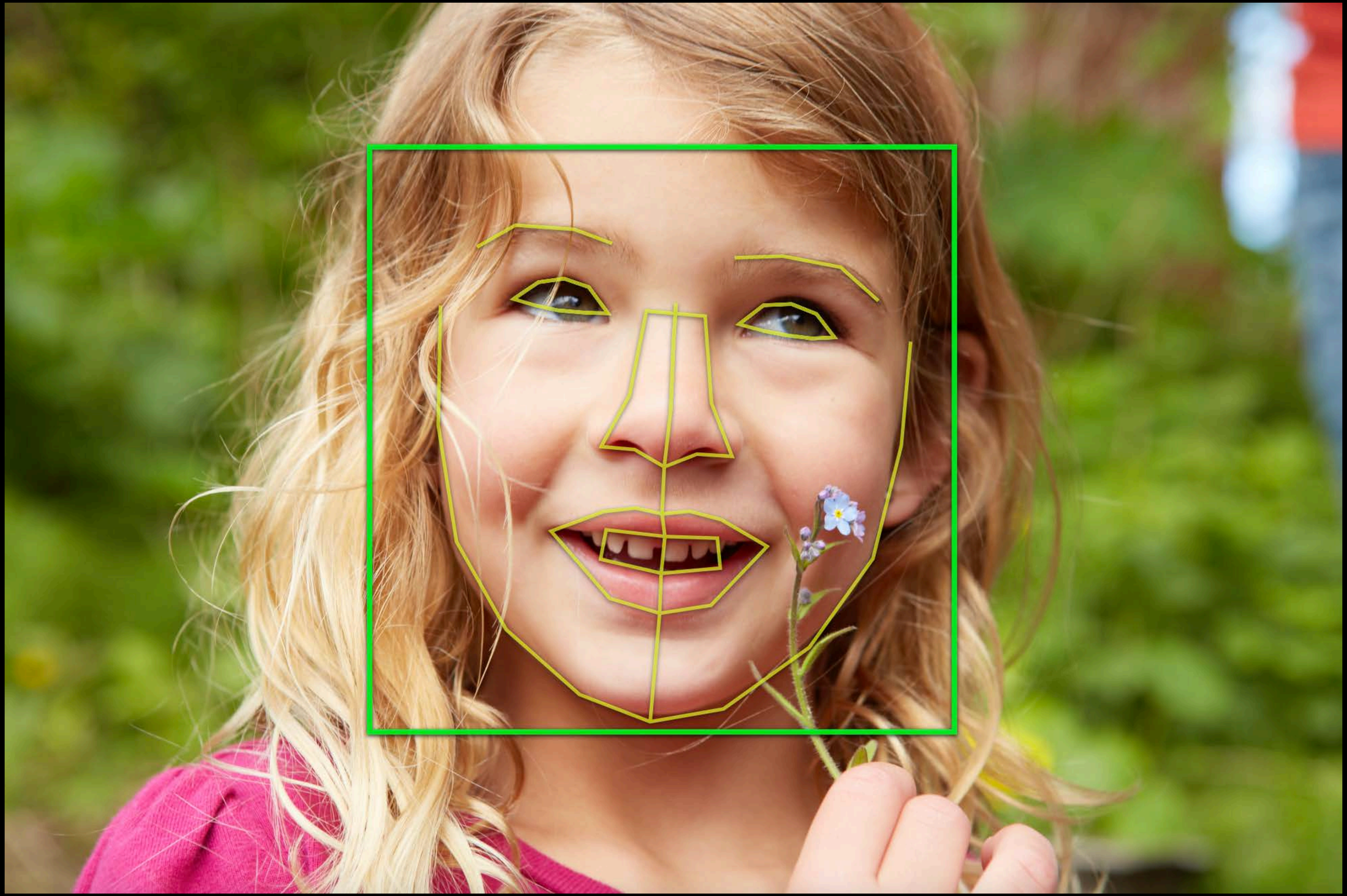


Face Detection: Hats and Glasses

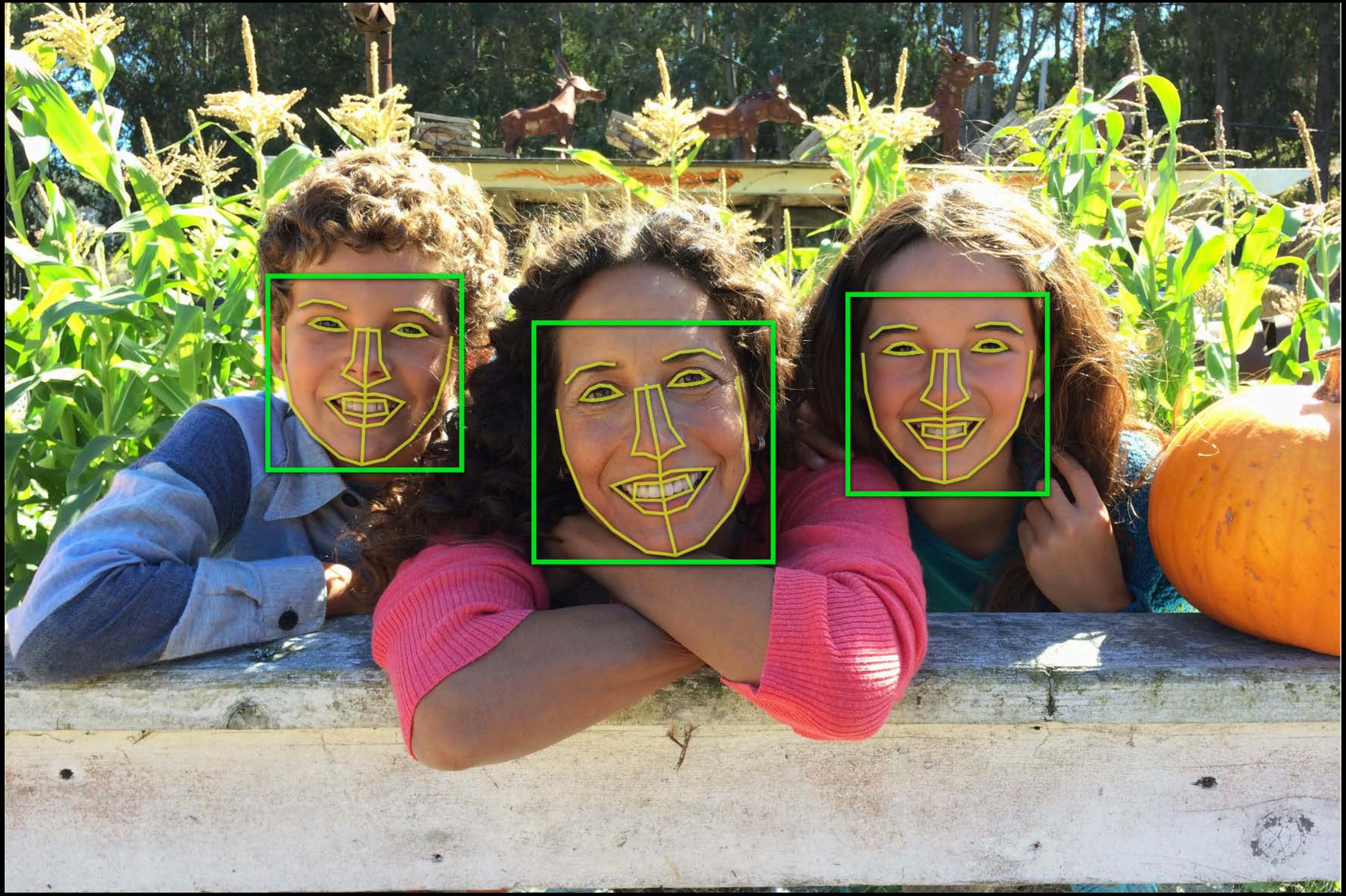


Face Landmarks

Face Landmarks



