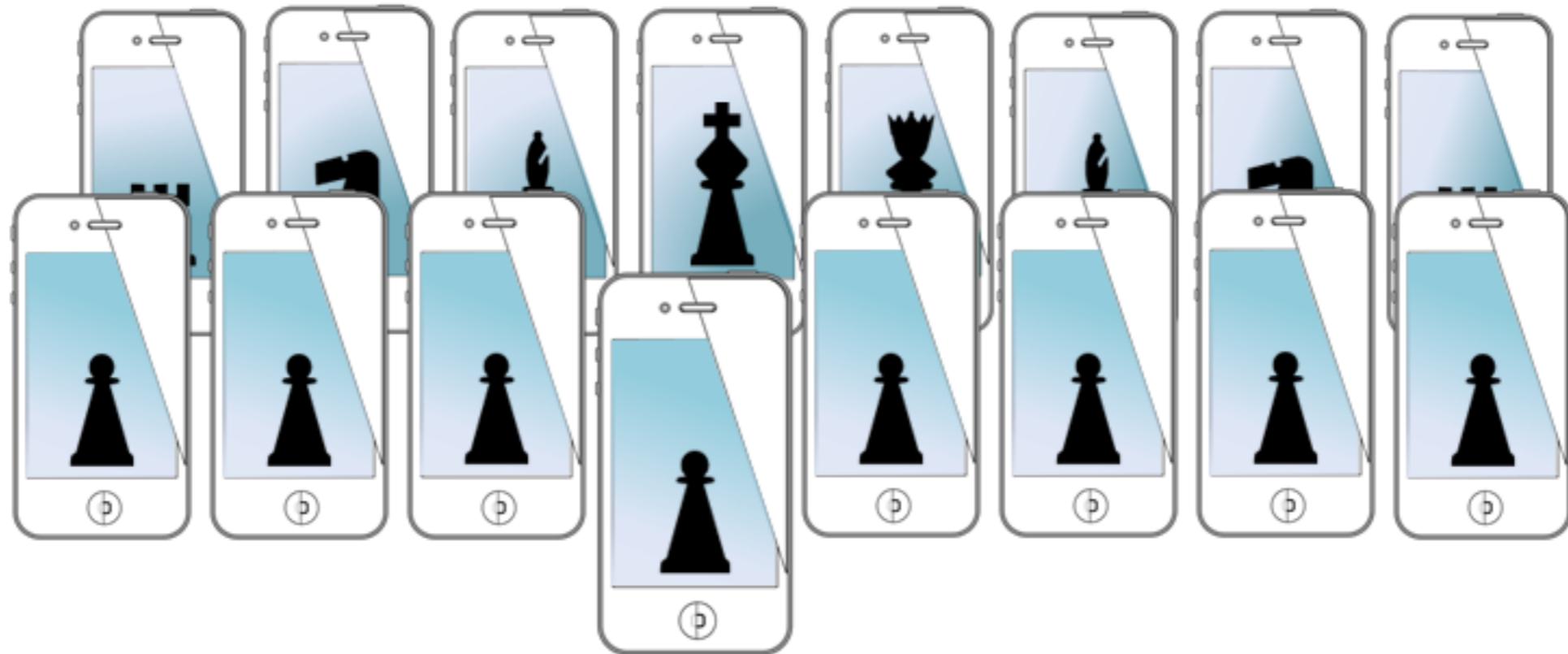


# MOBILE SENSING LEARNING



**CSE5323 & 7323**  
Mobile Sensing and Learning

week 5, lecture a: doppler and activity monitoring

Eric C. Larson, Lyle School of Engineering,  
Computer Science and Engineering, Southern Methodist University

# course logistics

- A1 grades coming soon
- A2 is due Friday

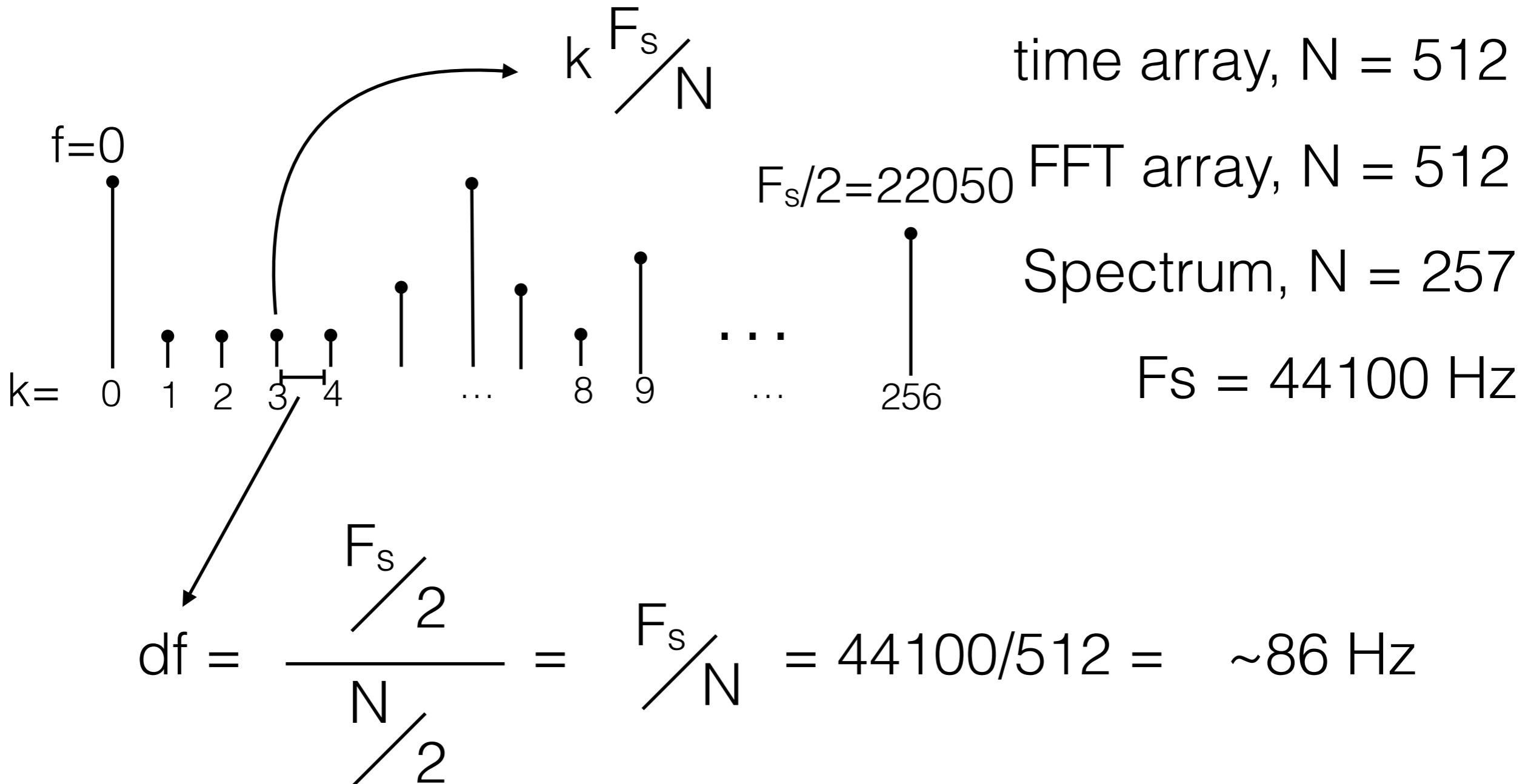
# agenda

- general FFT review
- the doppler effect
- A2 explanations
- peak finding
- motion processing

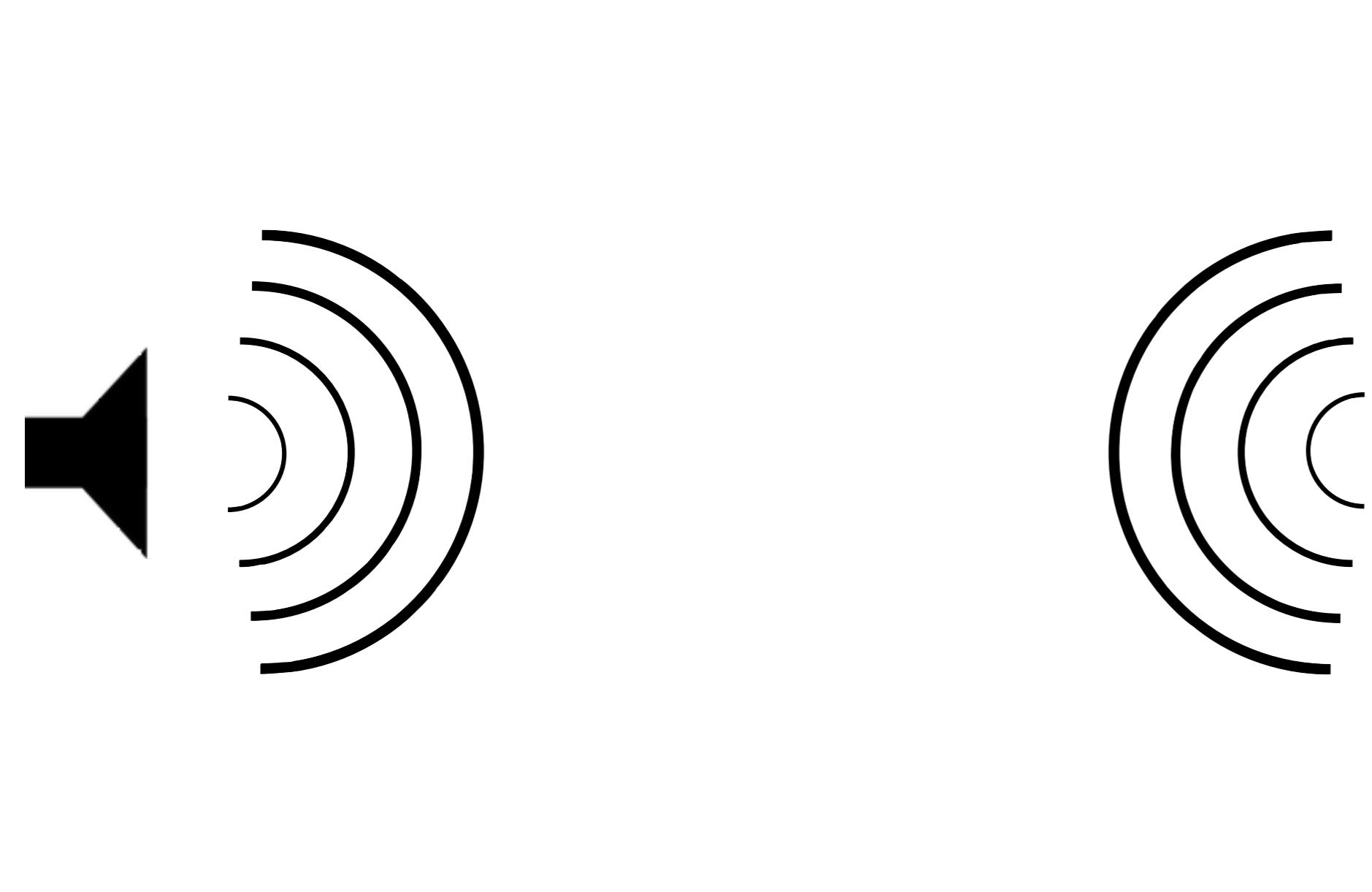
# FFT review

- sampling rate
  - dictates the time between each sample, ( $1 / \text{sampling rate}$ )
  - max frequency we can measure is half of sampling rate
- resolution in frequency
  - tradeoff between length of FFT and sampling rate
  - each frequency “bin” is an index in the FFT array
    - each bin represents  $(F_s / N)$  Hz
    - what does that mean for 6 Hz accuracy?

