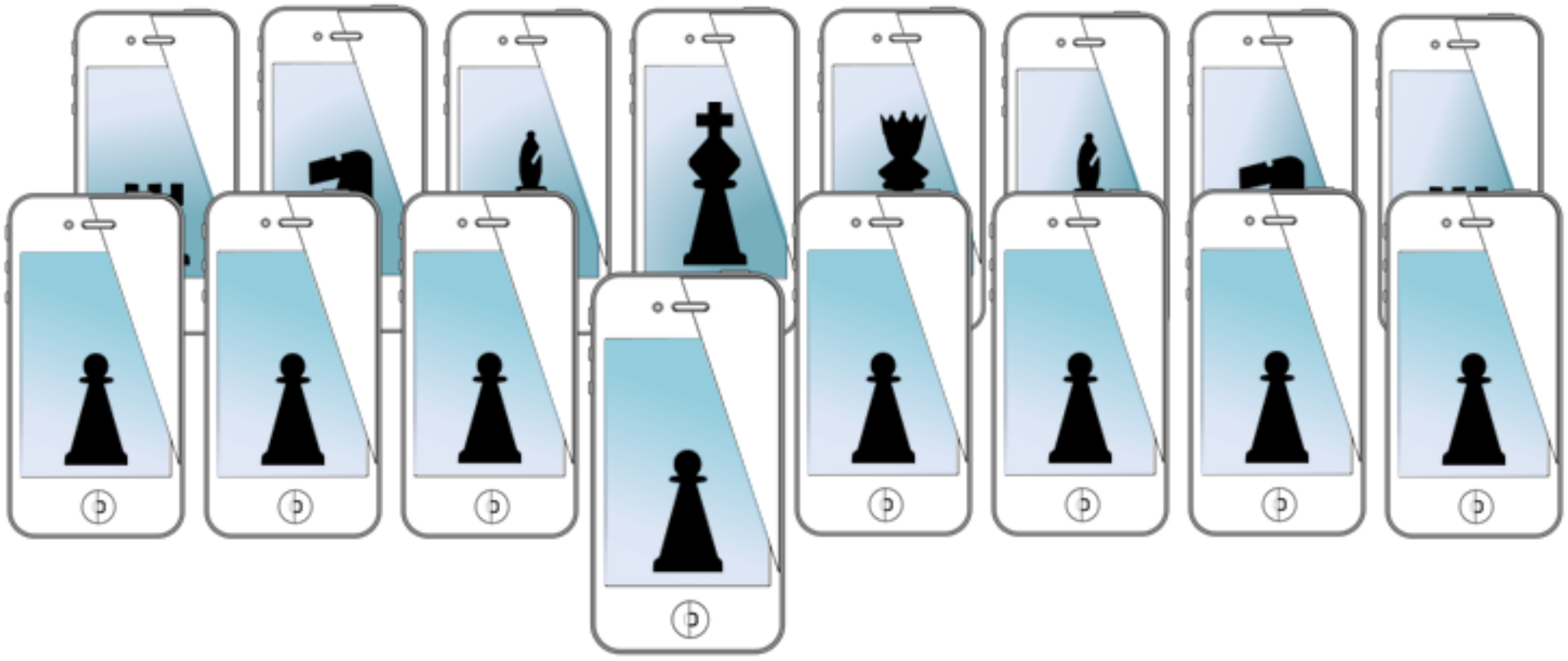
MOBILE SENSING LEARNING



CS5323 & 7323

Mobile Sensing and Learning

core image and image processing

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course logistics/agenda

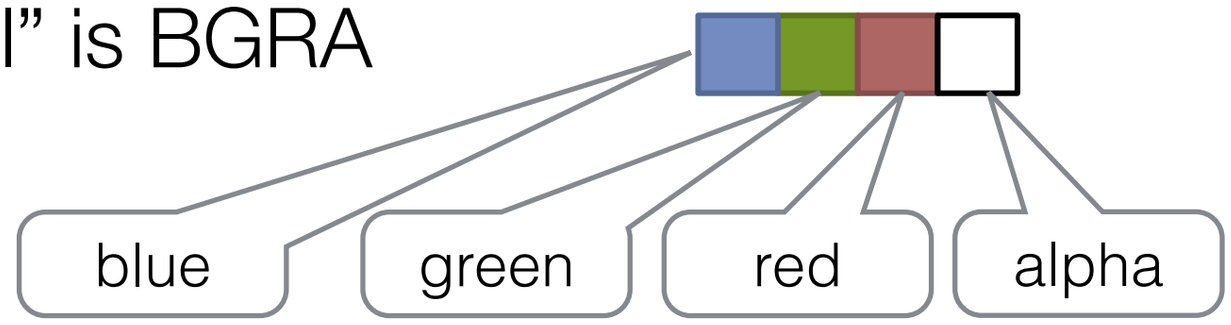
- logistics:
  - A2 due soon!
- today:
  - image processing basics
  - core image filtering

what is image processing?

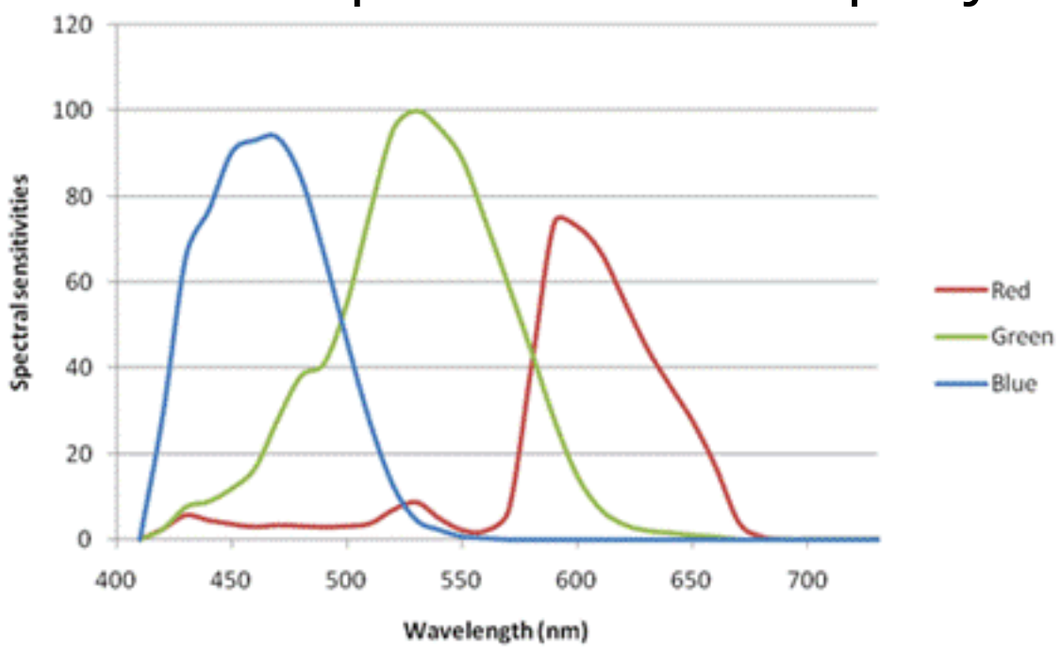
- the **art** and **science** of manipulating pixels
  - combining images (blending or compositing)
  - enhancing edges and lines
  - adjusting contrast, color
  - warping, transformation
  - filtering
  - …anything you can do in photoshop
  - also used in computer vision