Face Landmarks



Face Landmarks

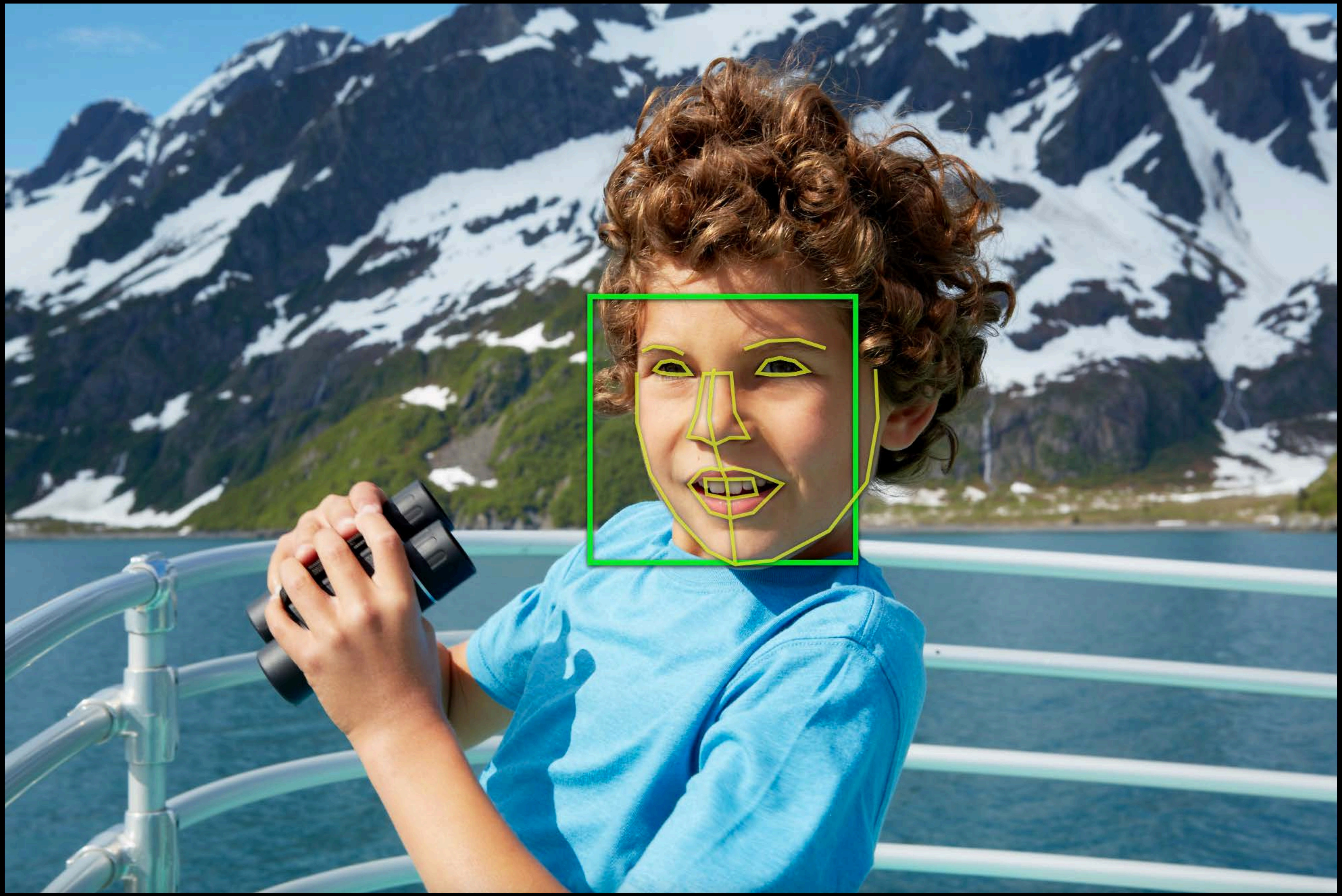
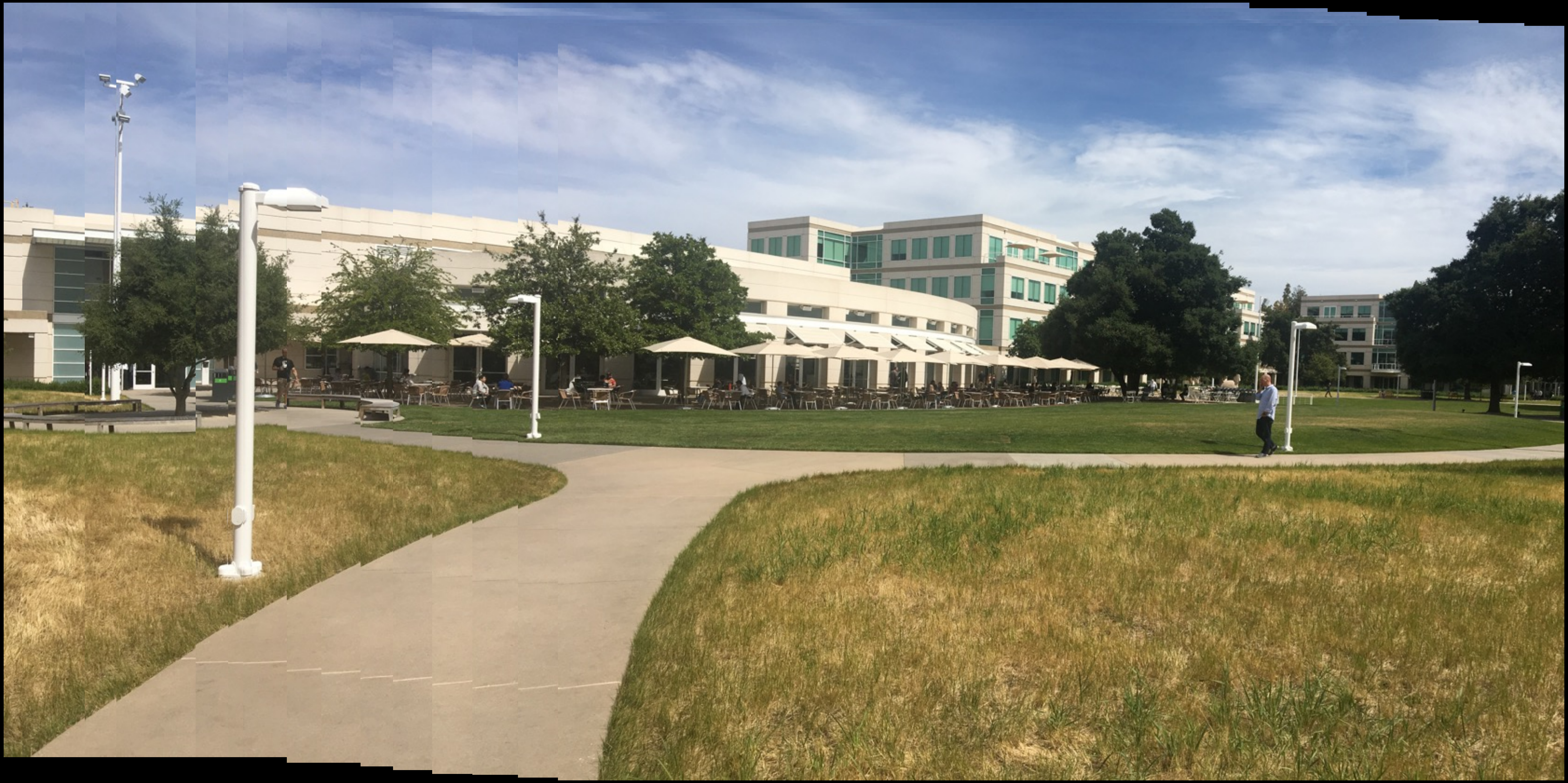
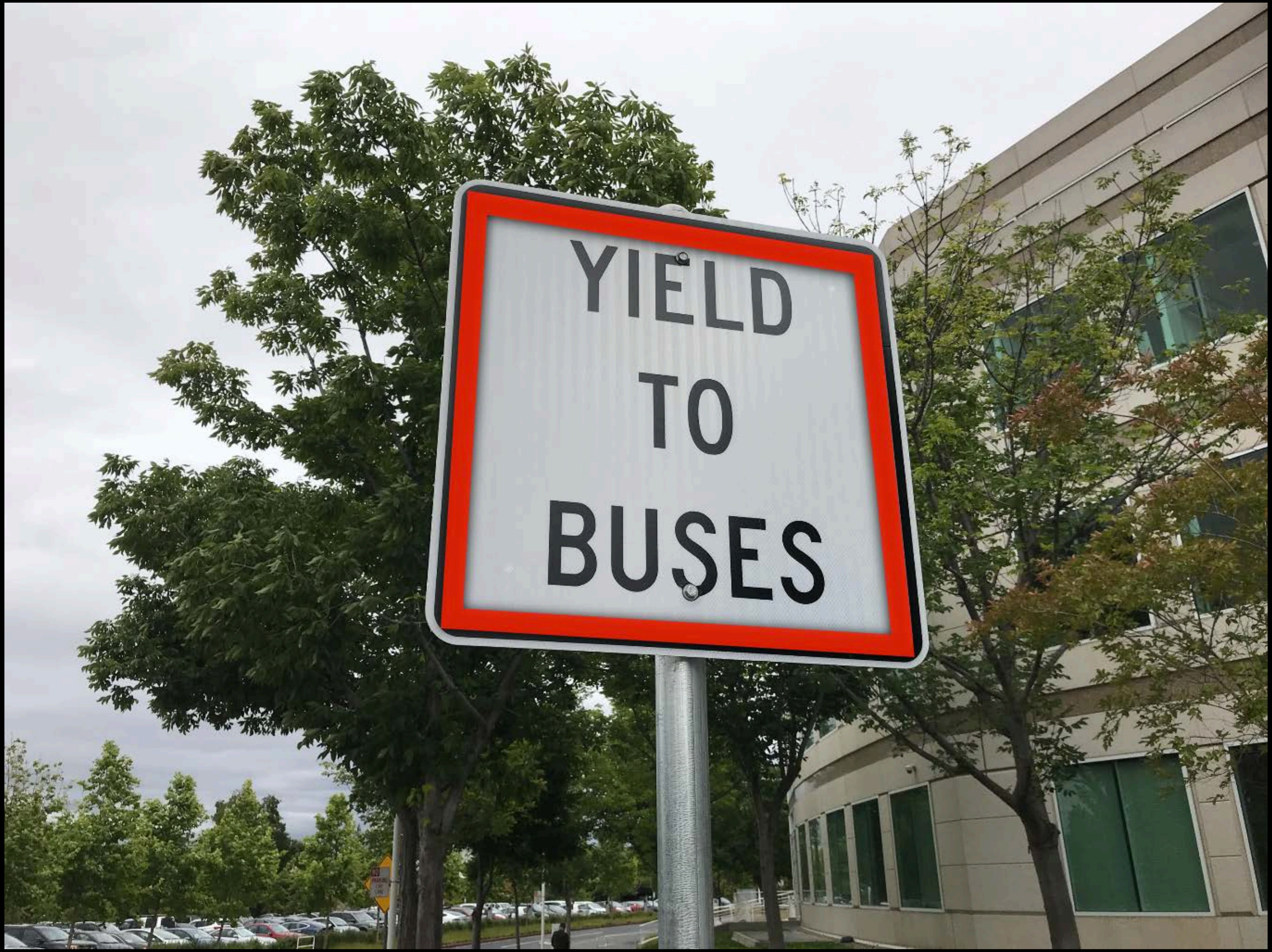