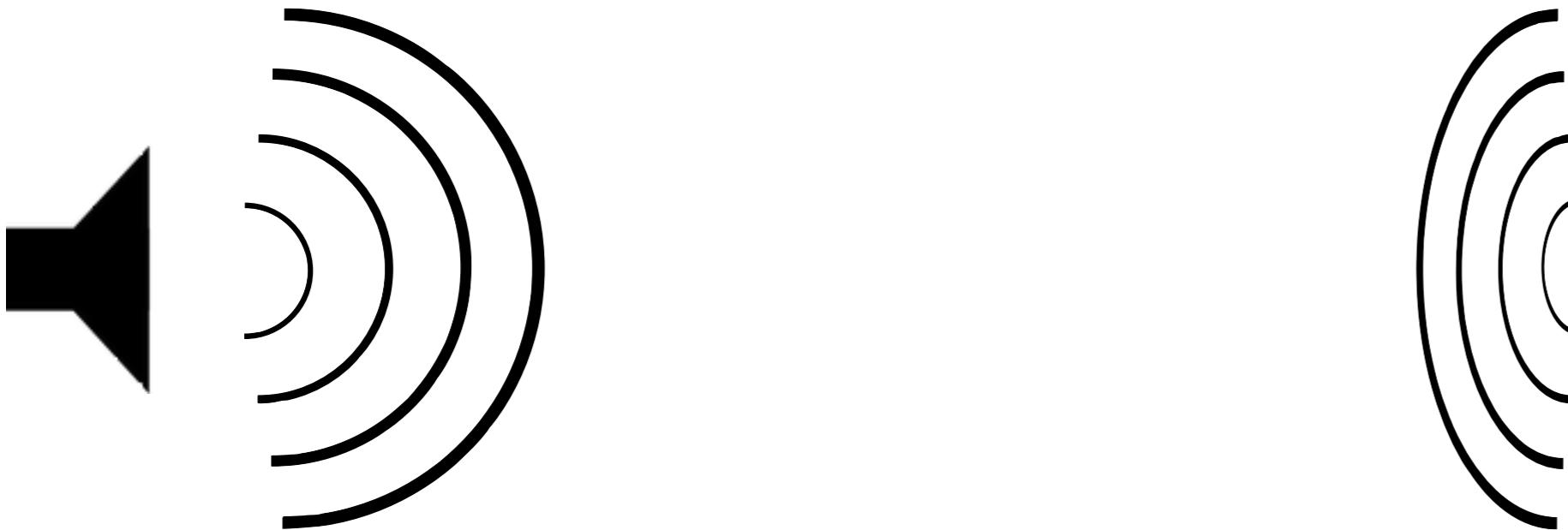
# time and frequency



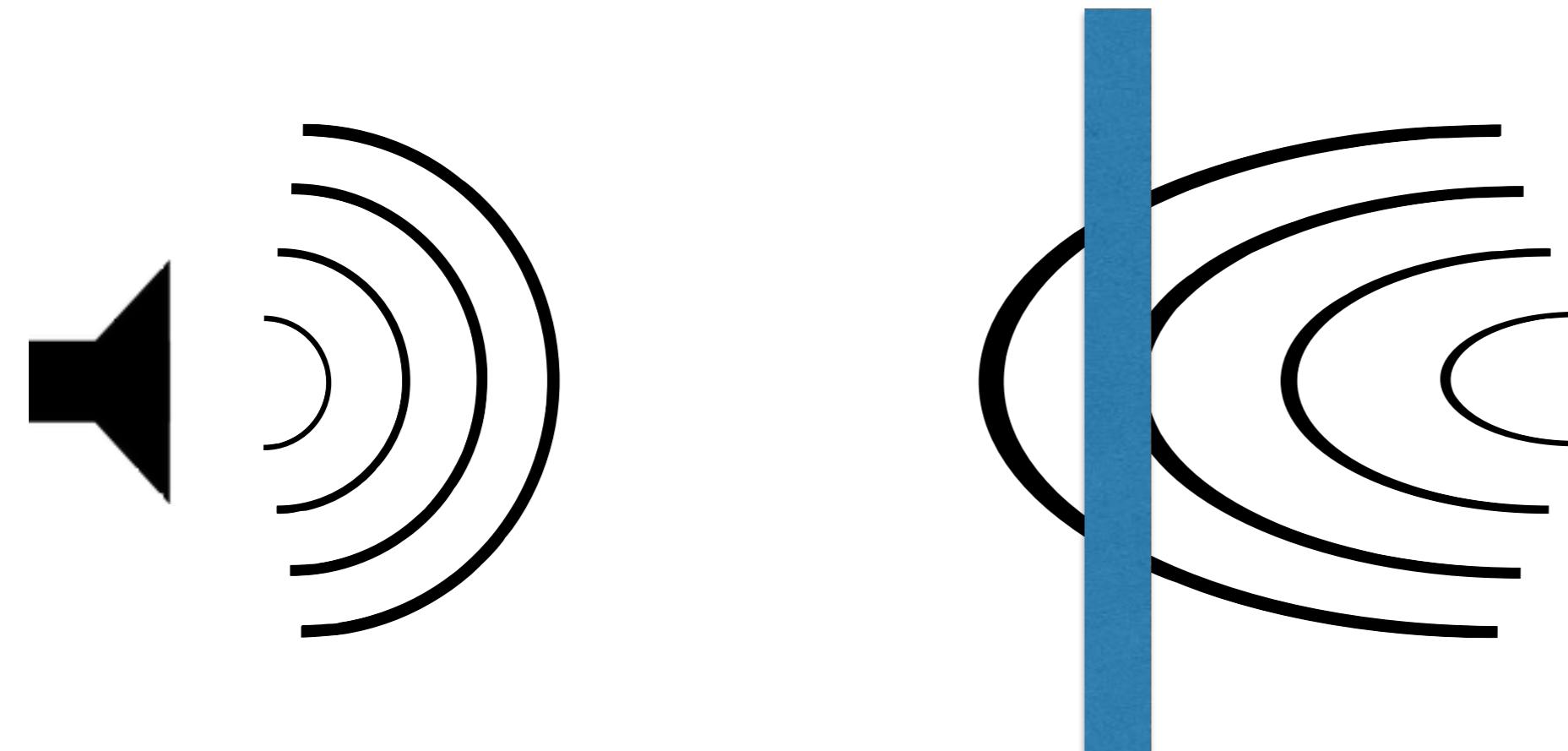
# the doppler effect



# the doppler effect



# the doppler effect



# the doppler effect

$$\Delta f = \frac{V_{object}}{c} f_0$$

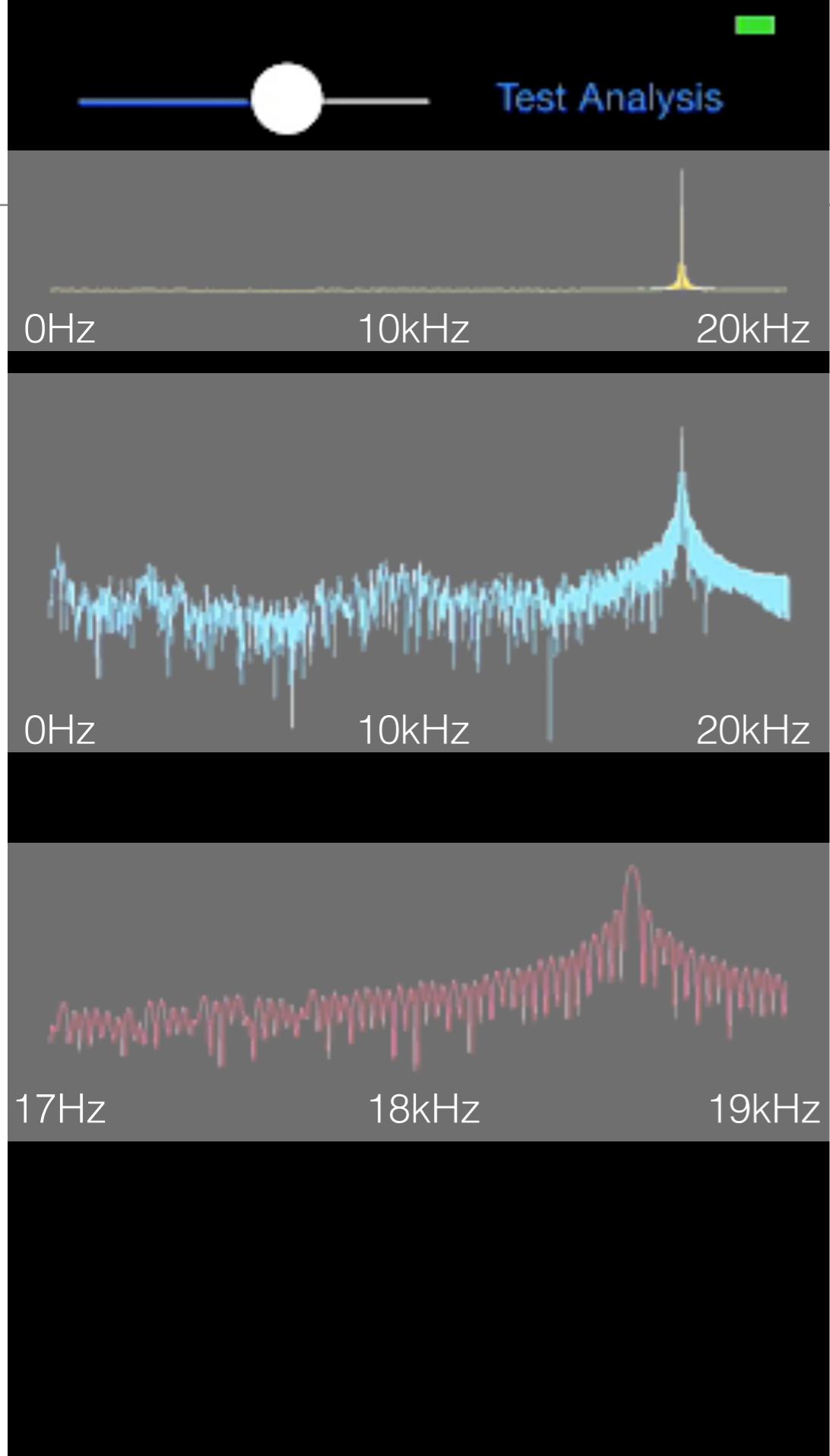
change in frequency

velocity of object

speed of sound

frequency of source

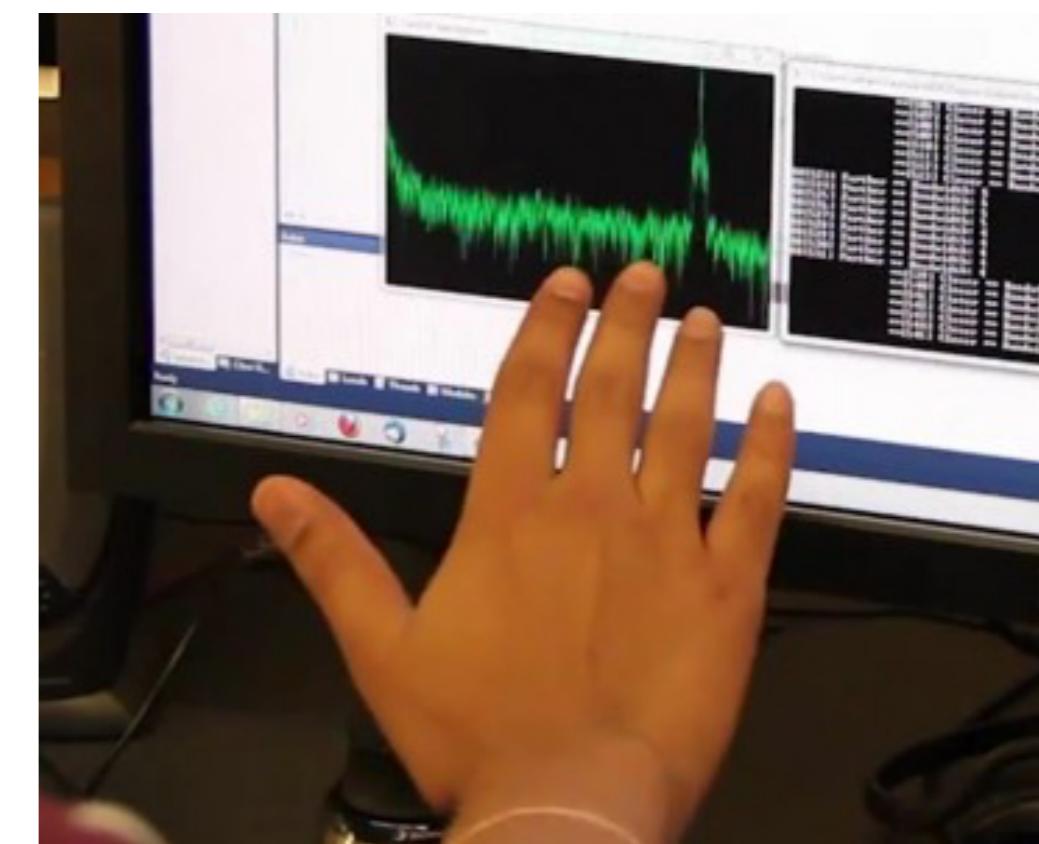
The diagram illustrates the formula for the Doppler effect. It features a central equation  $\Delta f = \frac{V_{object}}{c} f_0$ . Four callout boxes point to its components: 'change in frequency' points to  $\Delta f$ , 'velocity of object' points to  $V_{object}$ , 'speed of sound' points to  $c$ , and 'frequency of source' points to  $f_0$ .



linear

db

db zoomed (freq axis)