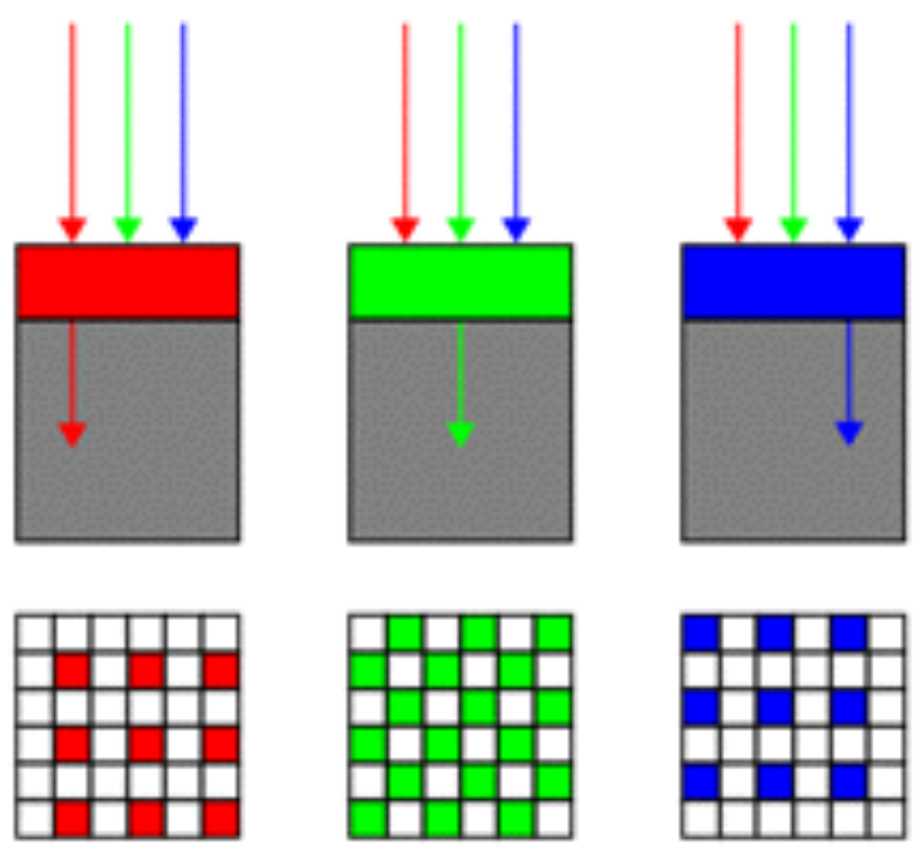
images as data

- an image can be represented in many ways
- most common format is a matrix of pixels
  - each “pixel” is BGRA



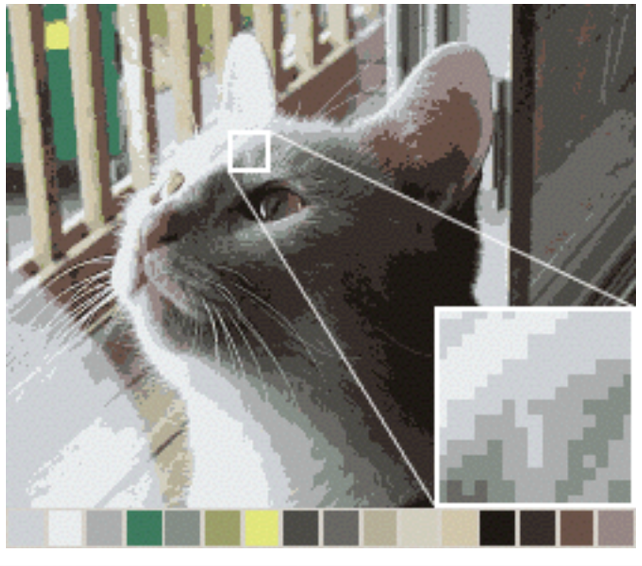
- used for capture and display





images as signals

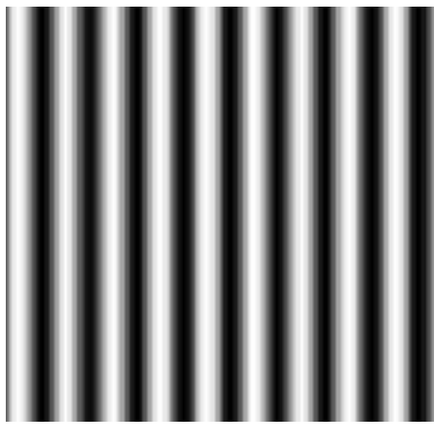
- everything from audio still applies
- quantization
  - each pixel can only take on 0-255 values
  - i.e., “stretching” in low light conditions



sampling errors

- in time (video)

- in space (resolution)
  - “frequency” is in terms of spatial sine waves



images as signals

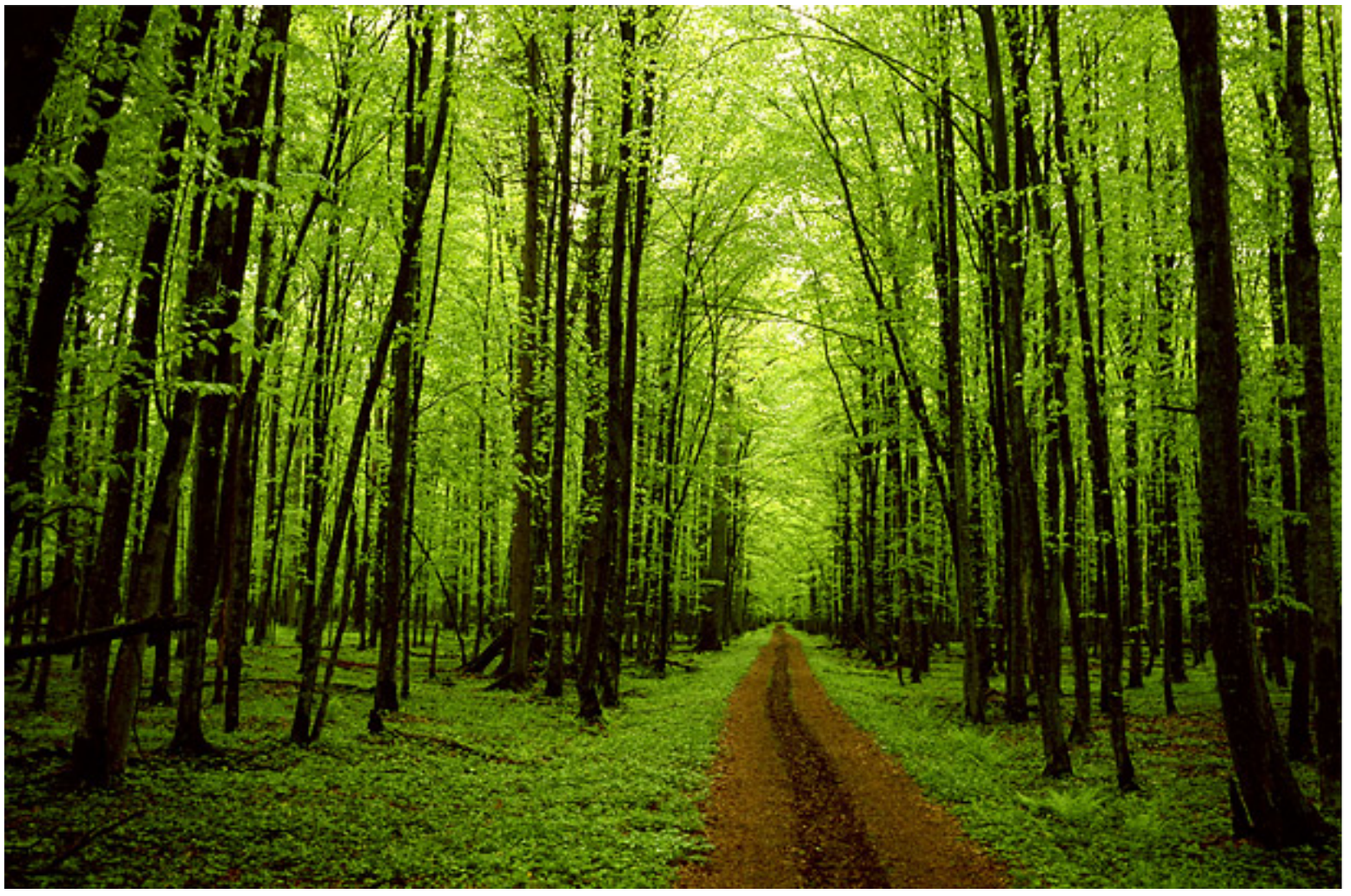


image with lots of high frequency

images as signals

image with lots of low frequency

what is filtering?