Image Registration

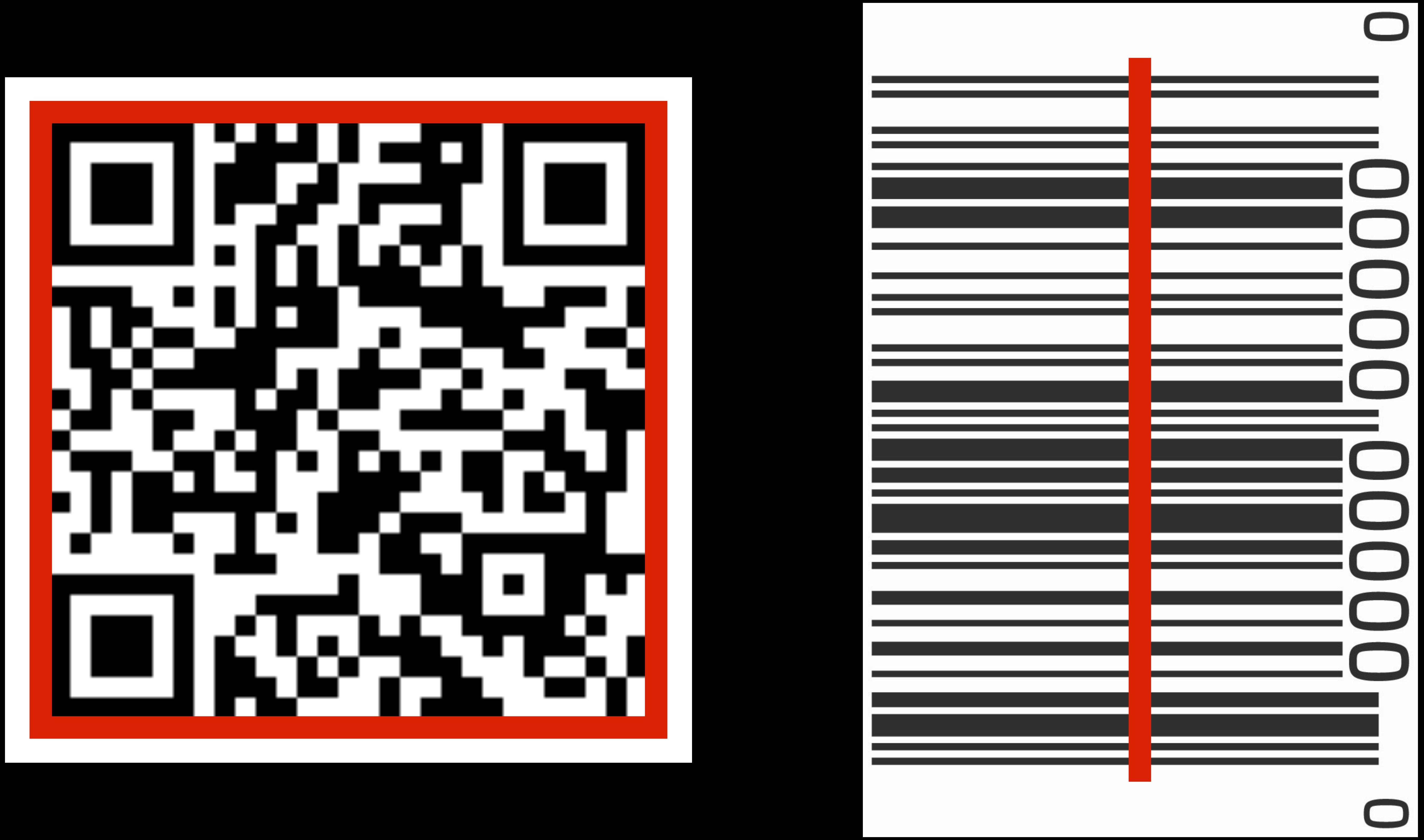
Image Registration



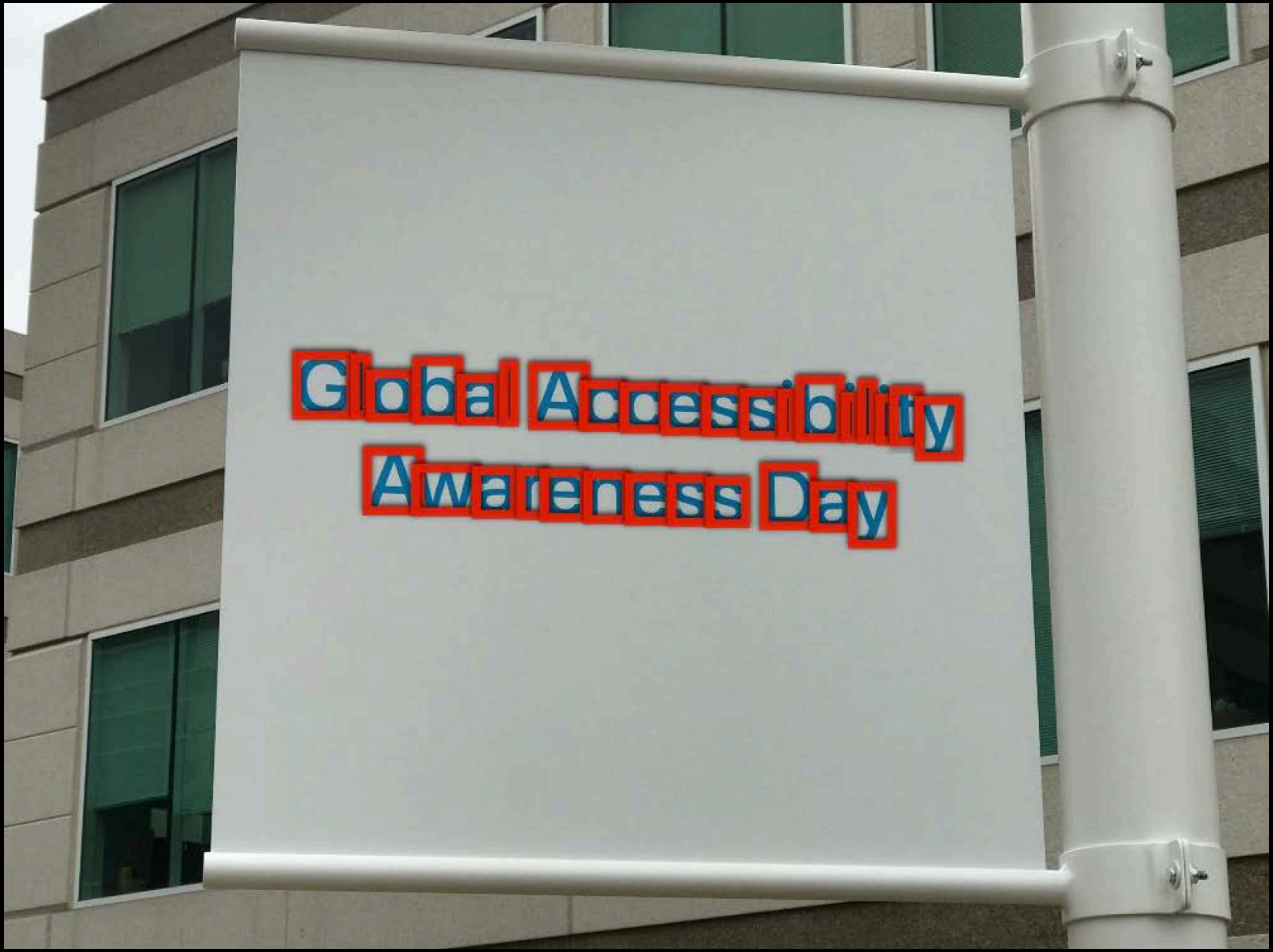
Rectangle Detection



Barcode Detection



Text Detection



Object Tracking

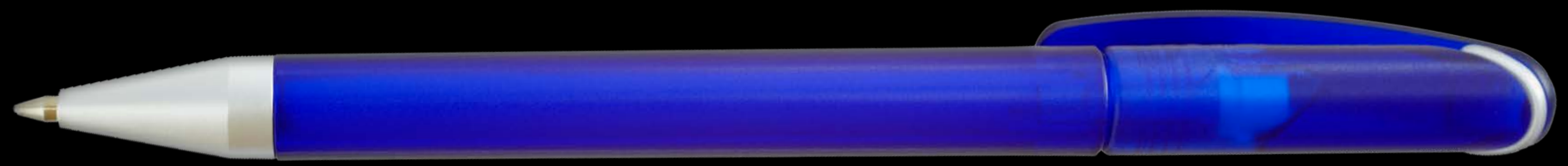
For faces, rectangles, and general templates

Integration with Core ML

Significant advances in Computer Vision through Machine Learning

Core ML provides native acceleration for custom models

Vision provides the imaging pipeline to support Core ML models



Classification:
Ballpoint, ballpoint pen, ballpen

Confidence:
0.86

Core ML and Natural Language Processing Lab	Technology Lab D	Thur 11:00AM-3:30PM
Core ML and Natural Language Processing Lab	Technology Lab D	Fri 1:50PM-4:00PM

High-level on-device solutions
to Computer Vision problems
through one simple API

High-Level Solutions

High-Level Solutions

You don’t have to be a Computer Vision expert

High-Level Solutions

You don’t have to be a Computer Vision expert

“I just want to know where the faces are”

High-Level Solutions

You don’t have to be a Computer Vision expert

“I just want to know where the faces are”

Handles the complexity for you

High-Level Solutions

You don’t have to be a Computer Vision expert

“I just want to know where the faces are”