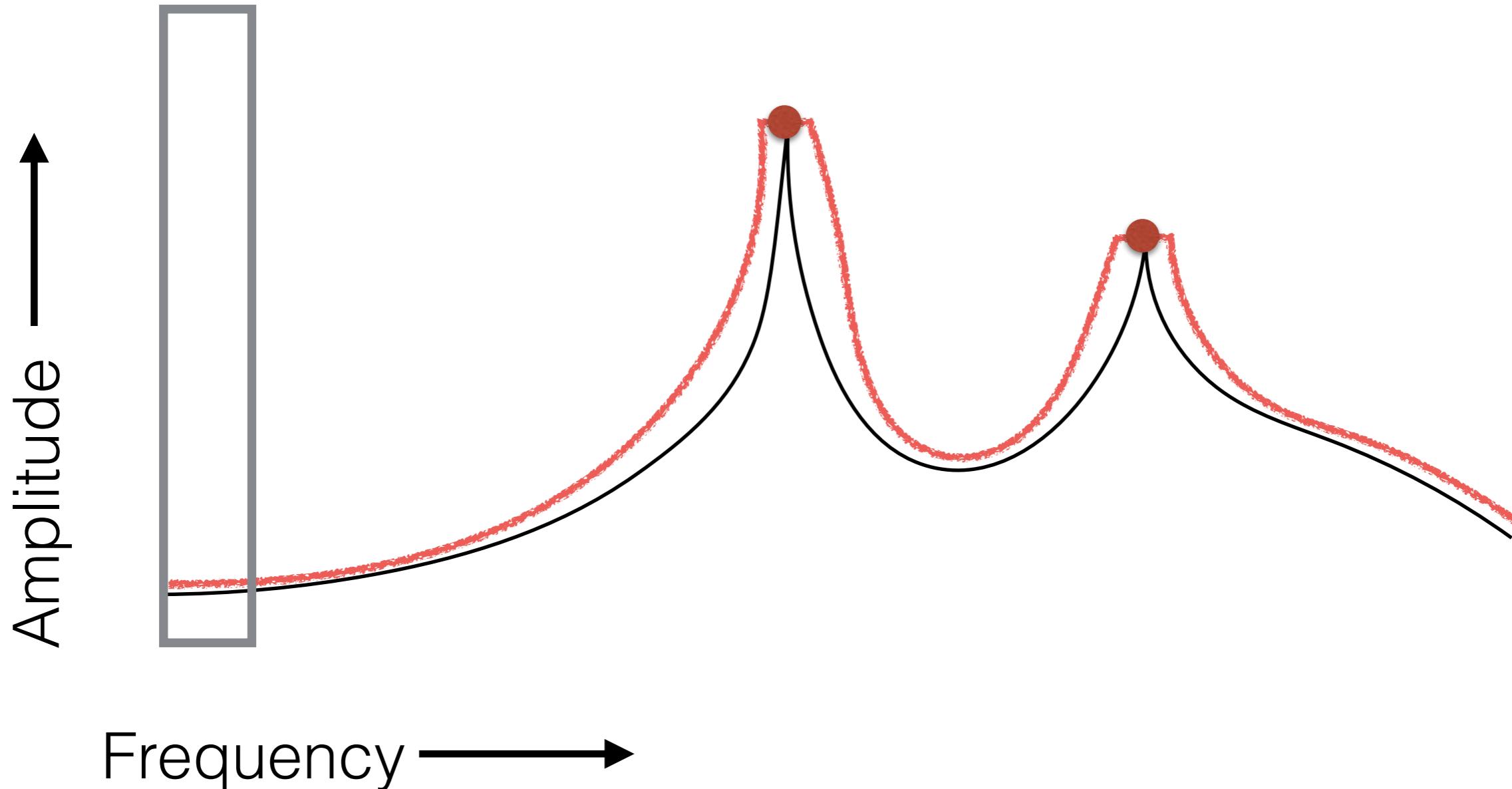


# A2 specifications

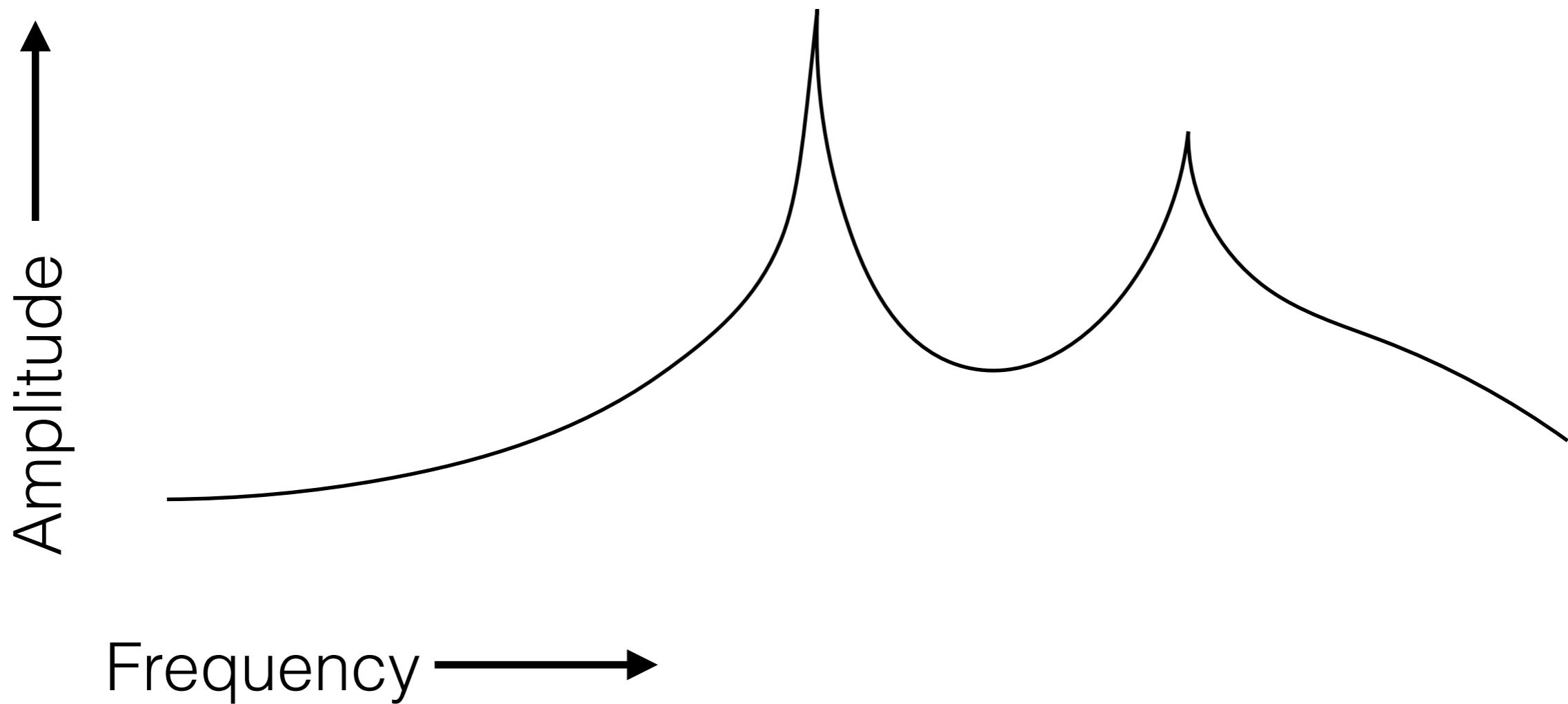
On Canvas

# local peak finding

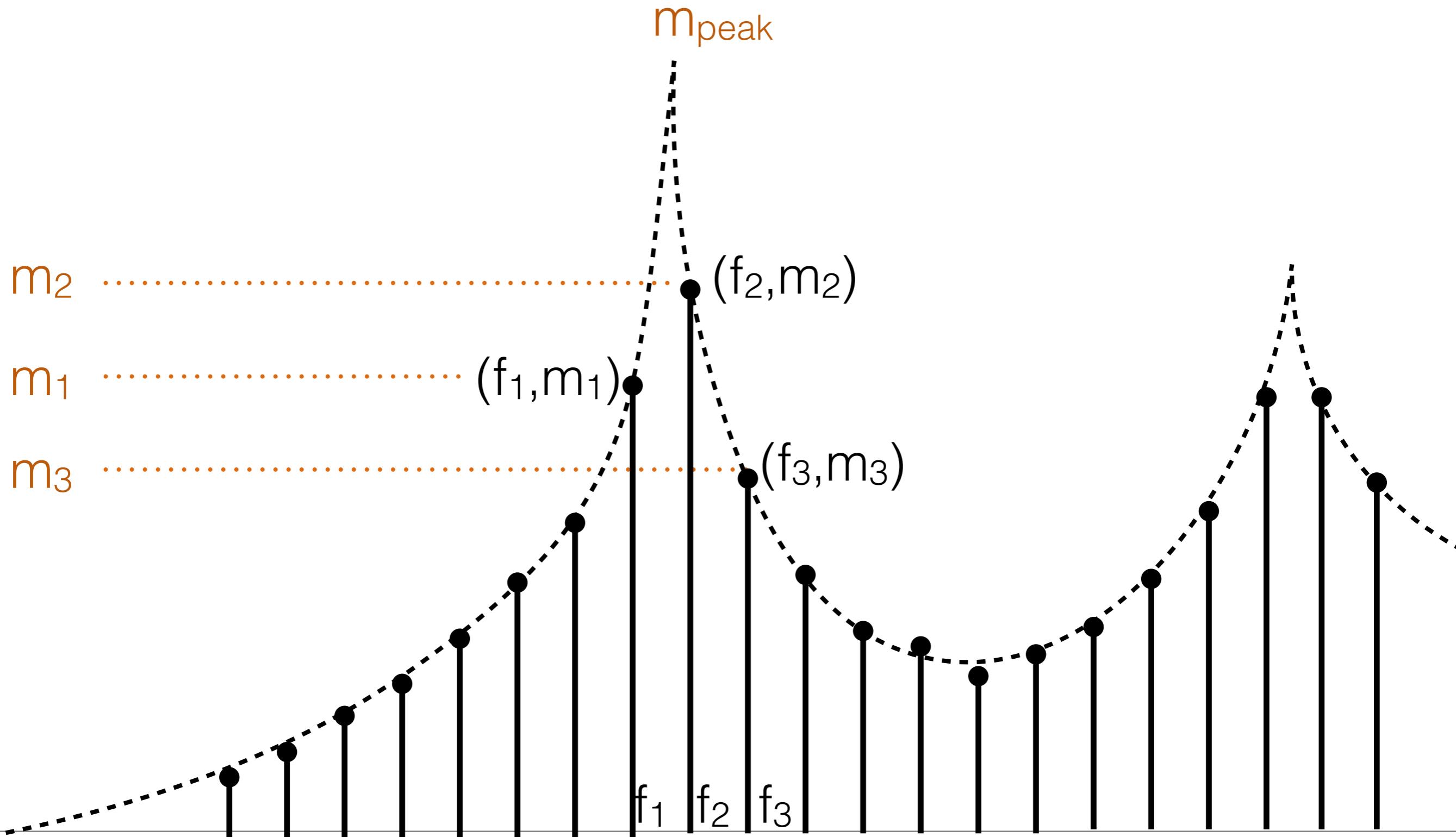
max in window



# peak interpolation

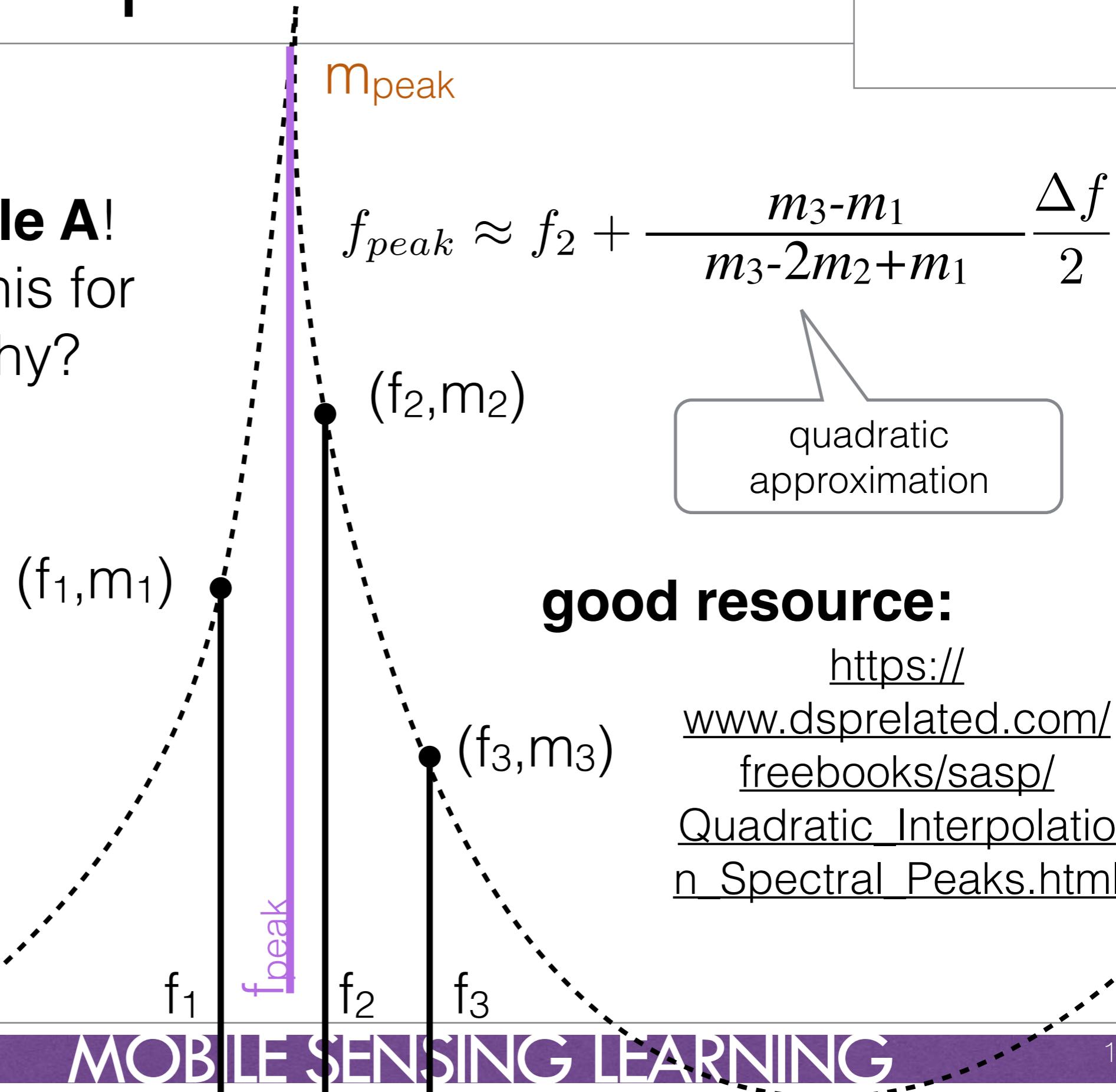


# peak interpolation



# peak interpolation

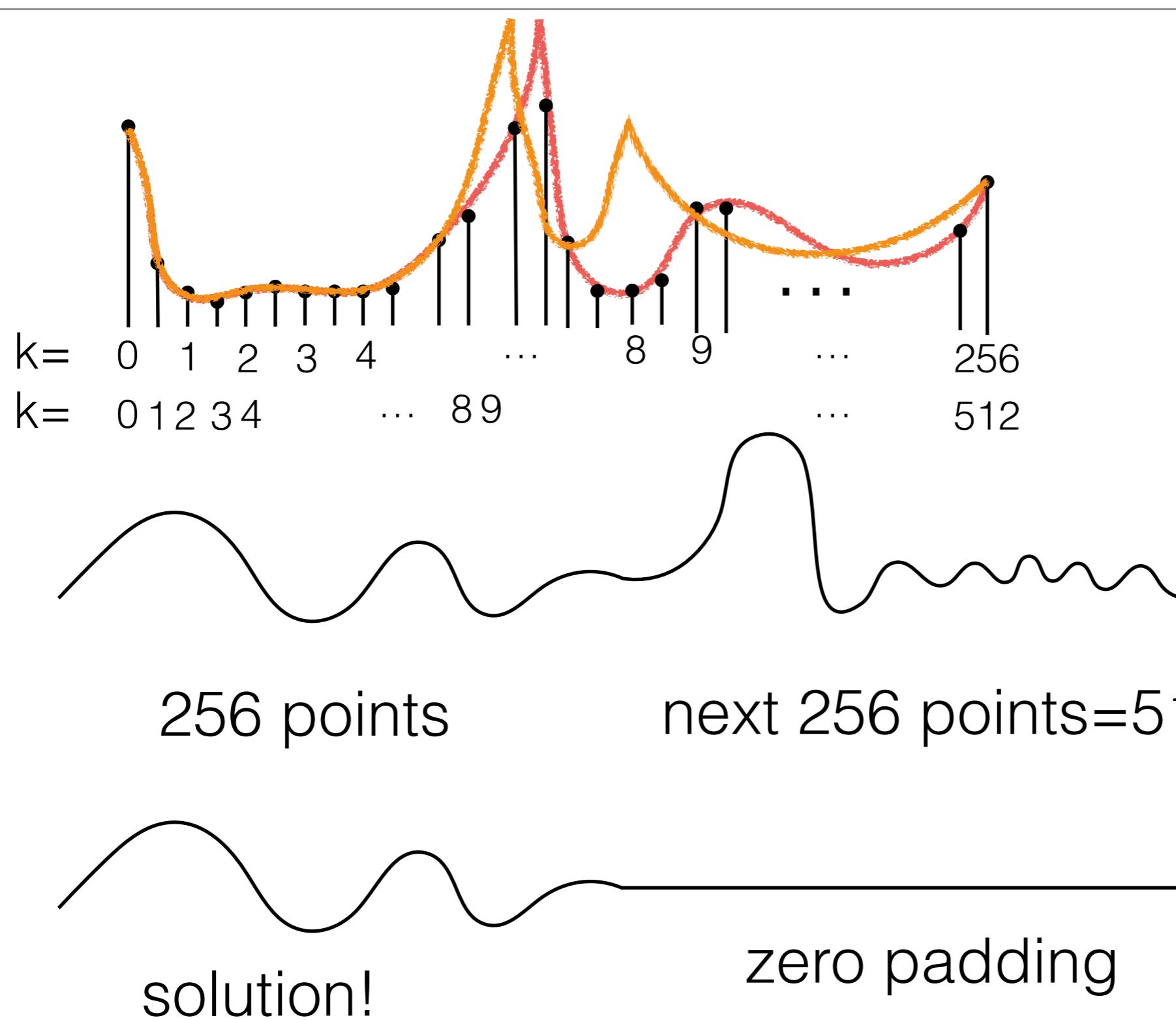
great for **module A!**  
no need to do this for  
**module B**, Why?



**good resource:**  
[https://  
www.dsprelated.com/  
freebooks/sasp/  
Quadratic\\_Interpolation  
\\_Spectral\\_Peaks.html](https://www.dsprelated.com/freebooks/sasp/Quadratic_Interpolation_Spectral_Peaks.html)

# resolution for the FFT

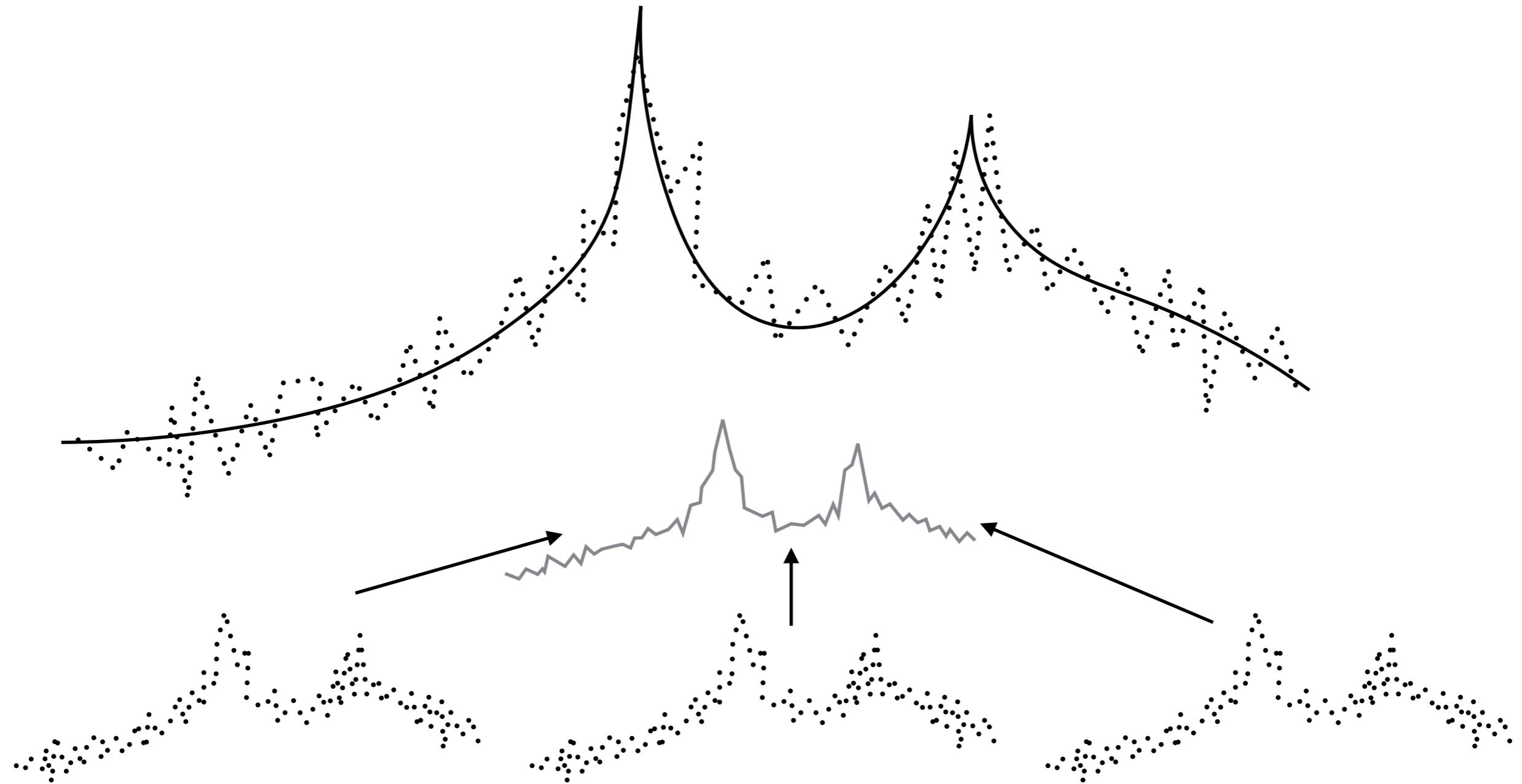