- same as audio
  - convolution (linear)

.11	.11	.11
.11	.11	.11
.11	.11	.11

kernel

averaging

image

1.1	1.5	2.4	2.7	4.3	3.2
1.6	2.3	4.0	4.7	6.8	4.8
1.8	2.6	4.5	5.6	7.5	5.1
1.4	2.2	4.3	6.1	8.0	5.2
1.4	2.3	4.5	6.3	8.0	5.2
1.3	2.1	4.3	5.8	7.7	5.1
1.2	1.7	3.3	4.1	5.2	3.3

what is filtering?

-1	0	1
-1	0	1
-1	0	1

vertical difference

-8	-2	-2	-7	-8	4
-12	-3	-6	-13	-7	5
-8	-2	-10	-15	-2	2
-8	-2	-16	-17	0	3
-8	-3	-17	-16	2	4
-8	-3	-16	-15	0	1
-8	-2	-9	-10	2	2

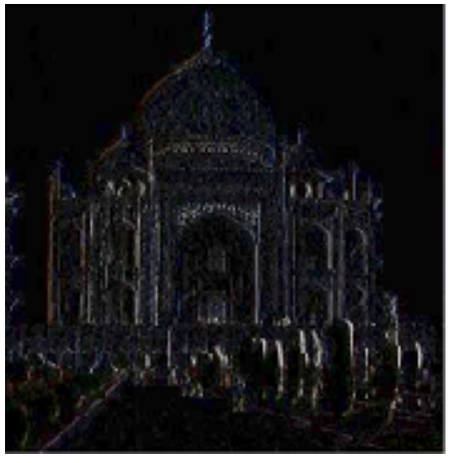
examples of filtering

Blur

1	1	1
1	1	1
1	1	1

Vertical Edges

-1	0	1
-1	0	1
-1	0	1

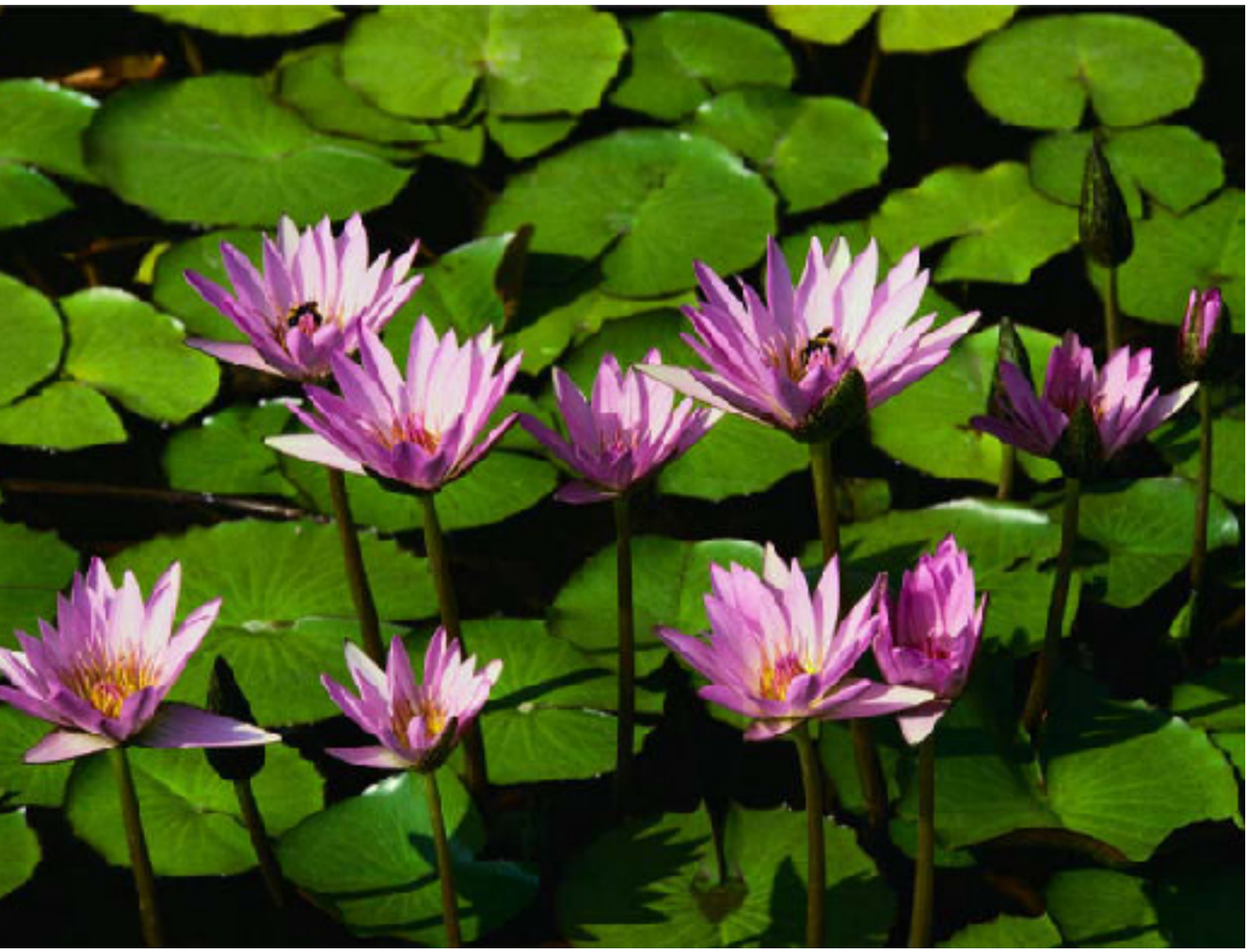


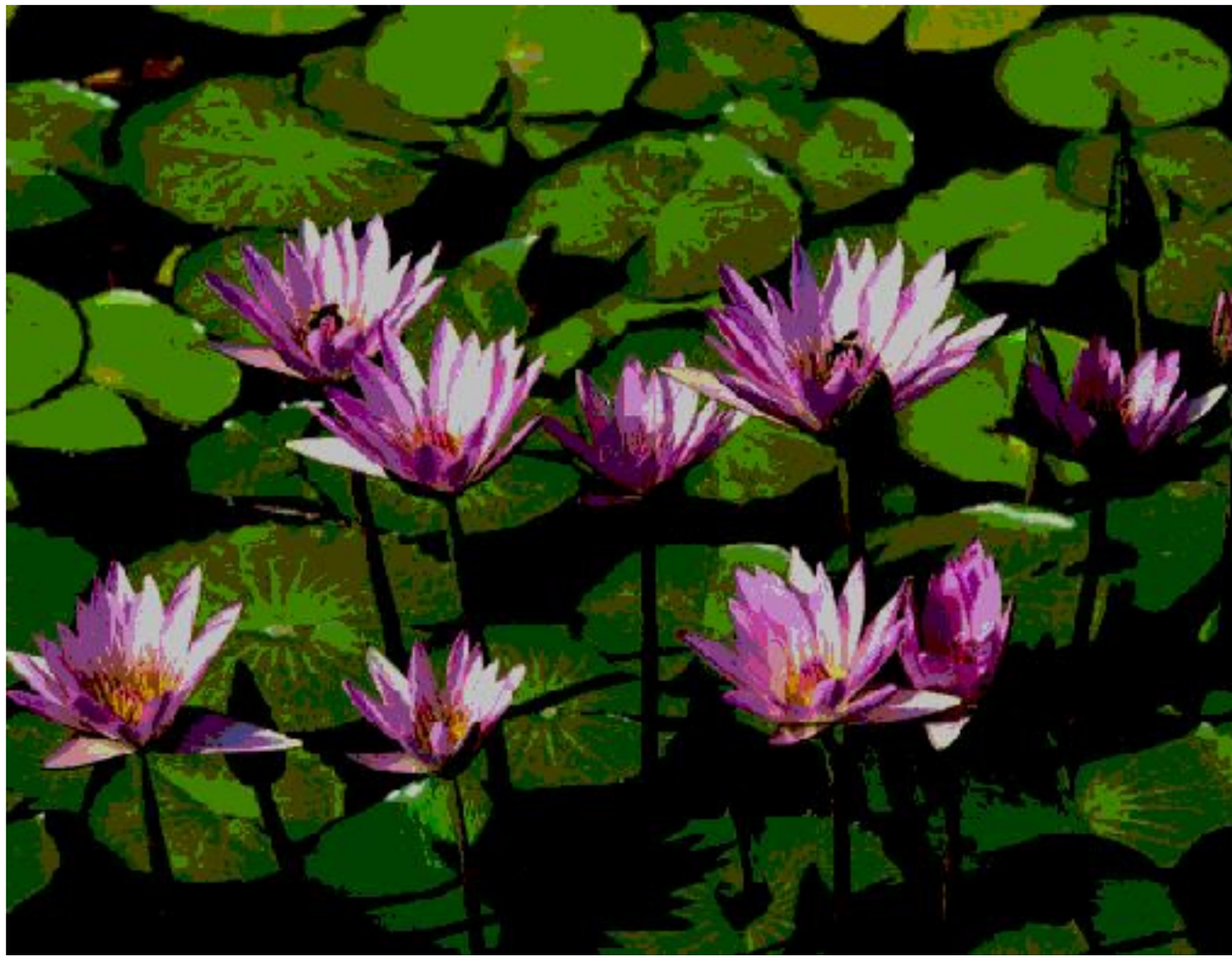
Sharpen

0	-1	0
-1	5	-1
0	-1	0

interesting operations

but there is no need to just perform linear convolution!





non-linear filtering

-	-	-
-	max	-
-	-	-

kernel

-	-	-
-	median	-
-	-	-

gray scale image

4	4	5	6	9	9
4	4	8	8	9	9
4	4	8	8	8	8
4	4	9	9	9	9
4	4	7	9	9	9
4	4	9	9	9	9
4	4	9	9	9	9

filtering with color

-	-	-
-	max	-
-	-	-

R

G

B

1	4	2	5	6	9
1	4	2	5	5	9
1	4	2	8	8	7
3	4	3	9	9	8
1	0	2	7	7	9
1	4	3	9	8	6
2	4	2	8	7	9

filtering video

- for default 5S available in class (it gets better with newer phones):