Handles the complexity for you

Traditional and deep learning algorithms

On Device vs. Cloud

On Device vs. Cloud

Privacy

- Images and video stay on device

On Device vs. Cloud

Privacy

- Images and video stay on device

Cost

- No usage fees
- No data transfer

On Device vs. Cloud

Privacy

- Images and video stay on device

Cost

- No usage fees
- No data transfer

Real-time use cases

- No latency, fast execution

Vision Concepts

Frank Doepke, He who wires things together

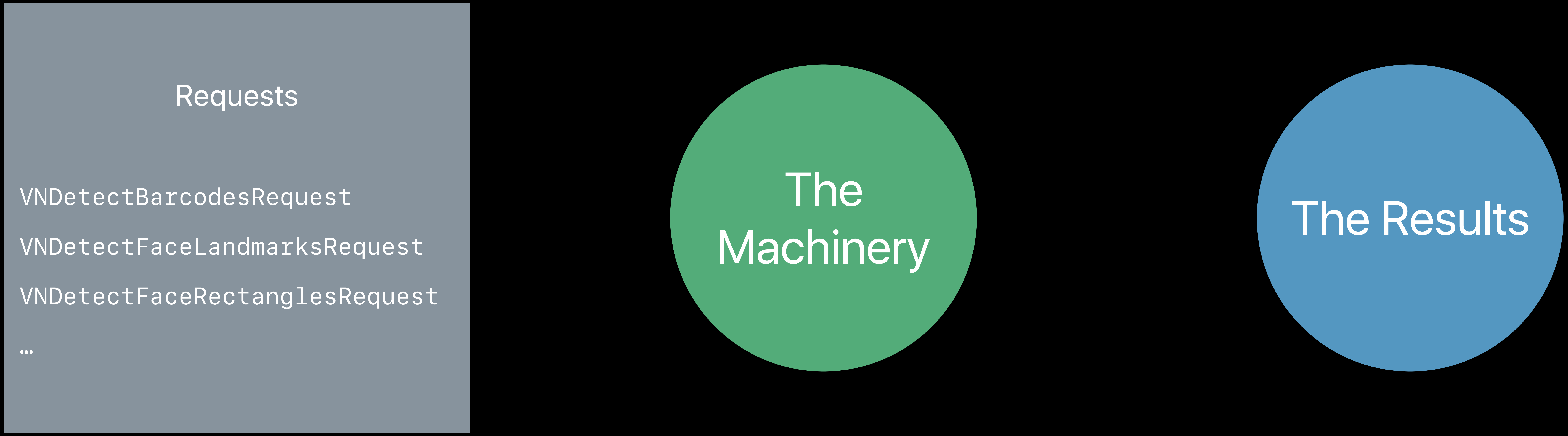
Analyzing an Image

The Asks

The Machinery

The Results

Analyzing an Image



Requests

VNDetectBarcodesRequest

VNDetectFaceLandmarksRequest

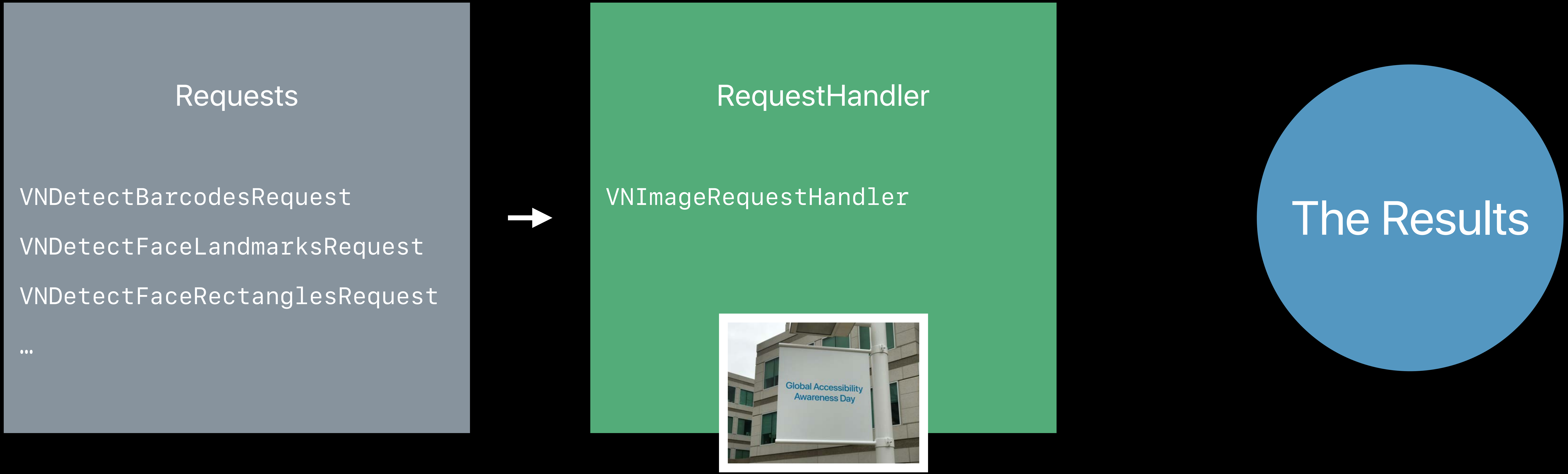
VNDetectFaceRectanglesRequest

…

The Machinery

The Results

Analyzing an Image



Requests

VNDetectBarcodesRequest

VNDetectFaceLandmarksRequest

VNDetectFaceRectanglesRequest

…

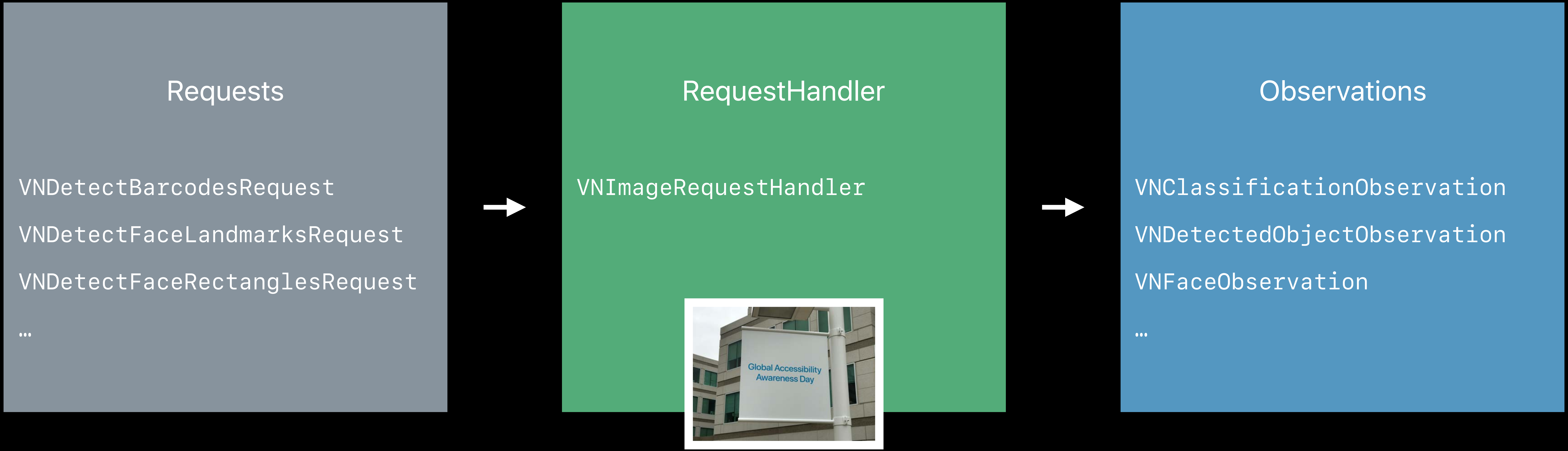
→

RequestHandler

VNImageRequestHandler

The Results

Analyzing an Image



Requests

VNDetectBarcodesRequest

VNDetectFaceLandmarksRequest

VNDetectFaceRectanglesRequest

…

→

RequestHandler

VNImageRequestHandler

→

Observations

VNClassificationObservation

VNDetectedObjectObservation

VNFaceObservation

…

Tracking in a Sequence

The Asks

The Machinery

The Results

Tracking in a Sequence

Requests

`VNTrackObjectRequest`

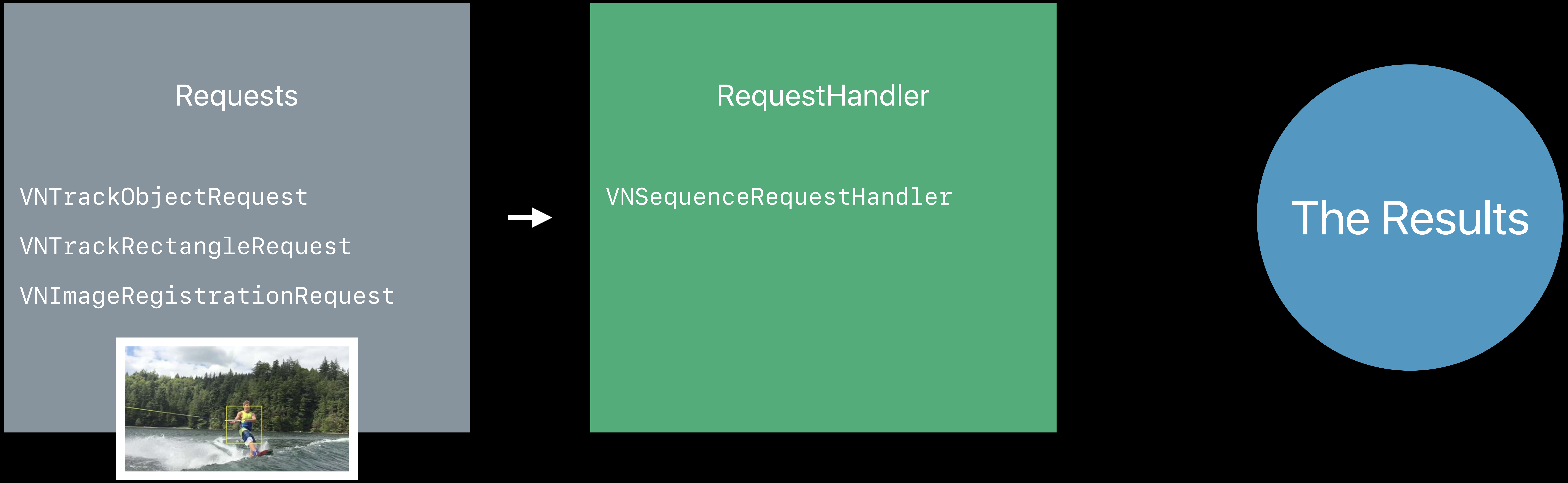
`VNTrackRectangleRequest`

`VNImageRegistrationRequest`

The Machinery

The Results

Tracking in a Sequence



Requests

VNTrackObjectRequest

VNTrackRectangleRequest

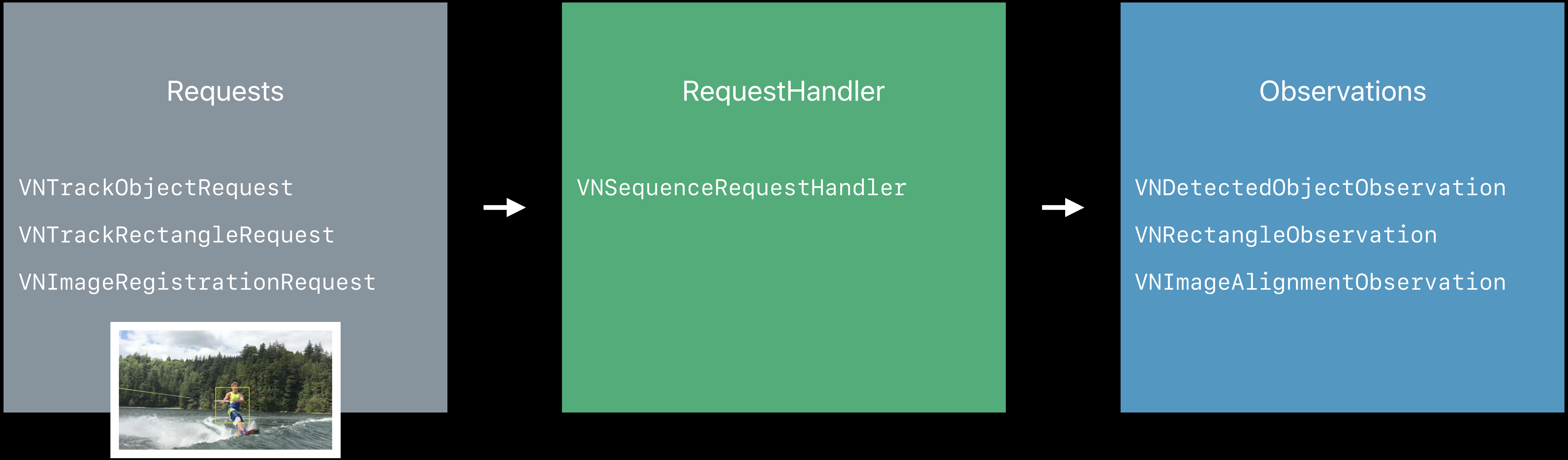
VNImageRegistrationRequest

RequestHandler

VNSequenceRequestHandler

The Results

Tracking in a Sequence



Requests

`VNTrackObjectRequest`

`VNTrackRectangleRequest`

`VNImageRegistrationRequest`

→

RequestHandler

`VNSequenceRequestHandler`

→

Observations

`VNDetectedObjectObservation`

`VNRectangleObservation`

`VNImageAlignmentObservation`

Image Request Handler

For interactive exploration of an image

Holds on to the image for its lifecycle

Allows optimization of various requests performed on an image

Sequence Request Handler

For anything that looks at images in a sequence like tracking

Does not optimize for multiple requests on an image

Putting It into Code

```swift
// Create request
let faceDetectionRequest = VNDetectFaceRectanglesRequest()
```

```swift
// Create request
let faceDetectionRequest = VNDetectFaceRectanglesRequest()

// Create request handler
let myRequestHandler = VNImageRequestHandler(url: fileURL, options: [:])
```

```swift
// Create request
let faceDetectionRequest = VNDetectFaceRectanglesRequest()

// Create request handler
let myRequestHandler = VNImageRequestHandler(url: fileURL, options: [:])

// send the requests to the request handler
myRequestHandler.perform([faceDetectionRequest])
```

```swift
// Create request
let faceDetectionRequest = VNDetectFaceRectanglesRequest()

// Create request handler
let myRequestHandler = VNImageRequestHandler(url: fileURL, options: [:])

// send the requests to the request handler
myRequestHandler.perform([faceDetectionRequest])

// Do we have a face
for observation in faceDetectionRequest.results as! [VNFaceObservation] {
        /// do something
}
```

```swift
// Create request
let faceDetectionRequest = VNDetectFaceRectanglesRequest()

// Create request handler
let myRequestHandler = VNImageRequestHandler(url: fileURL, options: [:])

// send the requests to the request handler
myRequestHandler.perform([faceDetectionRequest])

// Do we have a face
for observation in faceDetectionRequest.results as! [VNFaceObservation] {
        /// do something
}
```

```
// Create a sequence request handler
let requestHandler = VNSequenceRequestHandler()
```

```swift
// Create a sequence request handler
let requestHandler = VNSequenceRequestHandler()

// Start the tracking with an observation
let observations = detectionRequest.results as! [VNDetectedObjectObservation]
let objectsToTrack = observations.map { VNTrackObjectRequest(detectedObjectObservation: $0) }
```

```swift