optional



# noise in the FFT

optional

- variance around actual magnitude unavoidable



first  $N$  samples

second  $N$  samples

third  $N$  samples

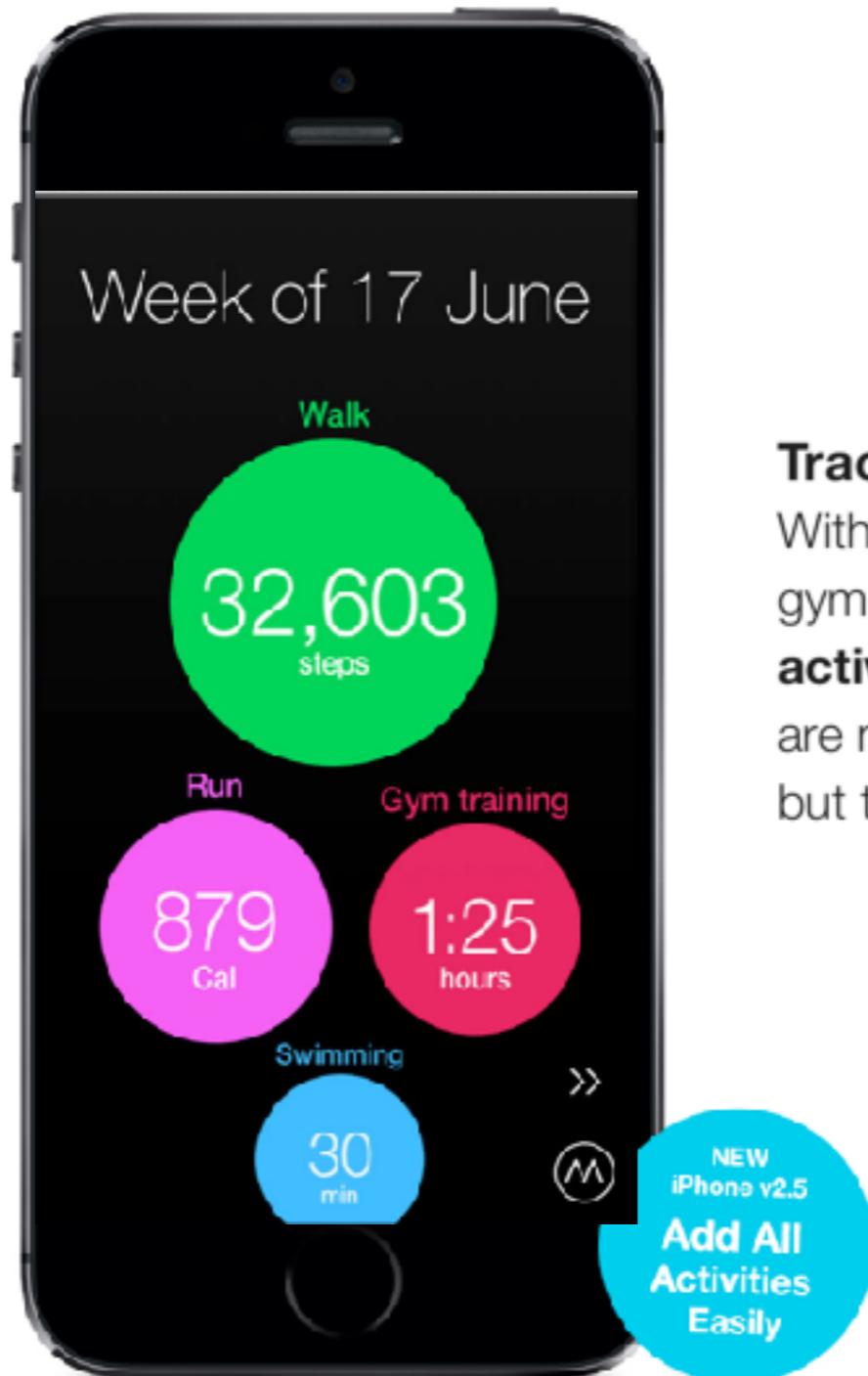
# Questions on the FFT

- we are about to move to motion processing...
- so ask now!
- ...or later...

# and now...

- no more microphone data!
- let's get data from the other sensors...
- core motion
  - the M# co-processor

# a nice example of core motion



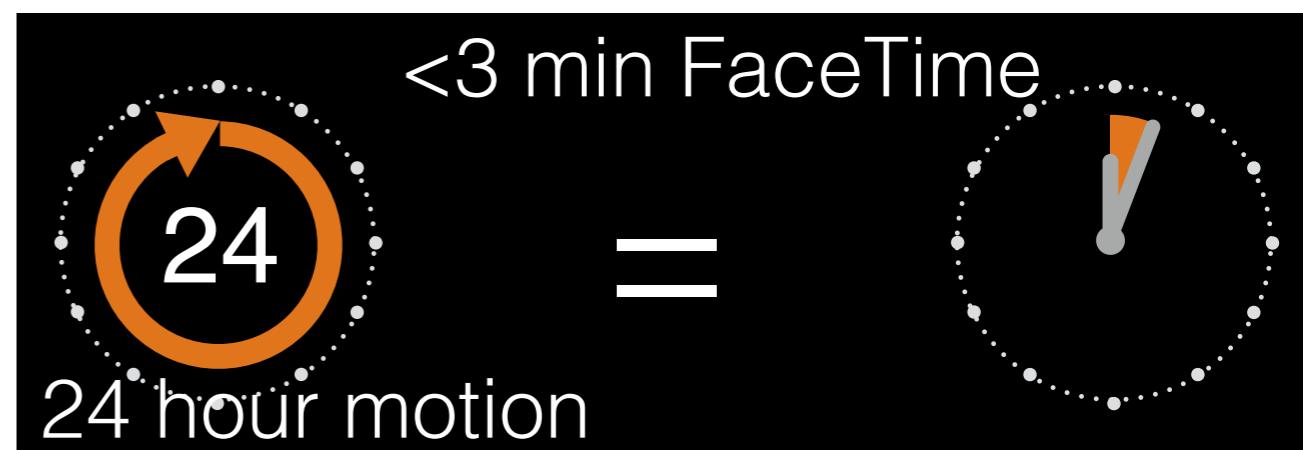
## Track all activity\*

With Moves 2.5 for iPhone, you can add gym training and **over 60 other activities** by duration. These activities are not (yet!) automatically recognized, but they are easy to add.