- back camera is capable of capturing
  - 8MP photos (~30 MB raw)
  - 1080p HD video at 30 fps
- face camera
  - 1.2MP photos
  - 720p HD video at 30 fps

- video on the face camera is 1280x720 x3 channels x30fps
  - 82.9 million samples per second

so much data !!!

- we need to hardware accelerate
- look back to audio:
  - why is this:

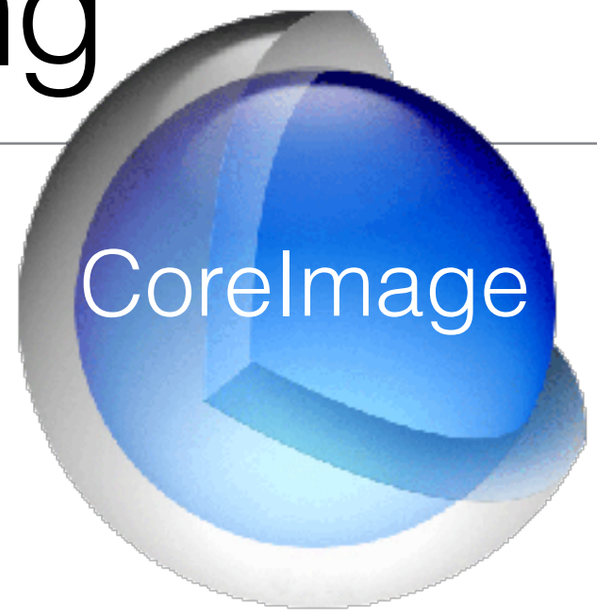
```
float one = 1.0;
vDSP_vdbcon(fftMagnitudeBuffer,1,&one,fftMagnitudeBuffer,1,kBufferLength/2,0);
```

  - faster than this:

```
for(int i=0;i<kBufferLength/2;i++){
        fftMagnitudeBuffer[i] = 20*logb(fftMagnitudeBuffer[i]);
    }
```

parallelized data processing images: GPU

options for image processing



- **CoreImage** (written by Apple)
  - somewhat extensible, very fast, easy to use
  - if not implemented, you can't do it (like computer vision), always getting better, can fall back on CPU

- **GPUImage** (independent developer)
  - open source, updated for swift, lots of users, very fast (comparable to CI), very easy to use
  - developed and maintained by one guy, Brad Larson
- **OpenCV** (started by Intel)
  - slow, requires c++, huge
  - most comprehensive functionality, biggest user base (gigantic),