// Create a sequence request handler
let requestHandler = VNSequenceRequestHandler()

// Start the tracking with an observation
let observations = detectionRequest.results as! [VNDetectedObjectObservation]
let objectsToTrack = observations.map { VNTrackObjectRequest(detectedObjectObservation: $0) }

// Run the requests
requestHandler.perform(objectsToTrack, on: pixelBuffer)
```

```
// Create a sequence request handler
let requestHandler = VNSequenceRequestHandler()

// Start the tracking with an observation
let observations = detectionRequest.results as! [VNDetectedObjectObservation]
let objectsToTrack = observations.map { VNTrackObjectRequest(detectedObjectObservation: $0) }

// Run the requests
requestHandler.perform(objectsToTrack, on: pixelBuffer)

// Lets look at the results
for request in objectsToTrack
    for observation in request.results as! [VNDetectedObjectObservation]
```

Best Practices

Envisioning a Vision Task

Envisioning a Vision Task

Which image type is right for me?

Envisioning a Vision Task

Which image type is right for me?

What am I going to do with the image?

Envisioning a Vision Task

Which image type is right for me?

What am I going to do with the image?

What performance do I need or want?

Which Image Type Is Right for Me?

Which Image Type Is Right for Me?

Vision supports various image types

```
CVPixelBufferRef
CGImageRef
CIImage
NSURL
NSData
```

Which Image Type Is Right for Me?

Vision supports various image types

`CVPixelBufferRef`

`CGImageRef`

`CIImage`

`NSURL`

`NSData`

The image type to choose depends on where the image comes from

Which Image Type Is Right for Me?

Vision supports various image types

`CVPixelBufferRef`

`CGImageRef`

`CIImage`

`NSURL`

`NSData`

The image type to choose depends on where the image comes from

You shouldn’t have to pre-scale the image

Which Image Type Is Right for Me?

Vision supports various image types

```
CVPixelBufferRef
CGImageRef
CIImage
NSURL
NSData
```

The image type to choose depends on where the image comes from

You shouldn’t have to pre-scale the image

Make sure to pass in the EXIF orientation of the image

Everything Streaming

CVPixelBuffer

Comes from a CMSampleBuffer in the VideoDataOut of a camera stream

Also a good low-level format to provide image data in memory

Files from Disk or Web

URL for image files on disk

NSData for images from the web

Least amount of memory footprint

Vision will do the scaling without reading the full image if possible

EXIF Orientation is derived from the file if possible but can be overwritten

Core Image

Already using Core Image

Preprocessing the image

Advances in Core Image: Filters, Metal, Vision, and More	Executive Ballroom	Thursday 1:50PM

Images Already Used in the UI

Use CGImage if the image was already used in the UI

UIImage and NSImage have accessors for CGImageRefs

What Am I Going to Do with the Image?

What Am I Going to Do with the Image?

Interactively explore the image

- Use VNImageRequestHandler and hold onto it
- Remember that the input image is immutable

What Am I Going to Do with the Image?

Interactively explore the image

- Use VNImageRequestHandler and hold onto it
- Remember that the input image is immutable

Tracking an observation

- Use VNSequenceRequestHandler
- Tracking state is kept in the VNSequenceRequestHandler
- Lifecycle of images is not tied to the life of the VNSequenceRequestHandler

What Performance Do I Need or Want?

Vision tasks can be time consuming and processing intensive

- Dispatch your work on a queue with appropriate QOS
- Use the completion handler to work with the results
- Completion handler is called on the same queue as the request

Yet Another Face Detector?

Vision uses deep learning for face detection

- Highest precision and recall
- Slower on older hardware in particular

Face Detector Landscape

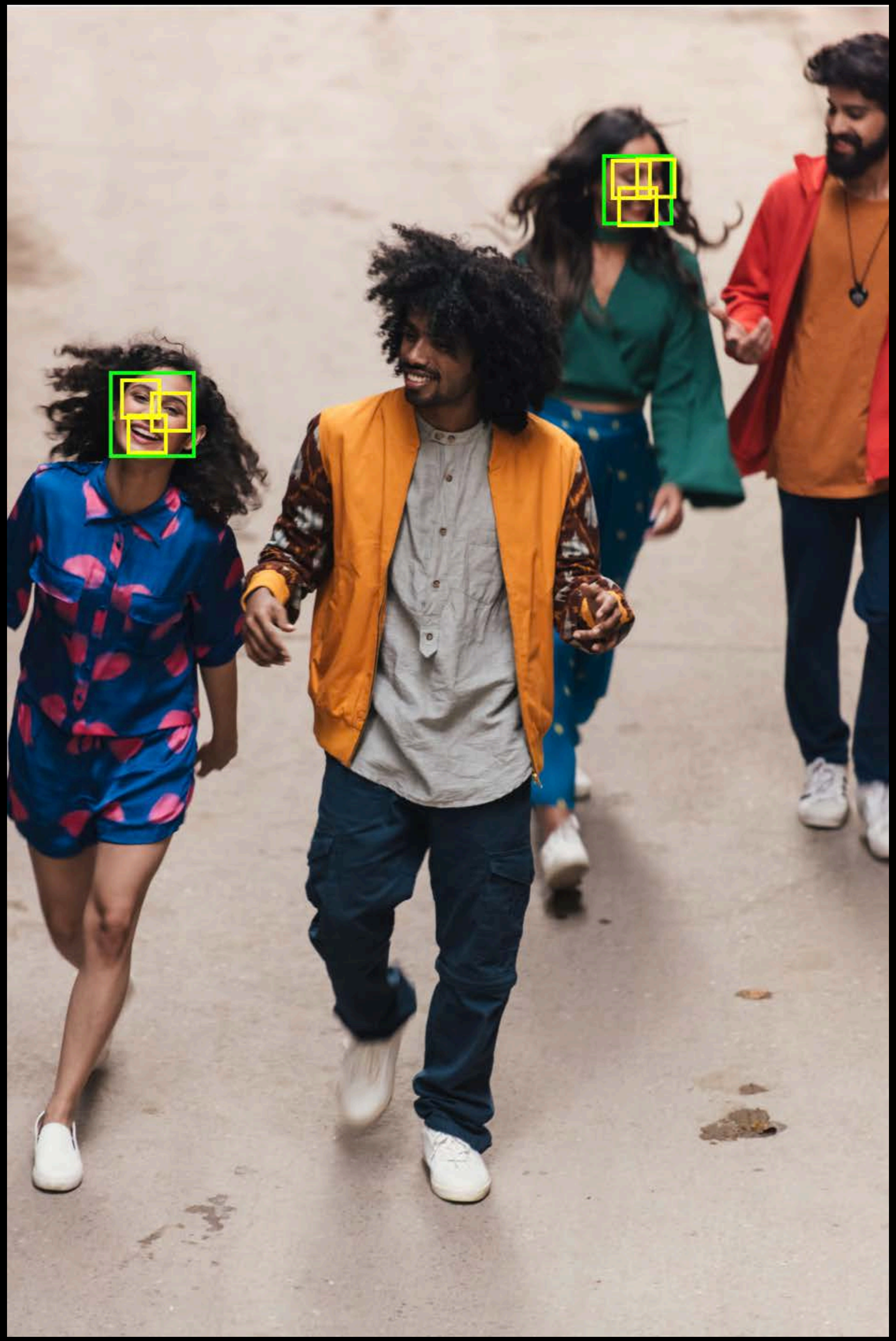
	Vision	Core Image	AV Capture
Accuracy	Best	Better	Good
Processing time	Fast	Faster	Fastest
Power usage	Good	Better	Best
Availability	iOS, macOS, tvOS	iOS, macOS, tvOS	iOS capture only