# the M- coprocessor

- 150MHz+ processor that reads all motion data from all “motion” sensors on the phone
  - accelerometer
  - magnetometer (compass)
  - gyroscope
  - barometer! (M8 and above)
- mediates all access to data
  - battery life++
  - parallel processing++
  - overhead += 0, seriously
- sensor fusion for more accurate analysis, very cool



# high level streams

- not just raw data!
  - the M- co-processor does sophisticated analysis of sensor data for you
  - enables naive access to “high level” information
- can register your app to receive “updates” from the co-processor unit
  - steps taken (and saved state of steps)
  - some common activity
    - running, walking, **cycling**, still, in car, unknown



# activity from M-

- uses the “core motion” framework (CM)
- mediated through the “CMActivityManager”
  - is device capable of activity?
  - query past activities (up to 7 days)
  - subscribe to changes
- interaction completely based on blocks and handlers

More help: <https://developer.apple.com/videos/wwdc/2014/>  
Navigate to: **Motion Tracking and Core Motion Framework**

# subscribing to activity



- updates are notifications

```
#import <CoreMotion/CoreMotion.h>

// from co-processor
@property (nonatomic, strong) CMMotionActivityManager *motionActivityManager;

// initialize the activity manager (check if available)
if ([CMMotionActivityManager isActivityAvailable] == YES) {
    self.motionActivityManager = [[CMMotionActivityManager alloc] init];
}

if ([CMMotionActivityManager isActivityAvailable] == YES) {
    [self.motionActivityManager startActivityUpdatesToQueue:[NSOperationQueue mainQueue]
        withHandler:^(CMMotionActivity *activity) {
            // do something with the activity info!
        }];
    NSLog(@"Activity Manager Running");
} else
    NSLog(@"Cannot start activity manager");

if([CMMotionActivityManager isActivityAvailable] == YES )
    [self.motionActivityManager stopActivityUpdates];
```

import framework

declare activity manager

device capable?

subscribe

instantiate

queue to run on

block to handle updates

end subscription

# swift version



```
import CoreMotion
```

import framework

```
let activityManager = CMMotionActivityManager()
```

declare activity manager

```
let customQueue = NSOperationQueue() // not the main queue
```

device capable?

```
override func viewDidLoad() {
```

super.viewDidLoad()

```
    if CMMotionActivityManager.isActivityAvailable(){
```

self.activityManager.startActivityUpdatesToQueue(customQueue)

```
        { (activity:CMMotionActivity?) -> Void in
```

NSLog(@"%@",activity!.description)

```
        }
```

```
}
```

**closure** to handle updates  
(*this one just prints description*)

```
}
```

```
override func viewWillDisappear(animated: Bool) {
```

```
    if CMMotionActivityManager.isActivityAvailable() {
```

self.activityManager.stopActivityUpdates()

```
    }
```

```
    super.viewWillDisappear(animated)
```

end subscription

# what's in an update?

- updated when any part of activity estimate changes
- each update is a CMMotionActivity class instance
  - startDate (down to seconds)
  - walking {0,1}
  - stationary {0,1}
  - running {0,1}
  - cycling {0, 1}
  - automotive {0,1} 
  - unknown {0,1}
  - confidence {Low, Medium, High}

```
startActivityUpdatesToQueue:[NSOperationQueue mainQueue]
                           withHandler:^(CMMotionActivity *activity)
{
    // do something with the activity info!
};
```

```
self.activityManager.startActivityUpdatesToQueue(customQueue)
{
    (activity:CMMotionActivity?) -> Void in
    // do something with the activity info!
}
```



# example update

inside handler

```
startActivityUpdatesToQueue:[NSOperationQueue mainQueue]
    withHandler:^(CMMotionActivity *activity) {
        // do something with the activity info!
    }];
}

// enum for confidence is 0=low,1=medium,2=high
 NSLog(@"%@", confidence: %ld \n stationary: %d \n walking: %d \n run: %d \n cycle %d \n in car: %d",
    activity.confidence,
    activity.stationary,
    activity.walking,
    activity.running,
    activity.cycling,
    activity.automotive);

switch (activity.confidence) {
    case CMMotionActivityConfidenceLow:
        self.confidenceLabel.text = @"low";
        break;
    case CMMotionActivityConfidenceMedium:
        self.confidenceLabel.text = @"med.";
        break;
    case CMMotionActivityConfidenceHigh:
        self.confidenceLabel.text = @"high";
        break;
    default:
        break;
}
```

from notification

access fields easily

look at confidence

# what's in an update?

## Example Scenarios

Device scenarios	stationary	walking	running	automotive	cycling	unknown
On table	true	false	false	false	false	false
On runner's upper arm	false	false	true	false	false	false
In dash of idling vehicle	true	false	false	true	false	false
In dash of moving vehicle	false	false	false	true	false	false
Passenger checking email	false	false	false	false	false	false
Immediately after reboot	false	false	false	false	false	true
In zumba class	false	false	false	false	false	false

# past activity

- query for an array of CMMotionActivity activities

```
// example of querying from certain dates
NSDate *now = [NSDate date];
NSDate *from = [NSDate dateWithTimeInterval:-60*60*24 sinceDate:now];

[self.motionActivityManager queryActivityStartingFromDate:from
    toDate:now
    toQueue:[NSOperationQueue mainQueue]
withHandler:^(NSArray *activities, NSError *error) {

    for(CMMotionActivity *cmAct in activities)
    {
        NSLog(@"At %@", cmAct.startDate, cmAct.walking);
    }
}];
```

setup date range

set dates

set queue

handle error!

handle output

- can you guess what the swift code looks like?

# what's in an update?

## Motion Activity Walking

Performance is fairly insensitive to location

- Detection can be suppressed when device is in hand

Relatively low latency

Very accurate, on average

- Expect intermittent transitions into and out of walking state



# what's in an update?

## Motion Activity

### Running

Completely insensitive to location

Shortest latency

Most accurate classification



# what's in an update?

## Motion Activity Automotive

Performance is sensitive to location

- Works best if device is mounted,  
or placed in dash or in cup holder

Variable latency

Relies on other information sources  
when available



# what's in an update?

## Motion Activity Cycling

Performance is very sensitive to location

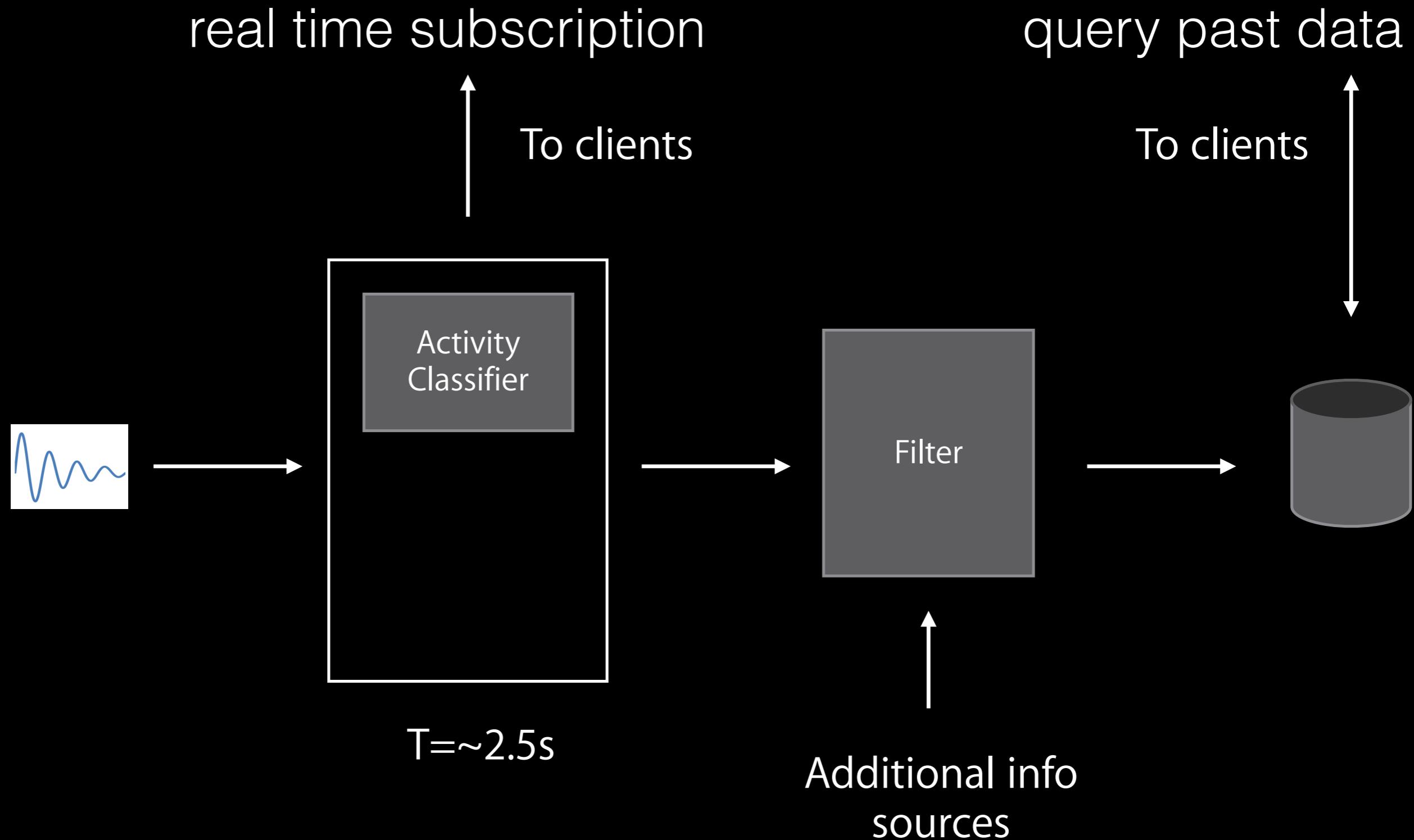
- Works best if device is worn on upper arm

Longest latency

- Best for retrospective use cases



# Motion Processing Architecture



# more than activity

- M- also tracks pedometer information during each activity
- like activity: setup as a **push** system (subscribe)
- pedometer: special handling from the M?
  - CMStepCounter is deprecated as of 2015!!!!!! Do not use it...
  - instead, we will use the CMPedometer class

# pedometer use

swift



```
let pedometer = CMPedometer()  
  
if CMPedometer.isStepCountingAvailable(){  
    pedometer.startPedometerUpdatesFromDate(NSDate())  
    { (pedData: CMPedometerData?, error:NSError?) -> Void in  
        NSLog(@"%@", pedData.description)  
    }  
}  
  
if CMPedometer.isStepCountingAvailable(){  
    self.pedometer.stopPedometerUpdates()  
}
```

declare and init

available on this device?

closure handler for updates

unsubscribe

# pedometer

- do not rely on the update to:
  - have any regularity
  - be what you asked for
- iOS: you get the update when we say you do!
  - which optimizes battery life
  - is not at expense of interaction
  - minimizes bus traffic on co-processor
  - is more accurate
  - and will keep track even if your app is in the background

# pedometer use revisiting



```
let pedometer = CMPedometer()  
  
if CMPedometer.isStepCountingAvailable(){  
    pedometer.startPedometerUpdatesFromDate(NSDate())  
    { (pedData: CMPedometerData?, error:NSError?) -> Void in  
        NSLog(@"%@",pedData.description)  
    }  
}  
  
if CMPedometer.isStepCountingAvailable(){  
    self.pedometer.stopPedometerUpdates()  
}
```

declare and init

available on this device?

properties from step counter

unsubscribe

CMPedometerData,<startDate 2016-09-06 17:13:54  
+0000. endDate 2016-09-06 17:14:21 +0000,  
steps 16, distance 14.11999999999534,  
floorsAscended 0, floorsDescended 0 currentPace  
0.3286592364311218 currentCadence  
3.295127630233765>

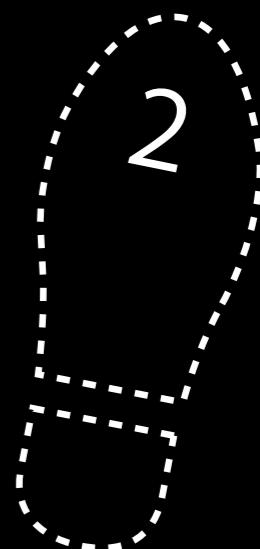
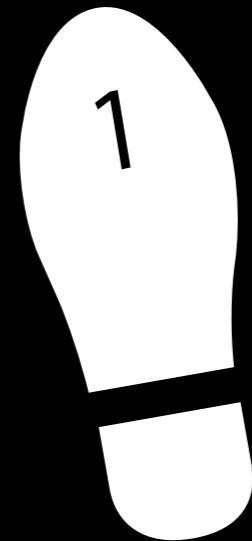
# Pedometer

## Step counting

Consistent performance across body locations

Extremely accurate

Robust to extraneous motions



# Pedometer

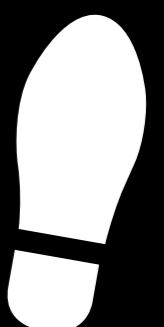
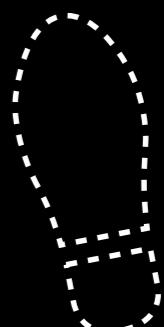
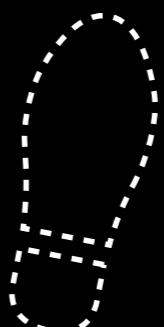
## Stride estimation