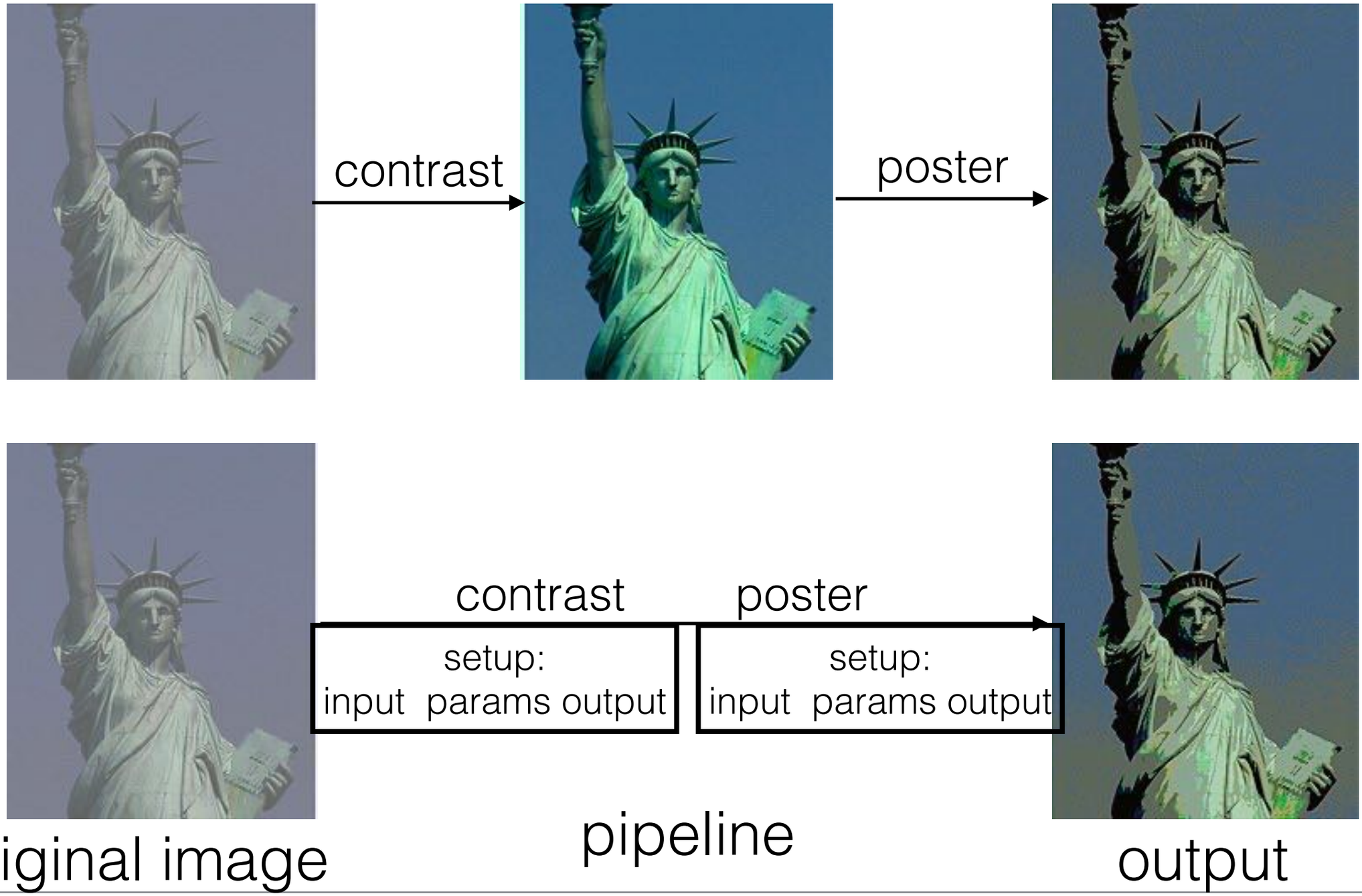
core image framework

- defines images as CIImage instances
- defines a set of filters that (can be) GPU accelerated
  - optimizes filters when cascaded
- filters created through CIFilter class instances

CIAdditionCompositing	CIColorCrossPolynomial	CIFourfoldReflectedTile	CIMaximumComponent	CISourceAtopCompositing
CIAffineClamp	CIColorPolynomial	CIFourfoldRotatedTile	CIMaximumCompositing	CILinearToSRGBToneCurve
CIAffineTile	CIColorPosterize	CIFourfoldTranslatedTile	CIMinimumComponent	CISRGBToneCurveToLinear
CIAffineTransform	CIConstantColorGenerator	CIGammaAdjust	CIMinimumCompositing	CISourceInCompositing
CIBarsSwipeTransition	CIConvolution3X3	CIGaussianBlur	CIModTransition	CISourceOutCompositing
CIBlendWithMask	CIConvolution5X5	CIGaussianGradient	CIMultiplyBlendMode	CISourceOverCompositing
CIBloom	CIConvolution9Horizontal	CIGlideReflectedTile	CIMultiplyCompositing	CIStarShineGenerator
CIBumpDistortion	CIConvolution9Vertical	CIGloom	CIOverlayBlendMode	CIStraightenFilter
CICheckerboardGenerator	CICopyMachineTransition	CIHardLightBlendMode	CIPerspectiveTile	CIStripesGenerator
CICircleSplashDistortion	CICrop	CIHatchedScreen	CIPerspectiveTransform	CISwipeTransition
CICircularScreen	CIDarkenBlendMode	CIHighlightShadowAdjust	CIPinchDistortion	CITemperatureAndTint
CIColorBlendMode	CIDifferenceBlendMode	CIHoleDistortion	CIPixellate	CIToneCurve
CIColorBurnBlendMode	CIDisintegrateWithMask	CIHueAdjust	CIRadialGradient	CITriangleKaleidoscope
CIColorControls	CIDissolveTransition	CIHueBlendMode	CIRandomGenerator	CITwelvefoldReflectedTile
CIColorCube	CIDotScreen	CILanczosScaleTransform	CISaturationBlendMode	CITwirlDistortion
CIColorDodgeBlendMode	CIEightfoldReflectedTile	CILightenBlendMode	CIScreenBlendMode	CIUnsharpMask
CIColorInvert	CIExclusionBlendMode	CILightTunnel	CISepiaTone	CIVibrance
CIColorMap	CIExposureAdjust	CILinearGradient	CISharpenLuminance	CIVignette
CIColorMatrix	CIFaceDetector	CILineScreen	CISixfoldReflectedTile	CIVortexDistortion
CIColorMonochrome	CIFalseColor	CILuminosityBlendMode	CISixfoldRotatedTile	CIWhitePointAdjust
CIColorClamp	CIFlashTransition	CIMaskToAlpha	CISoftLightBlendMode	CIQRCodeGenerator

core image framework

- nothing happens until the image is rendered!



core image syntax

- Loading an image from the bundle
  - we need a CIImage instance, which stores more than just pixels (**note**: not a UIImage!)

```
let urlPath = NSBundle.mainBundle().pathForResource("smu-campus", ofType: "jpg")
let fileURL = NSURL.fileURLWithPath(urlPath!)

let beginImage = CIImage(contentsOfURL: fileURL)

        …processing here…

self.imageView.image = UIImage(CIImage: beginImage)
```

get image path from bundle

load image

show inside a UIImageView

core image syntax

```
let urlPath = NSBundle.mainBundle().pathForResource("smu-campus", ofType: "jpg")
let fileURL = NSURL.fileURLWithPath(urlPath!)

let beginImage = CIImage(contentsOfURL: fileURL)
```

create filter

```
let filter = CIFilter(name: "CIBloom")!
```

filter type

set parameters

input image

thresholds

```
filter.setValue(beginImage, forKey: kCIInputImageKey)
filter.setValue(0.5, forKey: kCIInputIntensityKey)
```

get output

```
outputImage = filter.outputImage!
```

processing

```
self.sourceImageView.image = UIImage(CIImage: outputImage)
```

```
self.imageView.image = UIImage(CIImage: beginImage)
```

core image filters

- https://developer.apple.com/library/mac/documentation/graphicsimaging/reference/CoreImageFilterReference/Reference/reference.html
- names, parameters, examples, etc.

Filters (linear and non-linear)
- CICategoryBlur
- CICategorySharpen
- CICategoryStylize

Distortion
- CICategoryCompositeOperation
- CICategoryDistortionEffect
- CICategoryGeometryAdjustment
- CICategoryTileEffect

Other Images
- CICategoryGenerator
- CICategoryHalftoneEffect
- CICategoryGradient

Color
- CICategoryColorAdjustment
- CICategoryColorEffect

Features (histogram, averages)
- CICategoryReduction

core image filters

CIBloom

Softens edges and applies a pleasant glow to an image.

Parameters

inputImage

A `CIImage` object whose display name is Image.

inputRadius

An `NSNumber` object whose attribute type is `CIAttributeTypeDistance` and whose display name is Radius.

Default value: 10.00

inputIntensity

An `NSNumber` object whose attribute type is `CIAttributeTypeScalar` and whose display name is Intensity.