Core Image

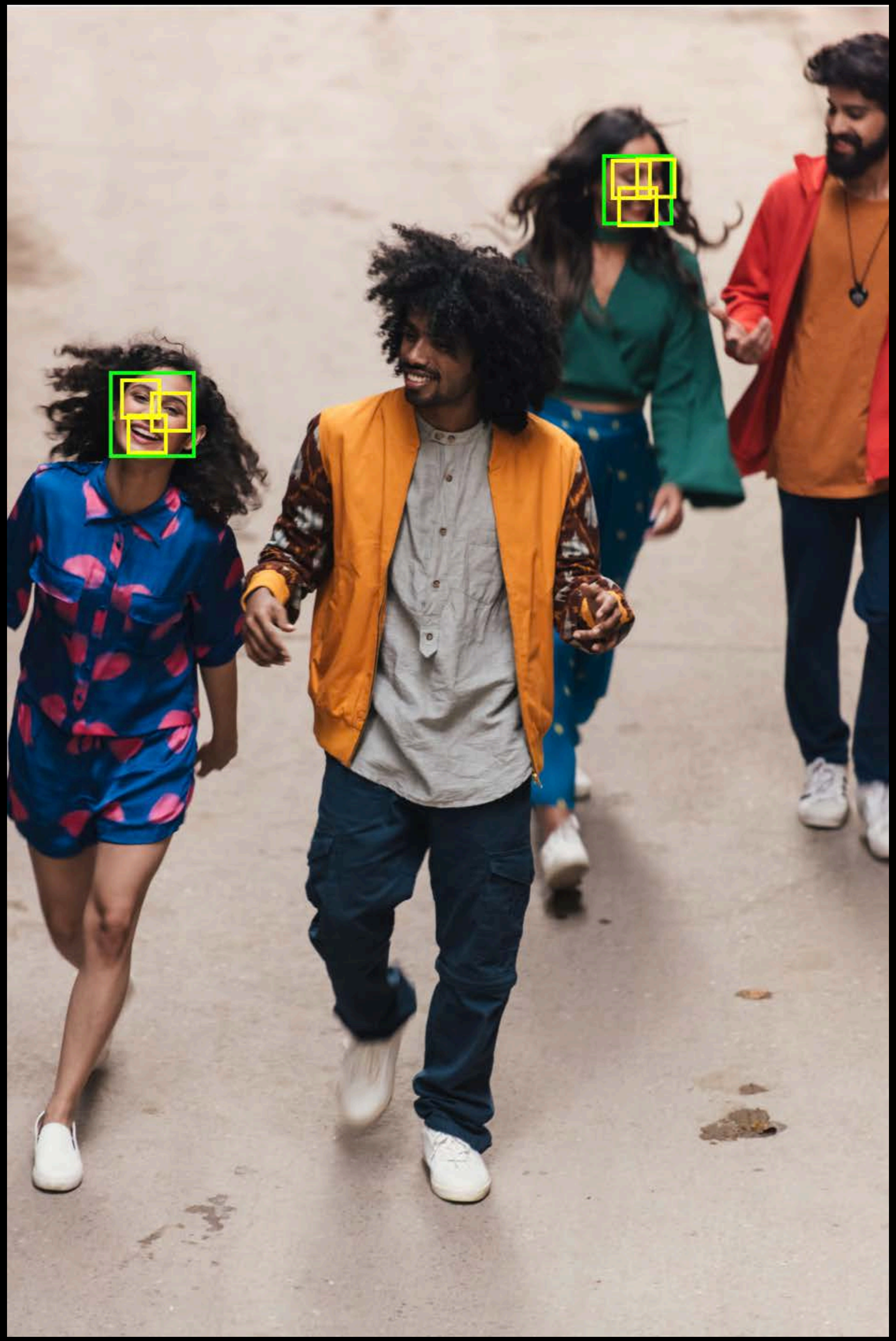
Vision

Core Image

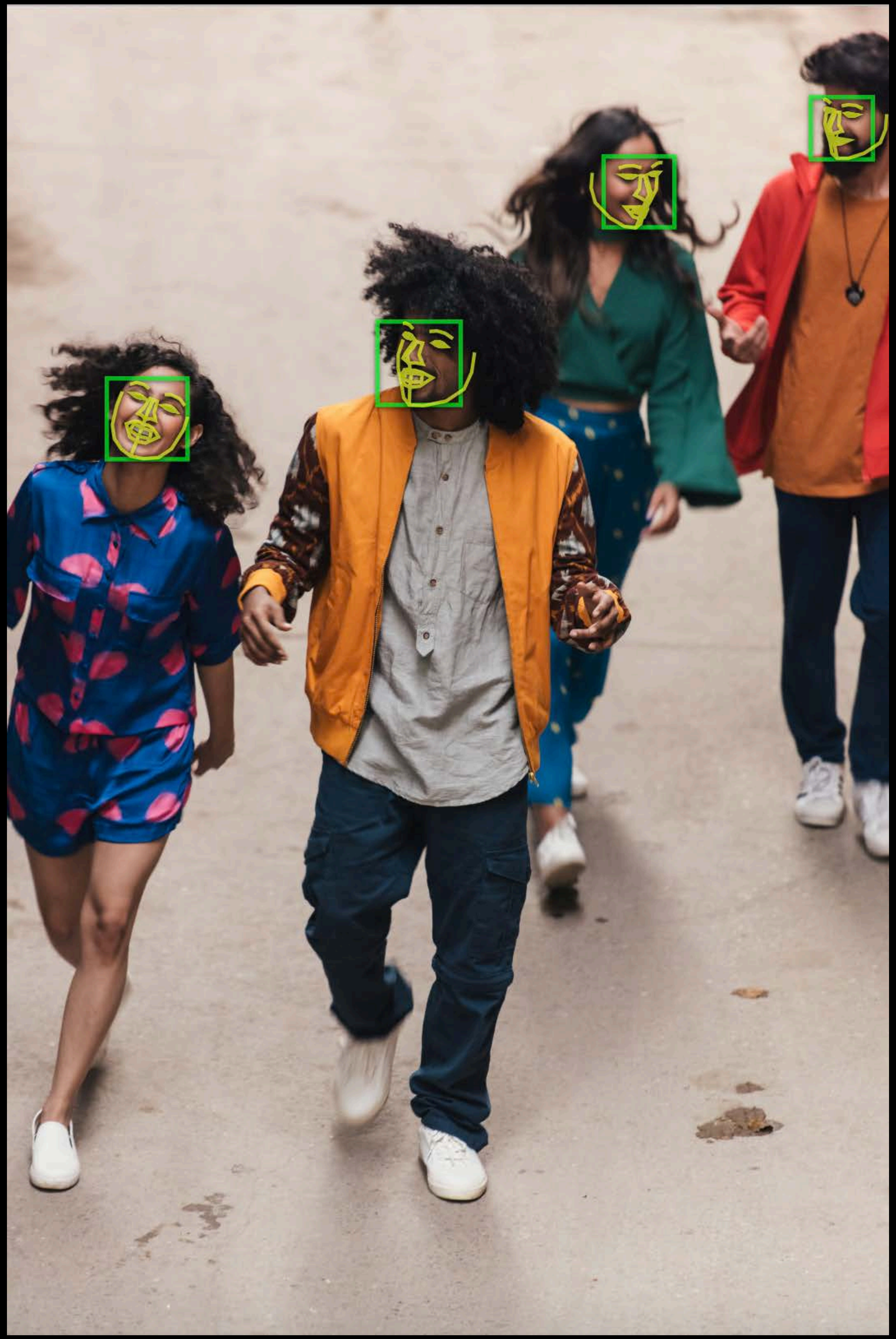
Vision



Core Image



Vision



CIDetector vs. Vision

CIDetector will remain as they are in Core Image

New algorithms will be exposed through Vision

Algorithm improvements will be made available in Vision