Consistent performance across body locations

Consistent performance across pace

Extremely accurate

Adapts to the user over time



# querying past steps



handle error!

```
let now = NSDate()
let from = now.dateByAddingTimeInterval(-60*60*24)

self.pedometer.queryPedometerDataFromDate(from, toDate: now)
{ (pedData: CMPedometerData?, error: NSError?) -> Void in

    let aggregated_string = "Steps: \(pedData.numberOfSteps) \n
        Distance \(pedData.distance) \n
        Floors: \(pedData.floorsAscended.integerValue)"

    dispatch_async(dispatch_get_main_queue()){
        self.activityLabel.text = aggregated_string
    }
}
```

access properties

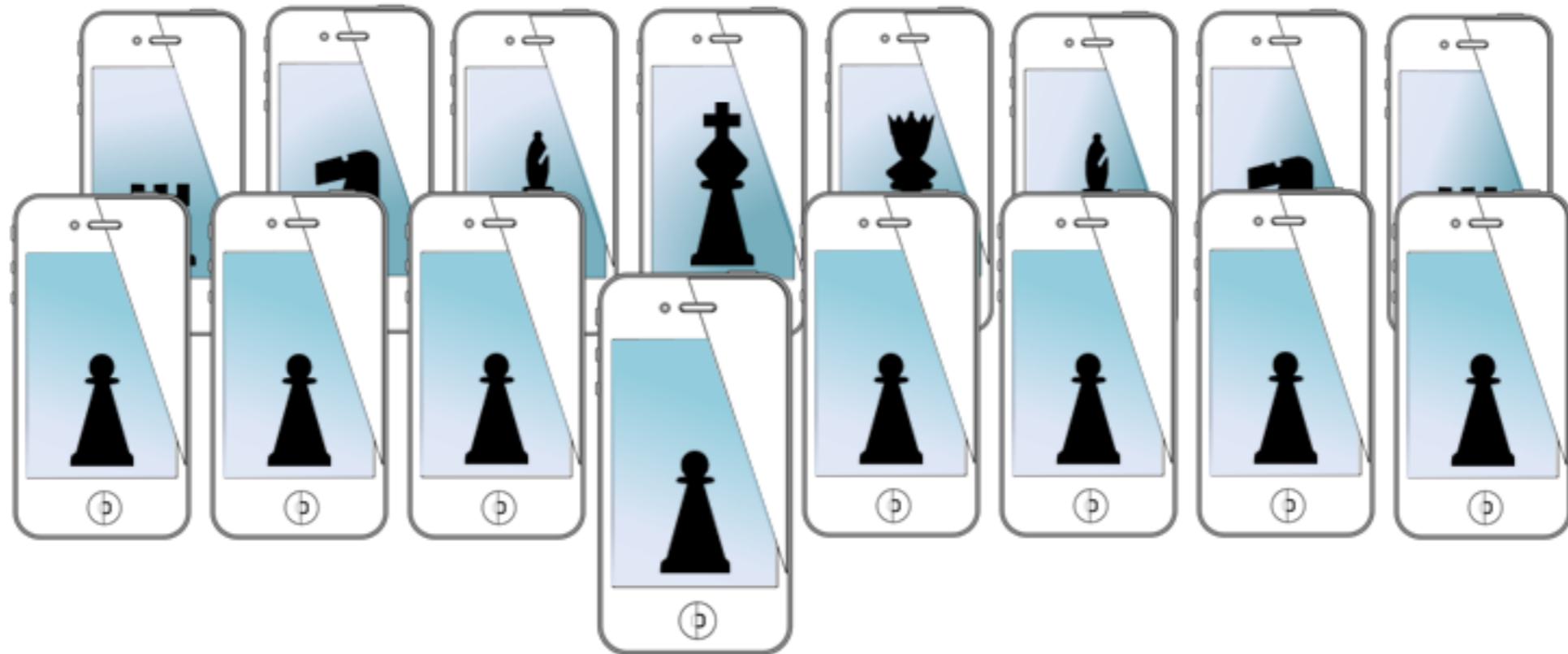
# M- pedometer/activity demo



And now its  
time for a demo

**if time!**

# MOBILE SENSING LEARNING

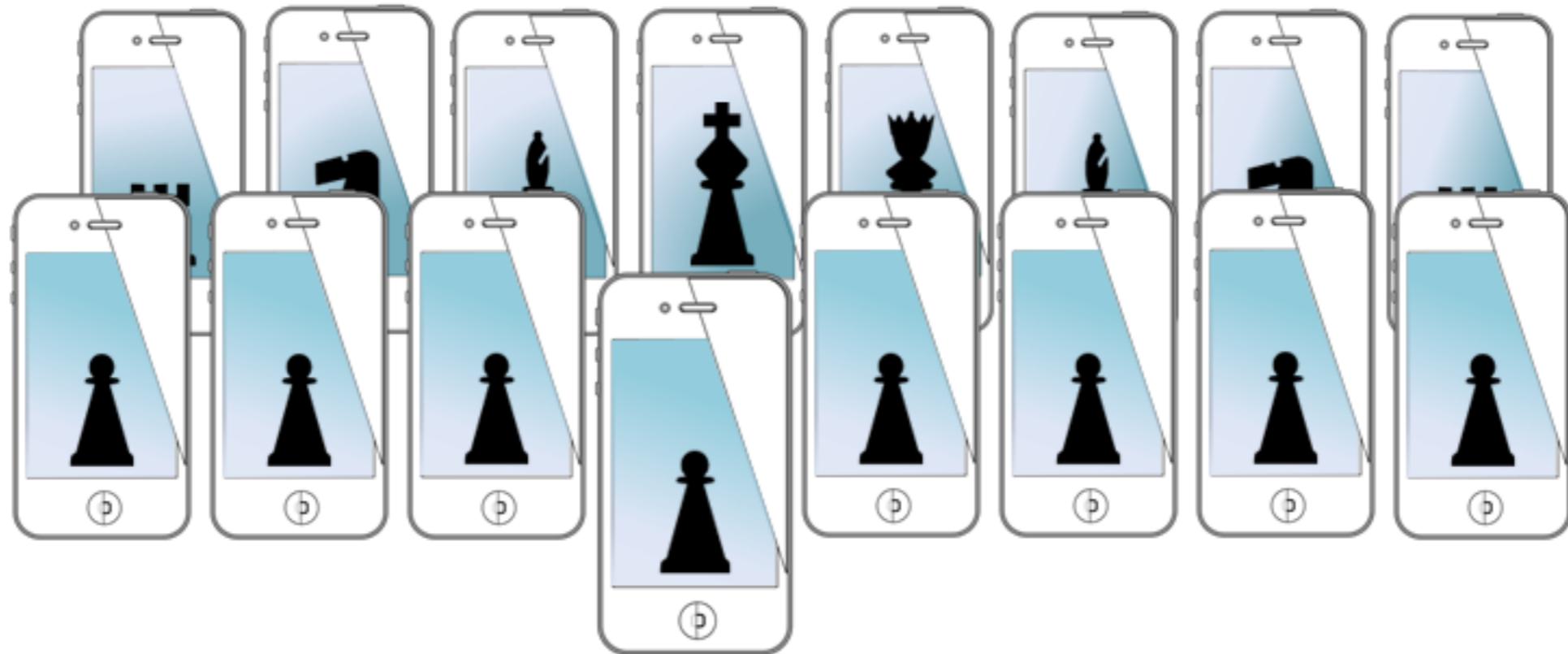


**CSE5323 & 7323**  
Mobile Sensing and Learning

week 5, lecture a: doppler and activity monitoring

Eric C. Larson, Lyle School of Engineering,  
Computer Science and Engineering, Southern Methodist University

# MOBILE SENSING LEARNING



**CSE5323 & 7323**  
Mobile Sensing and Learning

week 5 lecture b: activity, pedometers, and motion sensing

Eric C. Larson, Lyle School of Engineering,  
Computer Science and Engineering, Southern Methodist University

# course logistics

- A2 is due Friday
  - everyone okay?
- A3 is due a week from Friday
  - smaller set of deliverables

# agenda

- core motion (continued)
  - M- co-processor
- demo
- accelerometers, gyros, and magnetometers
- demo
- SpriteKit
- demo

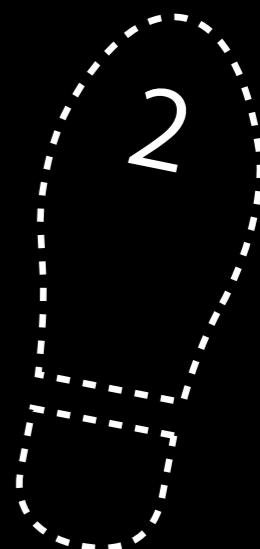
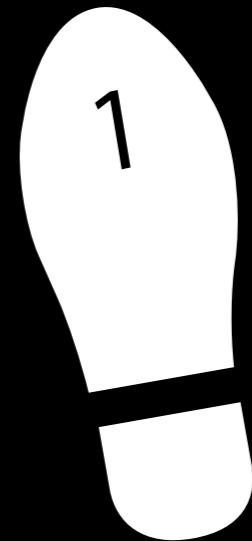
# Pedometer

## Step counting

Consistent performance across body locations

Extremely accurate

Robust to extraneous motions



# Pedometer

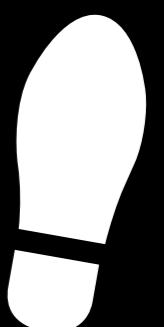
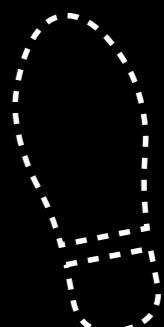
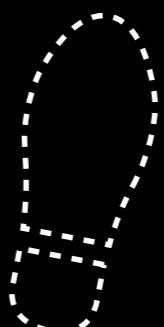
## Stride estimation

Consistent performance across body locations

Consistent performance across pace

Extremely accurate

Adapts to the user over time



# querying past steps



handle error!

```
let now = NSDate()
let from = now.dateByAddingTimeInterval(-60*60*24)

self.pedometer.queryPedometerDataFromDate(from, toDate: now)
{ (pedData: CMPedometerData?, error: NSError?) -> Void in

    let aggregated_string = "Steps: \(pedData.numberOfSteps) \n
        Distance \(pedData.distance) \n
        Floors: \(pedData.floorsAscended.integerValue)"

    dispatch_async(dispatch_get_main_queue()){
        self.activityLabel.text = aggregated_string
    }
}
```

access properties

# storing persistent defaults



- iOS supports NSUserDefaults for primitives and encapsulated data (or lists of)

```
// standardUserDefaults variable
let defaults = UserDefaults.standardUserDefaults()

// saving
defaults.setInteger(252, forKey:@"primitiveInteger")
defaults.setDouble(3.14, forKey:@"primitiveDouble")
defaults.setFloat
defaults.setBool
defaults.setURL

// saving an object
defaults.setObject("Coding Explorer", forKey: "userNameKey")

if let name = defaults.stringForKey("userNameKey") {
    print(name)
}

boolForKey      -> Bool
integerForKey   -> Int
dataForKey      -> NSData?
objectForKey    -> AnyObject?
arrayForKey     -> [AnyObject]?
stringArrayForKey-> [String]?
dictionaryForKey -> {String:AnyObject}?
```

import defaults

primitives

objects

access saved  
objects

# user defaults

key value behavior for setting and getting!

```
_dailyStepsGoal = @(50);

NSUserDefaults * standardUserDefaults = [NSUserDefaults standardUserDefaults];

NSInteger dailyStepGoalFromUser = [standardUserDefaults
                                    integerForKey:@"dailyStepGoal"];

if(!dailyStepGoalFromUser){
    [standardUserDefaults setInteger:[self.dailyStepsGoal intValue]
                           forKey:@"dailyStepGoal"];
}
else{
    self.dailyStepsGoal = @(dailyStepGoalFromUser);
}
```



# M- pedometer/activity demo



And now its  
time for a demo

**“continue” demo!**

# M- “raw” motion data



## Barometer

The barometer senses air pressure to determine your relative elevation. So as you move, you can keep track of the elevation you've gained. It can even measure stairs climbed or hills conquered.

## Accelerometer

The accelerometer can measure your distance for walking and running. And by using GPS to calibrate for your running stride, the sensor more accurately captures your movement.

## Gyroscope

In addition to knowing whether you're on the move or stationary, M8 works with the gyroscope to detect when you're driving. It also kicks into action when you're taking panoramic photos or playing games that react to your movement.