Default value: 1.00

Member of

`CICategoryBuiltIn`, `CICategoryStillImage`, `CICategoryVideo`, `CICategoryStylize`

Localized Display Name

Bloom

Figure 8 The result of using the CIBloom filter

Availability

Available in OS X v10.4 and later and in iOS 6.0 and later.

```
radius = 100;
CIFilter *filter =
[CIFilter filterWithName:@"CIBloom" keysAndValues:
          @"inputImage", myImage,
          @“inputRadius", @(radius),
          @"inputIntensity", @0.5,
          nil];
```

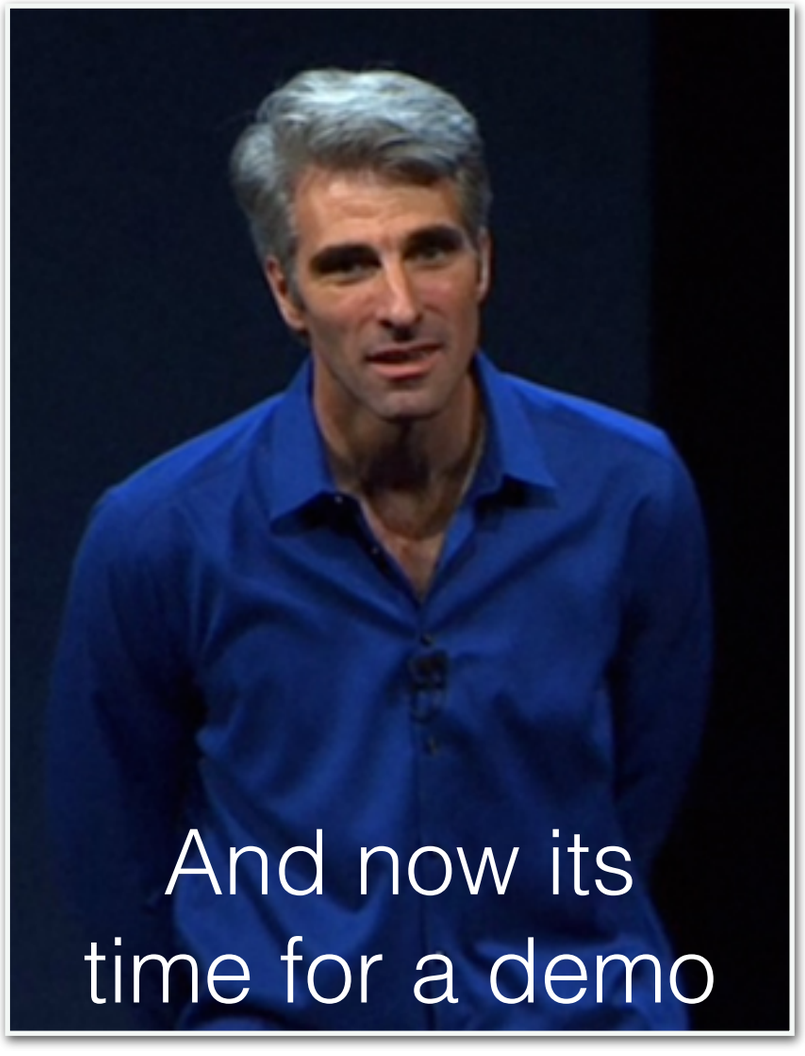
```
CIFilter *filter =
[CIFilter filterWithName:@“CIBloom”];

[filter setValue:myImage
          forKey:kCIInputImageKey];
```

available?

core image demo

- ImageLab, filter image from bundle

http://www.raywenderlich.com/76285/beginning-core-image-swift



custom filters

```
const CGFloat weights[] = { 1, 0, -1,
                            2, 0, -2,
                            1, 0, -1};
```

```
result =
[CIFilter filterWithName:@"CIConvolution3X3" keysAndValues:
                         @"inputImage", inputImage,
                         @"inputWeights",
                                [CIVector vectorWithValues:weights count:9],
                         @"inputBias", @0.5,
                    nil].outputImage;
```

chaining filters

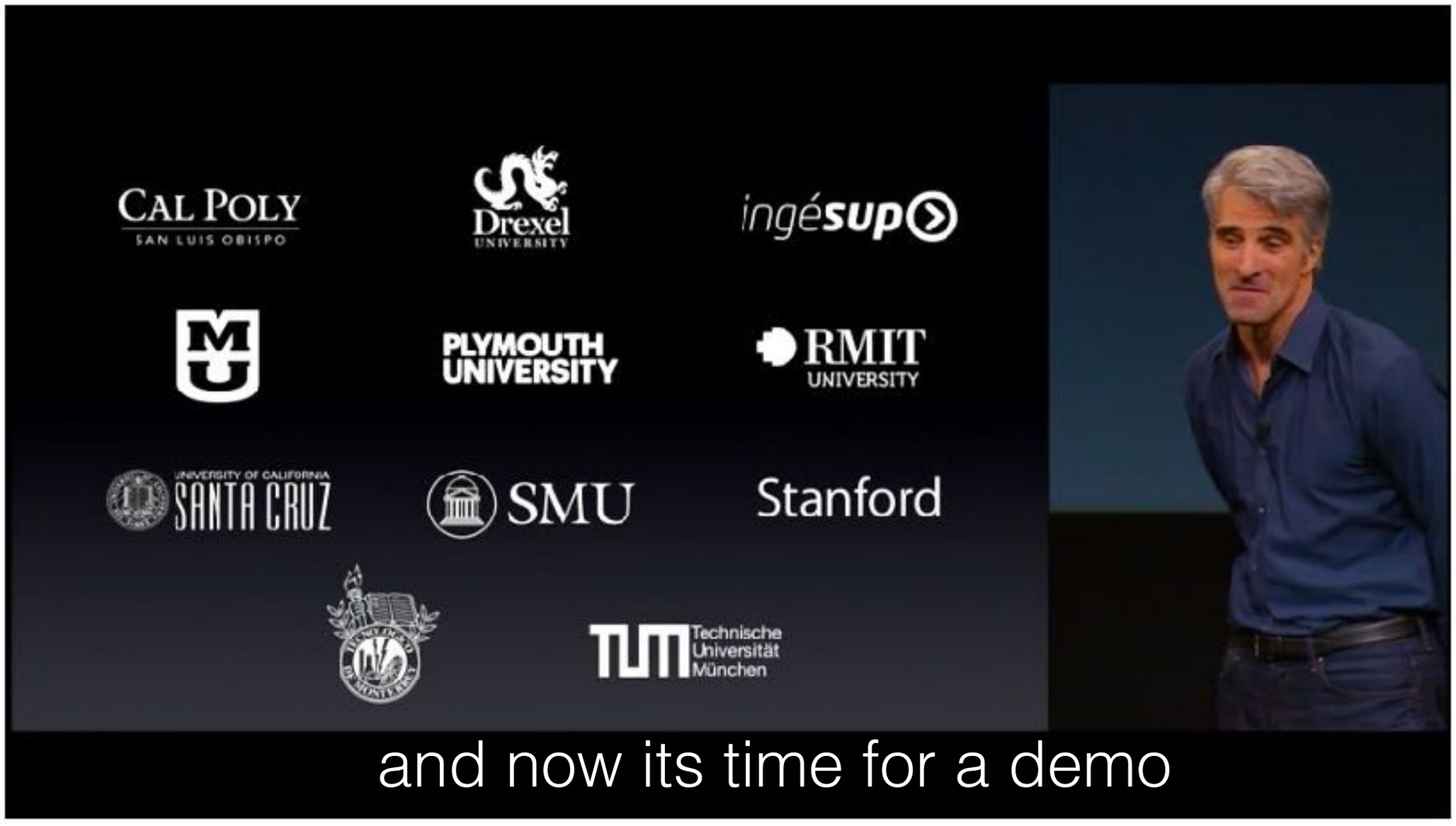
```
NSMutableArray *filters = [[NSMutableArray alloc]init];
  [filters addObject:[CIFilter filterWithName:@"CISepiaTone"]];
  [filters addObject:[CIFilter filterWithName:@"CIBloom"]];
  [filters addObject:[CIFilter filterWithName:@"CIColorInvert"]];

  outputImage = inputImage;
   for(CIFilter *filter in filters){
      [filter setValue:outputImage forKey:kCIInputImageKey];
      outputImage = filter.outputImage;
   }
```