Show and Tell

Part one

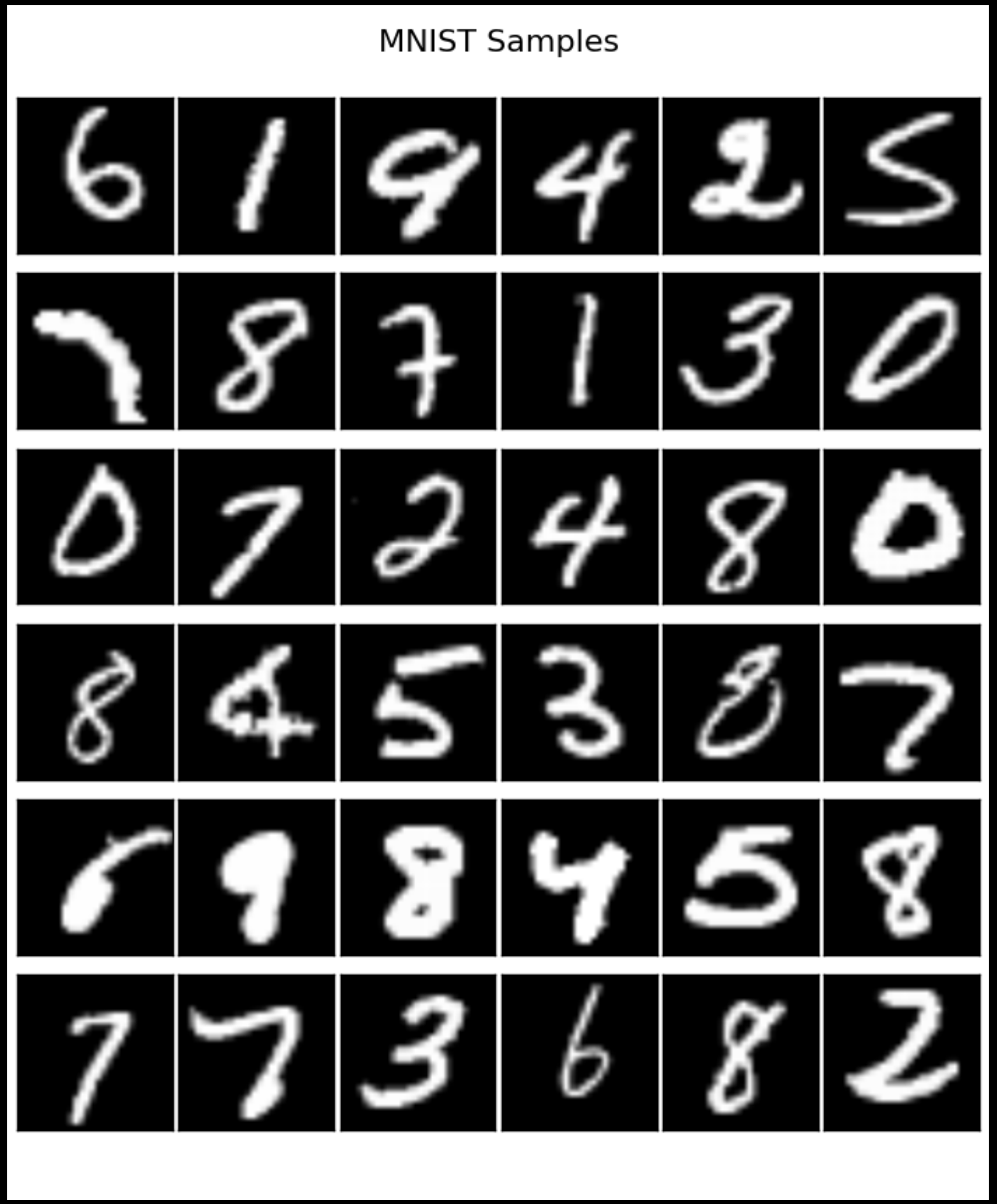
Show and Tell

Part two

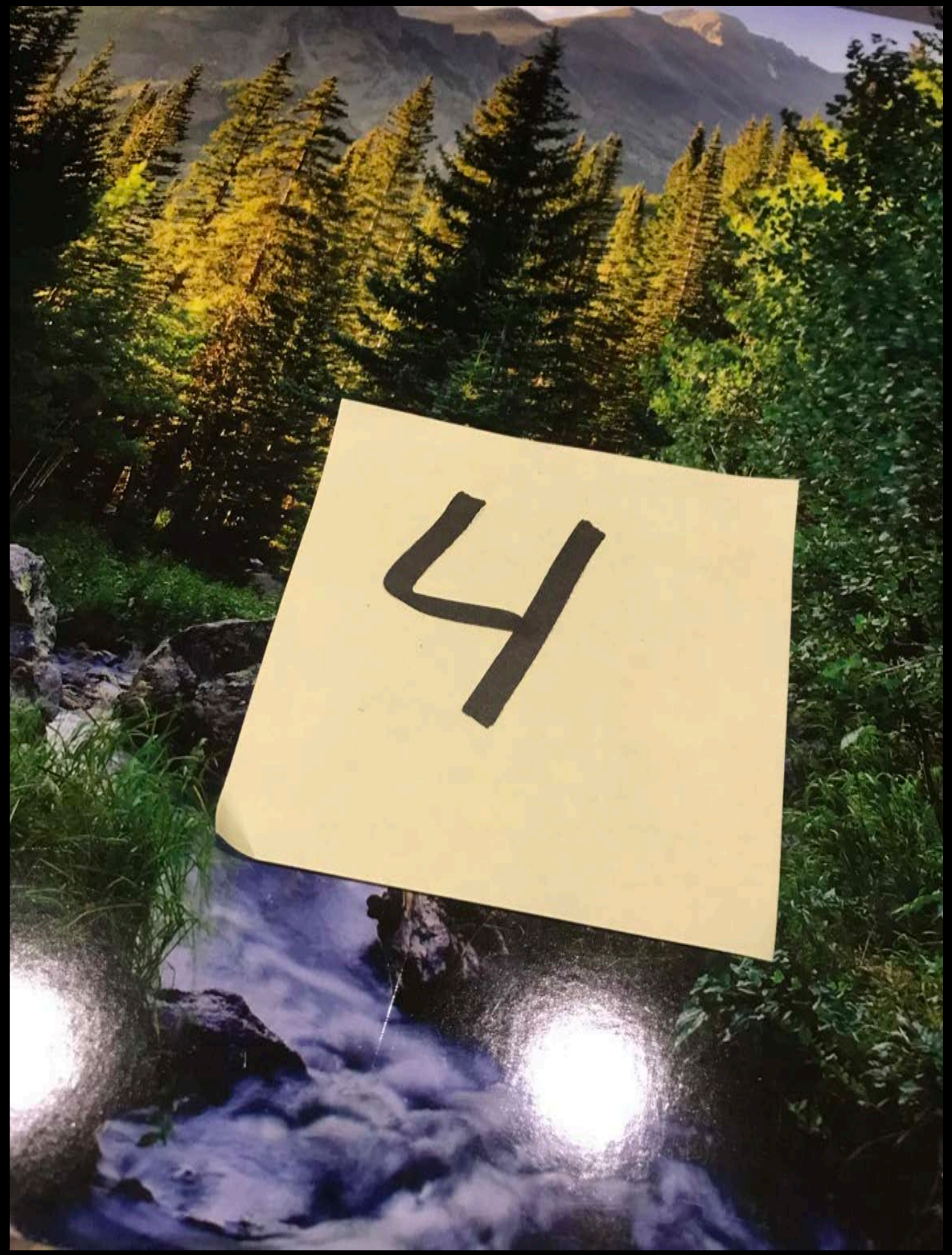
MNISTVision

Concepts to be covered

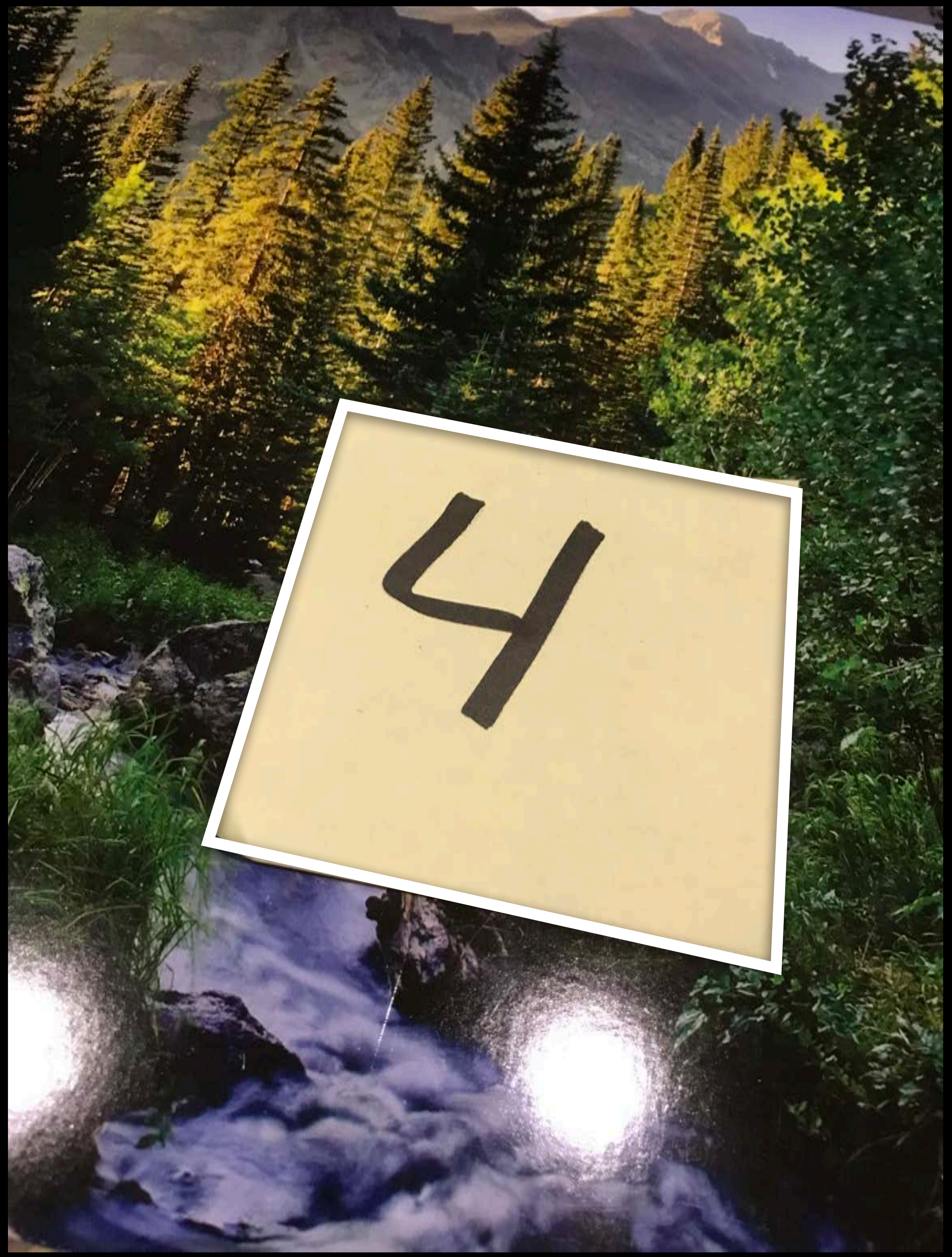
- Spin off requests from other requests
- Use Core Image for processing
- Use Core ML for machine learning