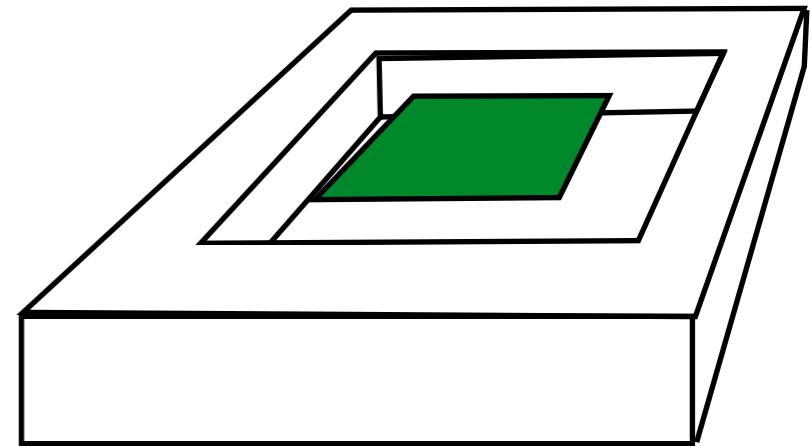
# M- “raw” motion data

- M- mediates access to data
- much lower battery consumption

iPhone 5	At 100Hz		At 20Hz	
	Total	Application	Total	Application
<b>DeviceMotion</b>	65%	20%	65%	10%
<b>Accelerometer</b>	50%	15%	46%	5%
<b>Accel + Gyro</b>	51%	10%	50%	5%
iPhone 5s	4%		1%	
iPhone 6, 6S	~2%		1%	
iPhone 7	~?%		?%	

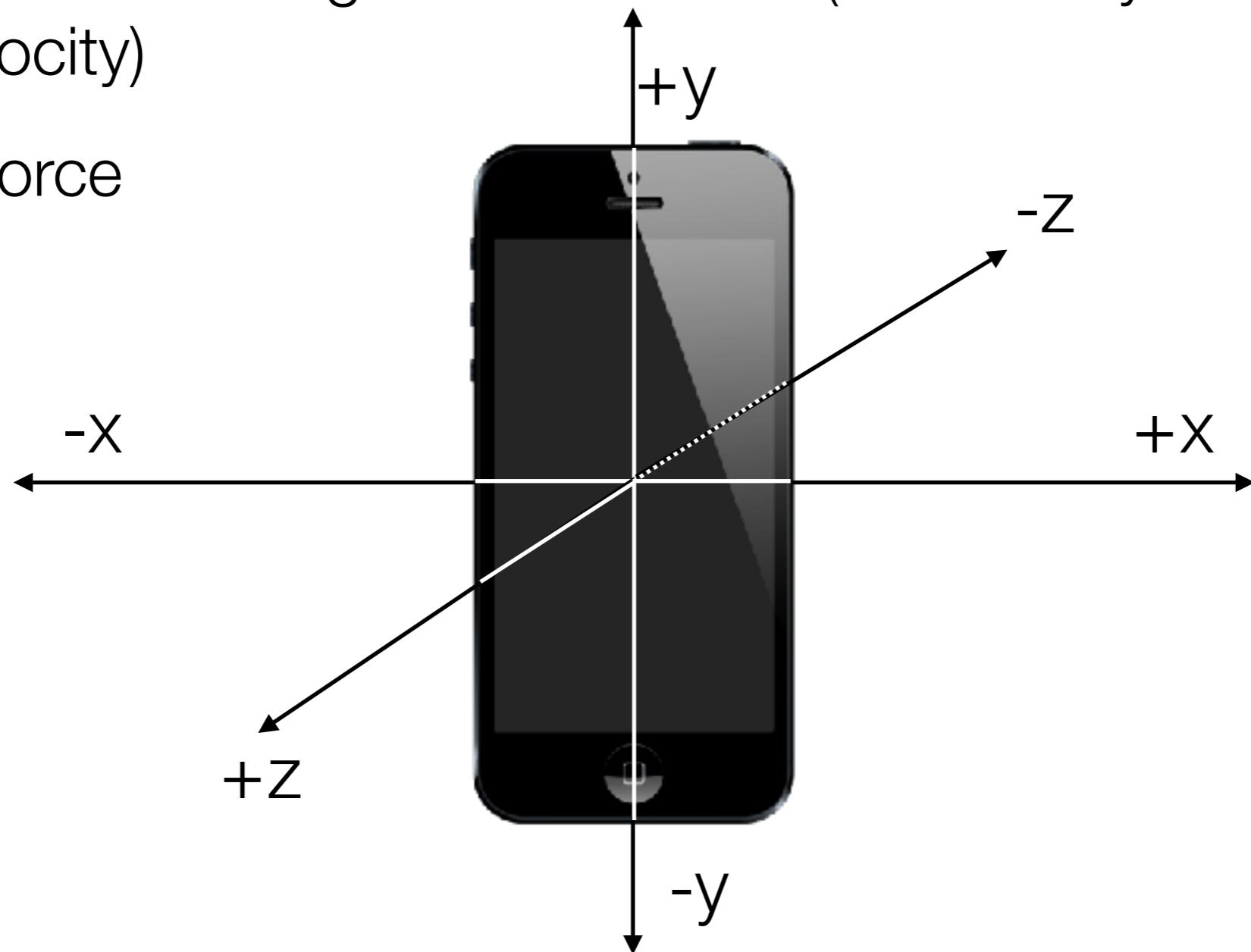
# accelerometers

- how does it work?
- solid state device (fabricated on a chip)
- it has specs (not made public by Apple)
  - swing
    - +-8g (force)
  - bias and variance
    - bias can be high, easy to zero out
  - resolution
    - 20 bits or 0.000015g
  - bandwidth
    - 100Hz sampling is highest recommended



# accelerometer

- measures “proper acceleration”
  - due to the weight of the device (not exactly derivative of velocity)
- g-force



# accessing the accelerometer



- usually don't want the raw accelerometer value
- gravity is always pulling “down” on the device at a constant force of ~9.81g
- the core motion API automatically subtracts gravity from the user acceleration

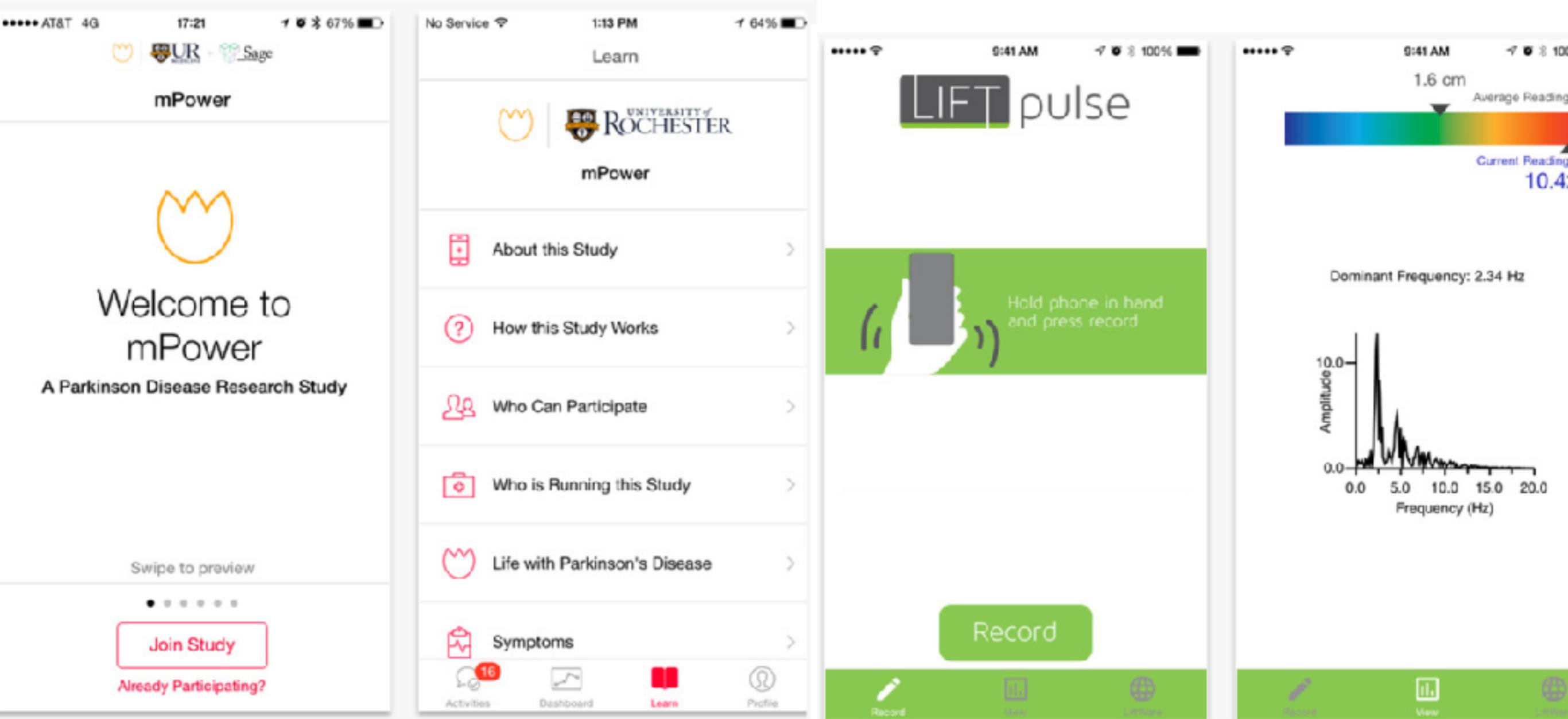
```
CMDDeviceMotion *deviceMotion  
  
deviceMotion.gravity  
deviceMotion.userAcceleration  
  
CMAcceleration gravity, CMAcceleration userAcceleration  
  
gravity.x;  
gravity.y;  
gravity.z;  
  
userAcceleration.x;  
userAcceleration.y;  
userAcceleration.z;
```

access through a different field!

Orientation	gravity.y	userAcceleration.x	userAcceleration.y
Portrait (top)	-9.81	+9.81	
Landscape Left (left)	+9.81	-9.81	
Landscape Right (right)	-9.81	+9.81	

user movement

# a cool example



# gyroscope

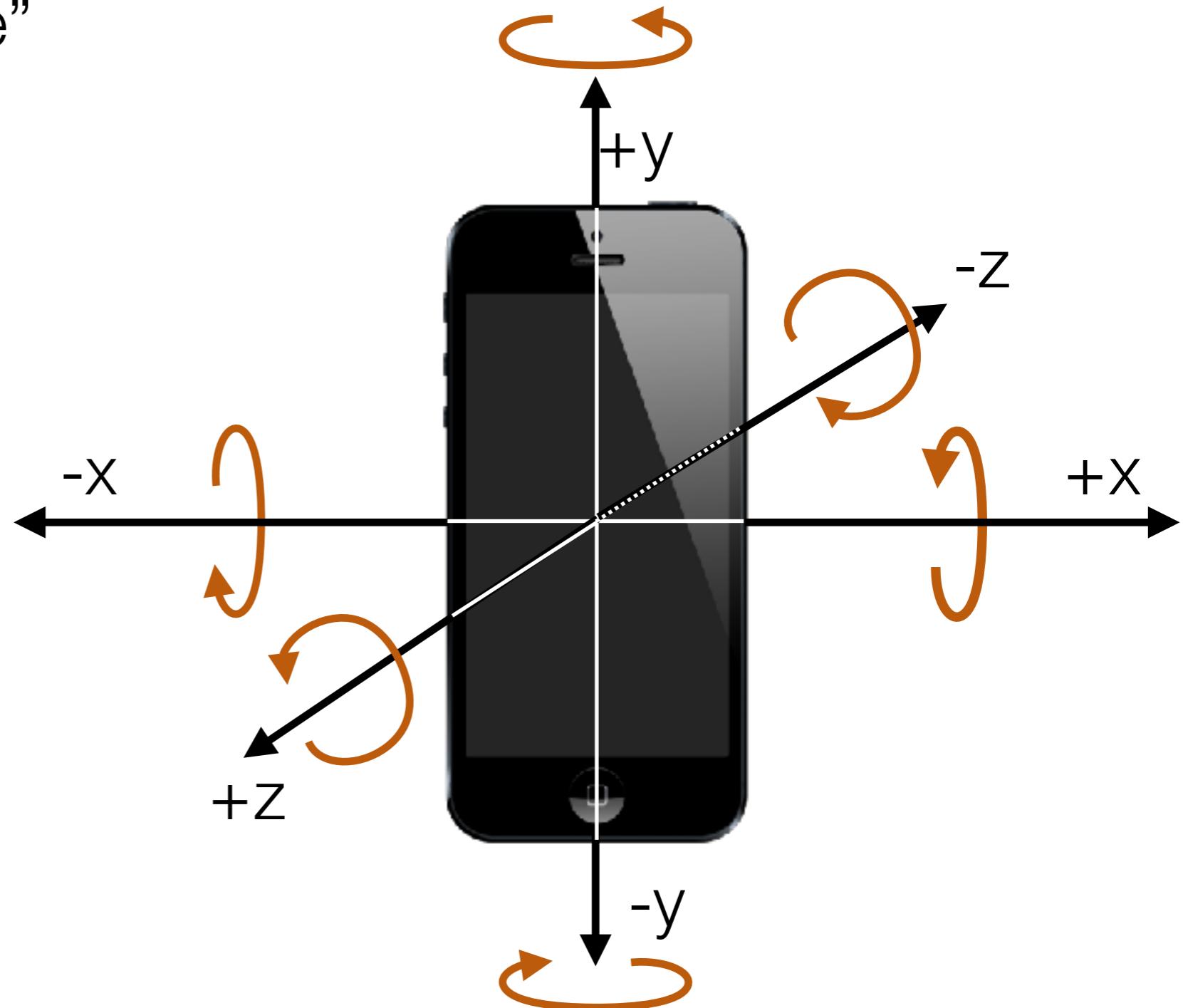
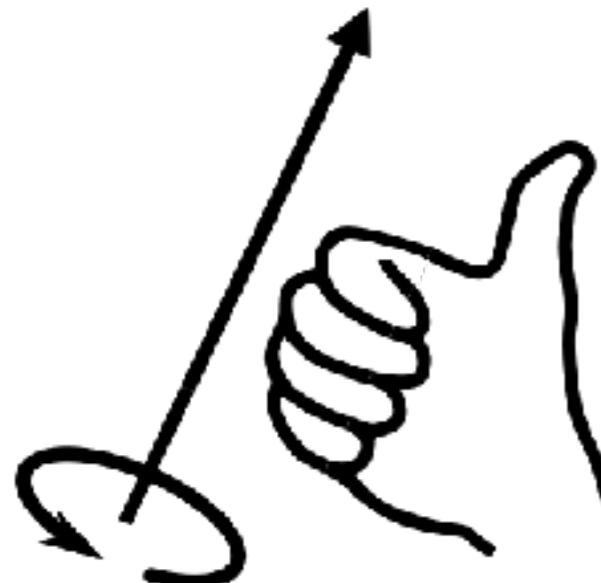
- measures the rate of rotation of the device
- MEMs device
  - essentially a microscopic, vibrating plate that resists motion



so it knows force in any rotating direction

# gyroscope

- the “right hand rule”