beyond the main bundle

- easy to get photos!
- demos in the branch of **ImageLab**, if you are interested!
- from library:
  - use the `UIImagePickerControllerDelegate` protocol
- from camera:
  - use the `UIImagePickerControllerDelegate` protocol
  - `cameraUI.sourceType = UIImagePickerControllerSourceTypeCamera`
- https://developer.apple.com/library/ios/documentation/AudioVideo/Conceptual/CameraAndPhotoLib_TopicsForIOS/Introduction/Introduction.html#//apple_ref/doc/uid/TP40010405-SW1

core image demo

- ImageLab, using the camera



but we want video…

- want to access incoming video in real time
  - and display to screen!
- that is a lot of processing
- setup needs to occur in conjunction with GPU
  - setup proper context (i.e., OpenGL)
  - renderers, processing pipeline
- you need to understand this intuitively
  - but you won't write the code to do it

AVCaptureSession

- mediates all access to incoming video and screen
- the screen output and camera input need to speak the same language
  - same color representation (BGRA vs ARGB)
  - and transforms (mirroring, rotation)
  - important: same rendering context (for speed)
- capture session is optimized for video chat
  - so audio can also be captured here (not unlike Novocaine)

AVCaptureSession

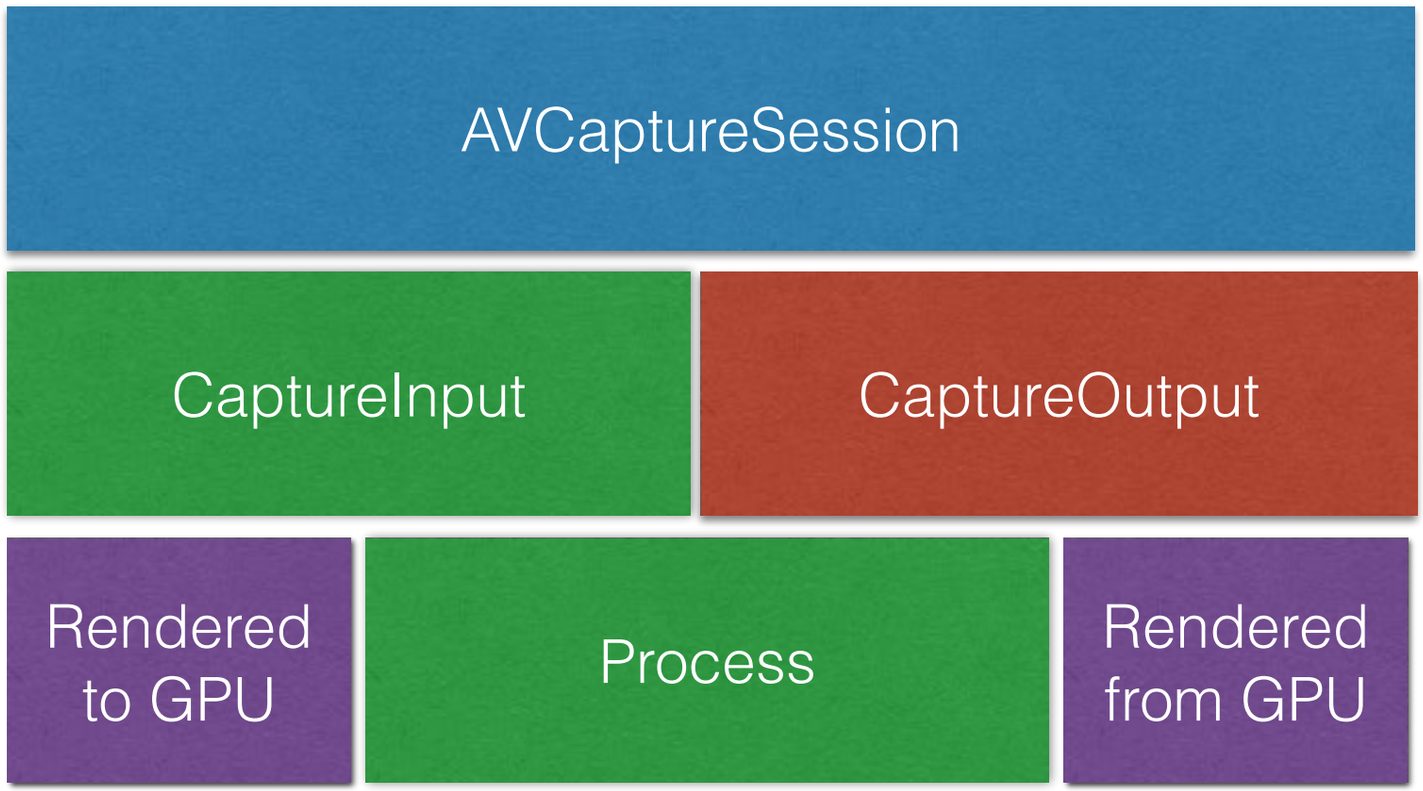
- setup the capture
  - device: front or back camera

```
AVCaptureDevicePositionFront
AVCaptureDevicePositionBack
```

  - quality preset:

```
NSString *const AVCaptureSessionPresetPhoto;
NSString *const AVCaptureSessionPresetHigh;
NSString *const AVCaptureSessionPresetMedium;
NSString *const AVCaptureSessionPresetLow;
NSString *const AVCaptureSessionPreset352x288;
NSString *const AVCaptureSessionPreset640x480;
NSString *const AVCaptureSessionPreset1280x720;
NSString *const AVCaptureSessionPreset1920x1080;
NSString *const AVCaptureSessionPresetiFrame960x540;
NSString *const AVCaptureSessionPresetiFrame1280x720;
```

conceptual architecture



use core image, with processing setup for GPU
no data transfer from the GPU!

how to program this?

- what did we do with audio?
  - don't reinvent the wheel: use Novocaine
- now: use **VideoAnalgesic.swift**
  - takes the pain out of GPU capture, render, and processing

declare

```
var videoAnalgesic:VideoAnalgesic! = nil
```

init

```
self.videoAnalgesic = VideoAnalgesic(mainView:self.view)
```

start

```
if !self.videoAnalgesic.isRunning{
    self.videoAnalgesic.start()
}
```

options

```
self.videoAnalgesic.setPreset(AVCaptureSession.Preset.medium)
self.videoAnalgesic.toggleCameraPosition()
self.videoAnalgesic.setCameraPosition(AVCaptureDevice.Position.front)
```

stop

```
if self.videoAnalgesic.isRunning{
            self.videoAnalgesic.stop()
            self.videoAnalgesic.shutdown()
        }
```

VideoAnalgesic

- processing: similar to Novocaine
  - assumed that the output is always the screen of phone
  - use blocks and return image to draw to screen

```
        // setup a block to perform any processing
         self.videoAnalgesic.setProcessingBlock()
             {(inputImage:CIImage)->(CIImage) in
                 return inputImage
         }
```