The Flow Chart



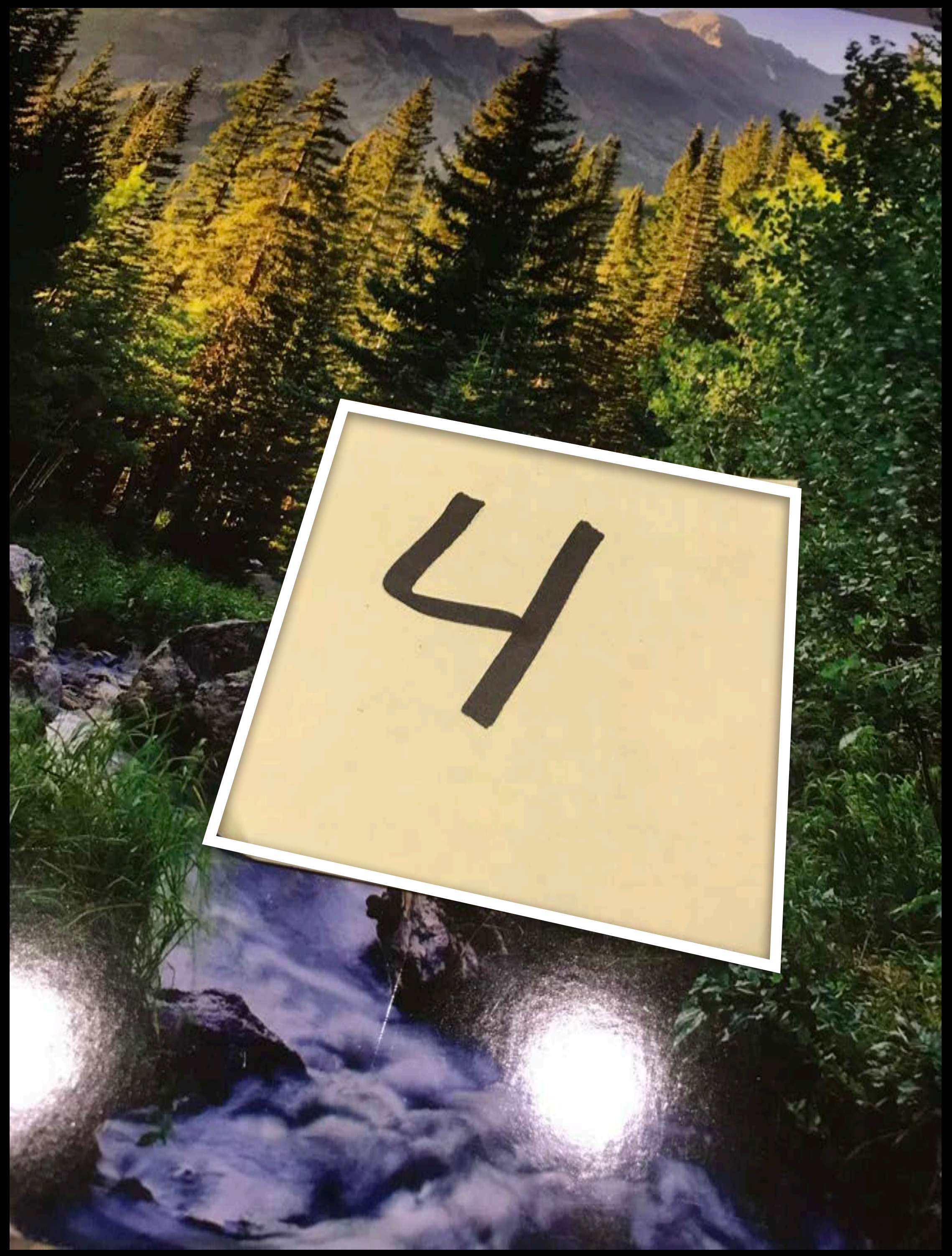
The Flow Chart



Step 1

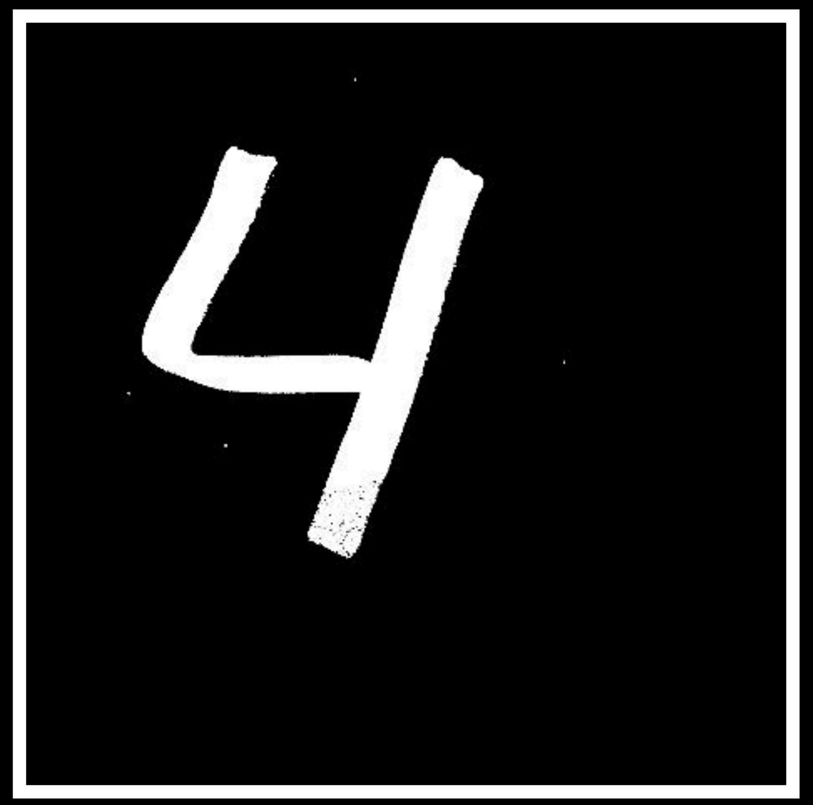
Find sticky note using Rectangle Detector

The Flow Chart



Step 1

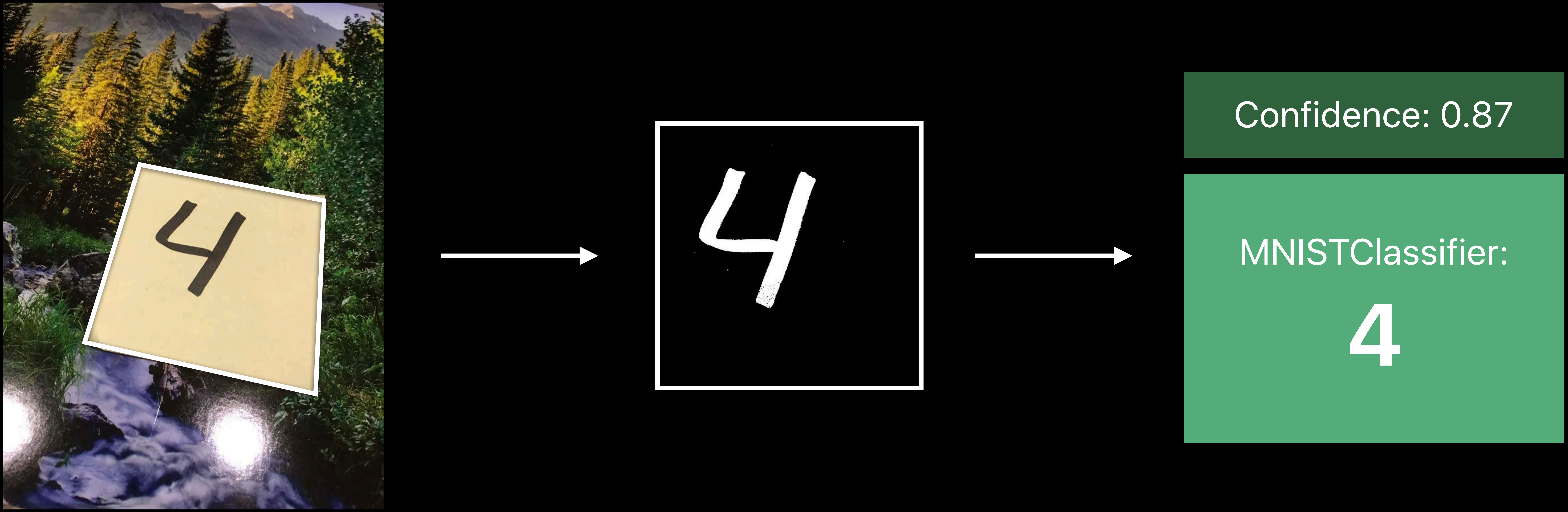
Find sticky note using Rectangle Detector



Step 2

Use CI for perspective correction and image processing

The Flow Chart



Confidence: 0.87

MNISTClassifier:

4

Step 1

Find sticky note using
Rectangle Detector

Step 2

Use CI for perspective correction
and image processing

Step 3

Run MNIST classifier on
resulting CIImage

Demo

And that is Vision.framework

Summary

Vision is a new high-level framework for Computer Vision

Various detectors and tracking through one consistent interface

Integration with Core ML allows you to use custom models with ease

More Information

https://developer.apple.com/wwdc17/506

Related Sessions

Introducing Core ML		WWDC 2017
Photography Get Together	Technology Lab J	Wednesday 6:30PM
Core ML in Depth	Hall 3	Thursday 9:00AM
Advances in Core Image: Filters, Metal, Vision, and More	Executive Ballroom	Thursday 1:50PM

Labs

Core ML and Natural Language Processing Lab	Technology Lab D	Thur 11:00AM–3:30PM
AVFoundation Lab	Technology Lab F	Thur 12:00PM–3:00PM
Photos Editing and Core Image Lab	Technology Lab F	Thur 3:10PM–6:00PM
Vision Lab	Technology Lab A	Fri 1:50PM–4:00PM
Core ML and Natural Language Processing Lab	Technology Lab D	Fri 1:50PM–4:00PM

WWDC17