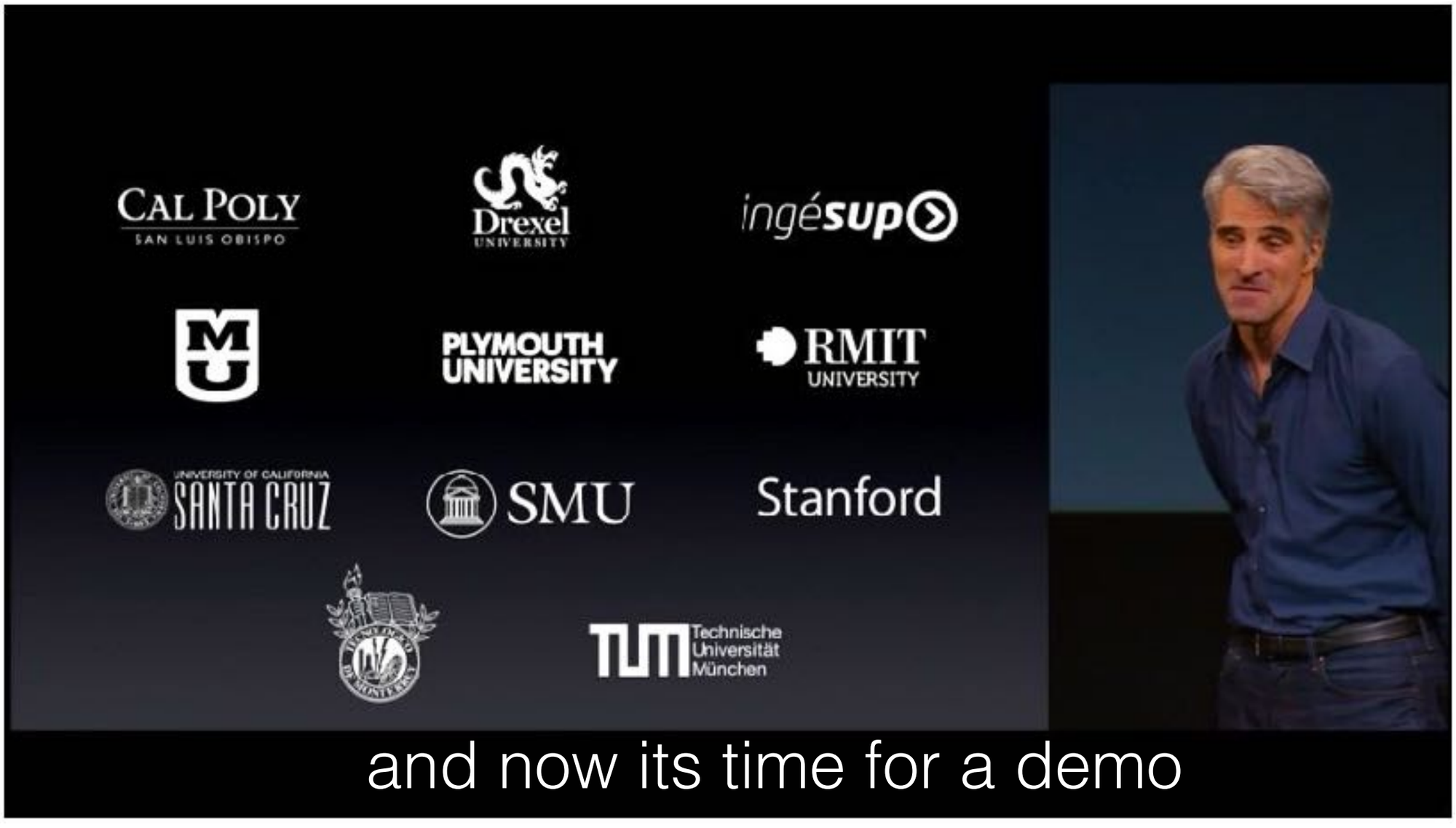
image from camera passed in

return image to draw to screen

```
        let filter:CIFilter = CIFilter(name: "CIBloom")

            // setup a block to perform any processing
            self.videoAnalgesic.setProcessingBlock()
                {(inputImage:CIImage)->(CIImage) in
                    filter.setValue(inputImage, forKey: "inputImage")
                    return filter.outputImage
            }
```

video process demo

- ImageLab++

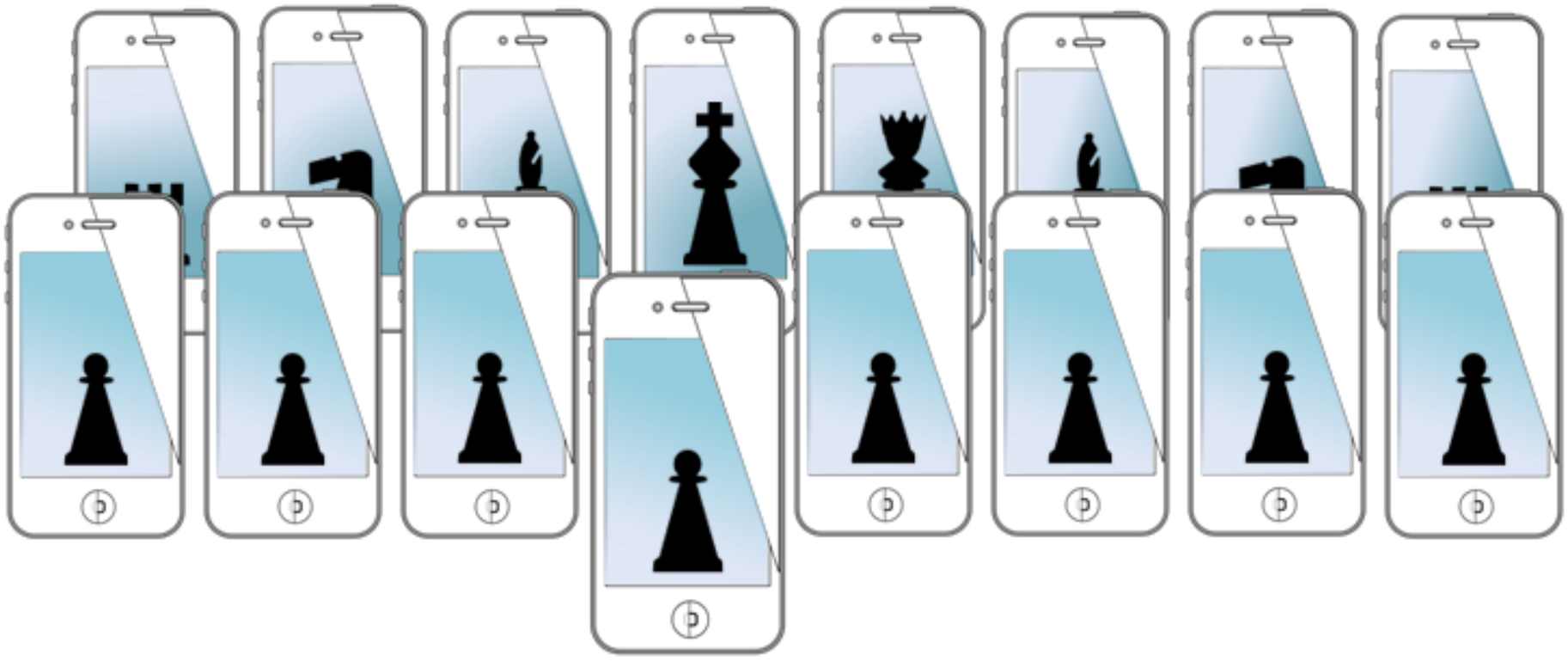


for next time…

- remainder of computer vision:
  - filters
  - faces
  - physiology

- then: the next in-class assignment!!
  - computer vision with OpenCV
    - generic operations
    - tracking

MOBILE SENSING LEARNING



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