# accessing the gyro

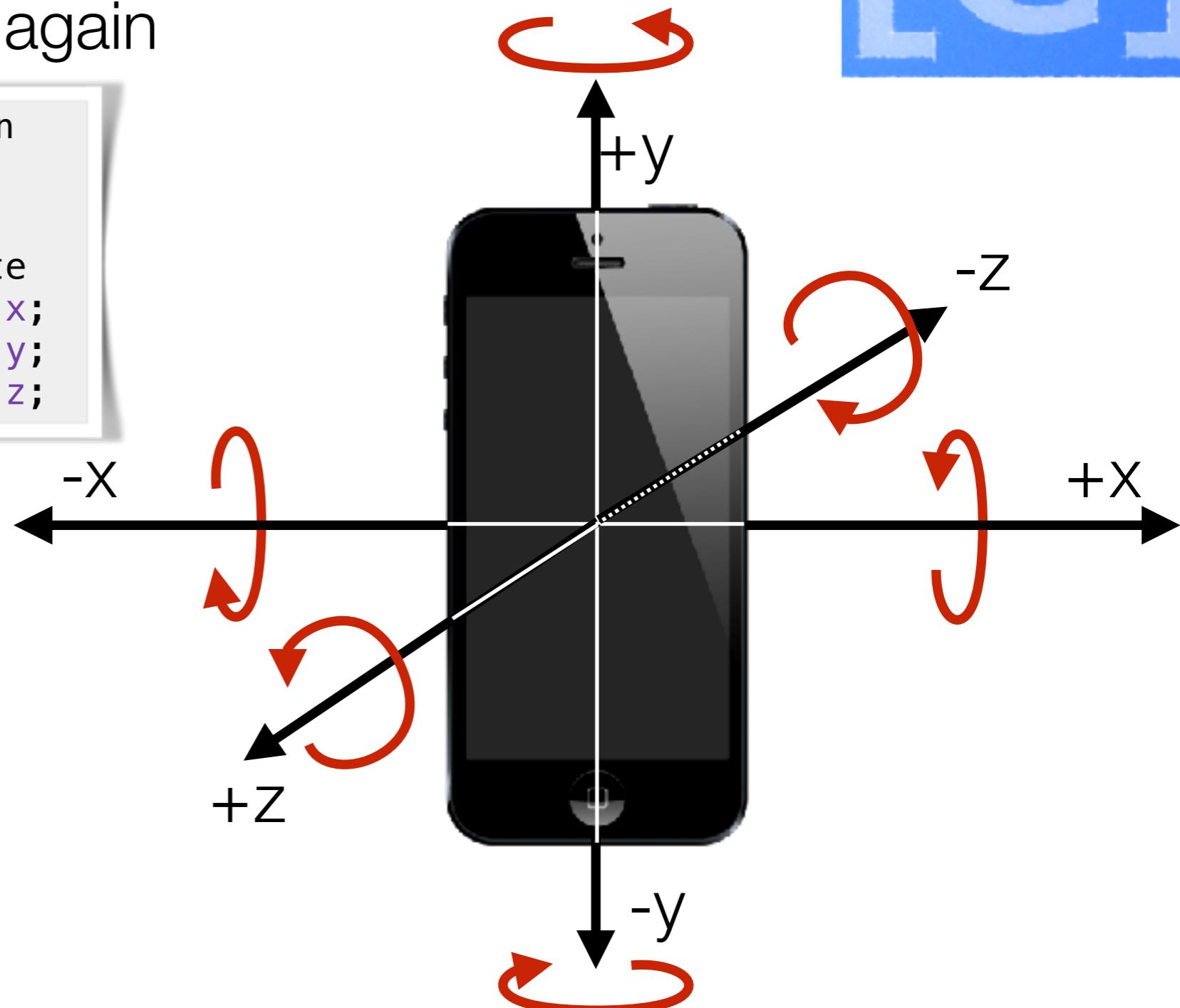
IC1

- use device motion again

```
CMDeviceMotion *deviceMotion  
deviceMotion.rotationRate  
CMRotationRate rotationRate  
rotX[head] = rotationRate.x;  
rotY[head] = rotationRate.y;  
rotZ[head] = rotationRate.z;
```

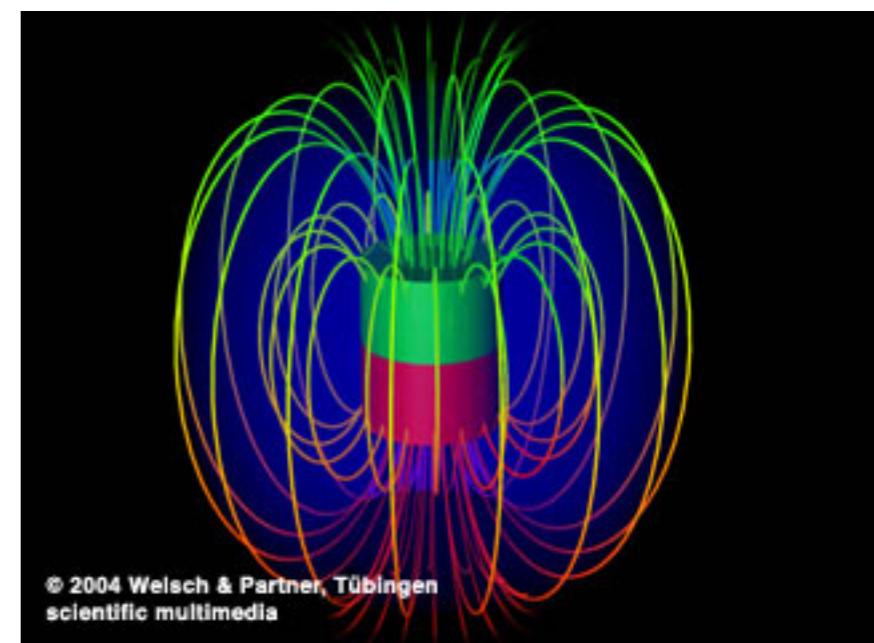
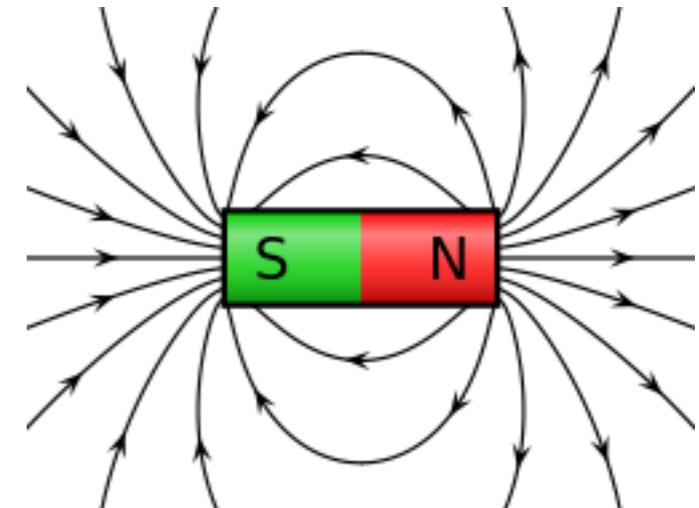
measures **rate**  
of motion

in this example,  
saves it to array



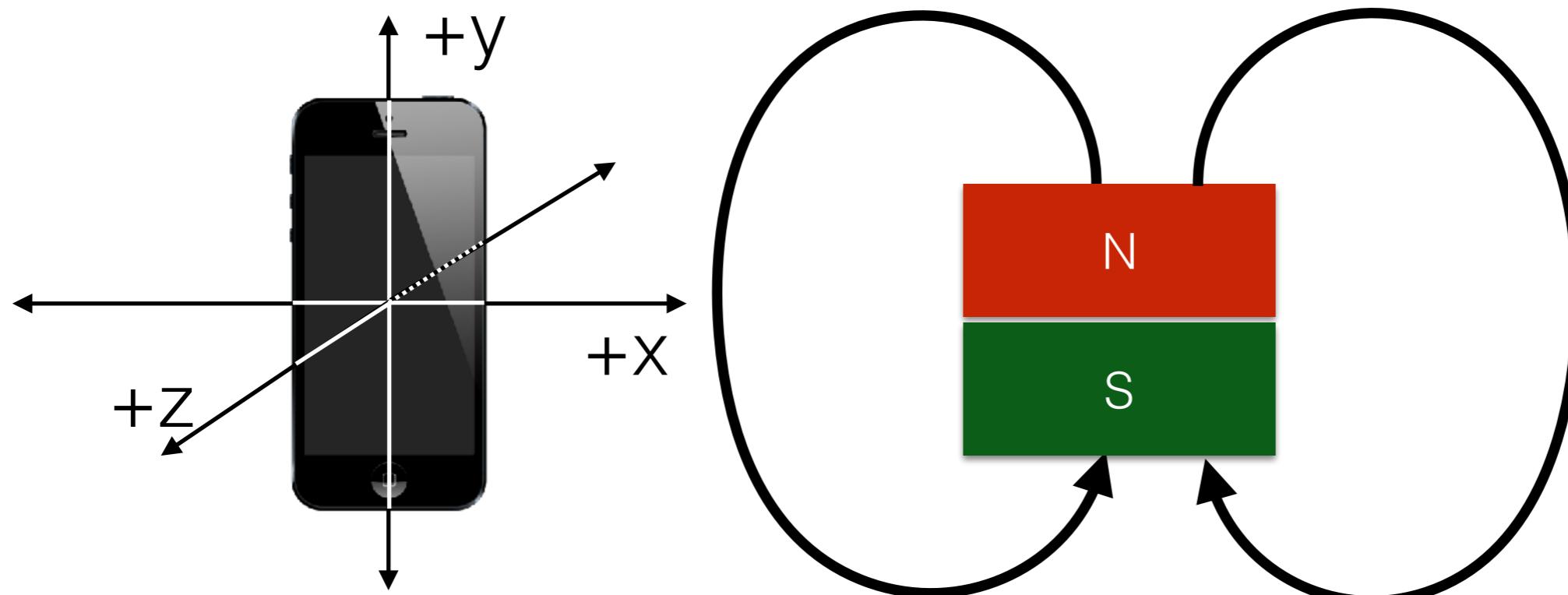
# magnetometers

- measure magnetic fields
- magnets are measured in tesla (T)
  - **how:** essentially, there is a tight coupling between electricity flow and magnetic fields
- earth's magnetic field varies, but is around 50 uT
- iPhone can measure up to 1T with a resolution of about 8uT
- magnetic fields have direction!



# magnetic fields

- measure magnetic field along axis, towards “south”



# but iPhone has magnetic bias

- the phone uses electricity and therefore is a magnet
  - good thing Apple subtracts that out for us!

```
CMDDeviceMotion *deviceMotion

deviceMotion.magneticField
CMCalibratedMagneticField magneticField;

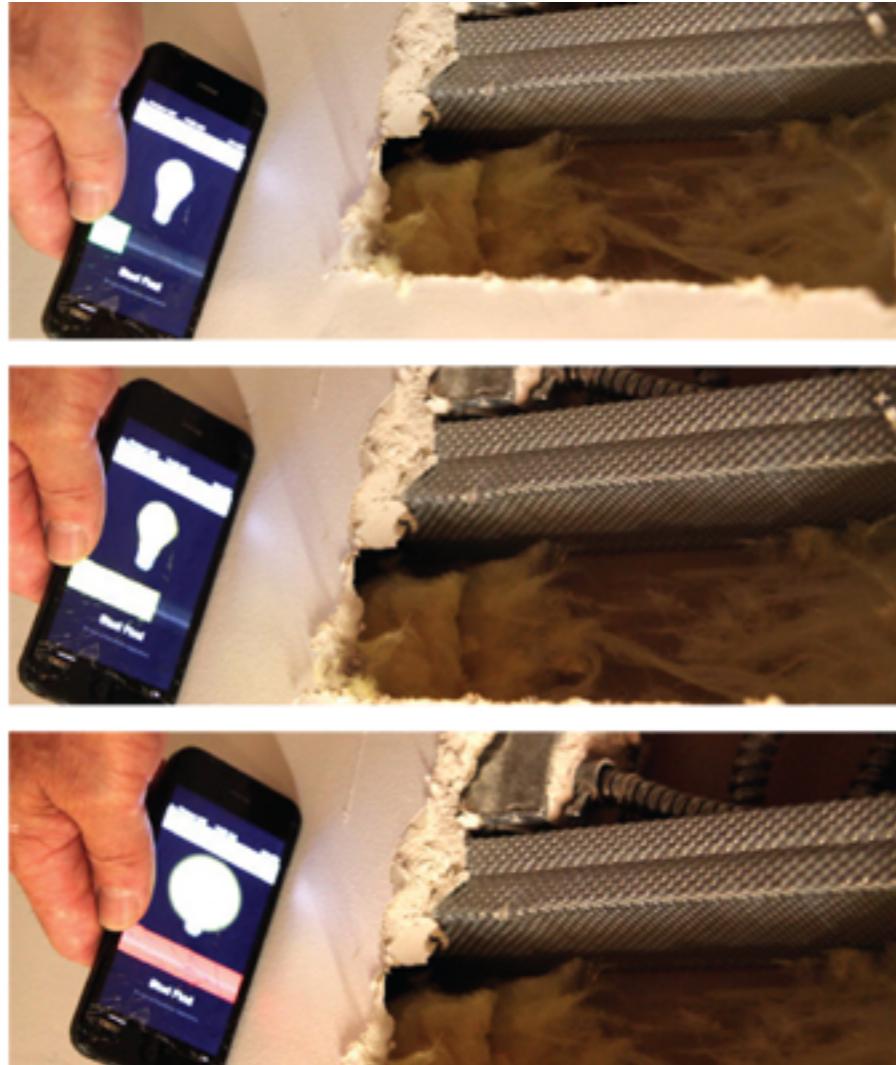
magneticField.field.x
magneticField.field.y
magneticField.field.z

magneticField.accuracy

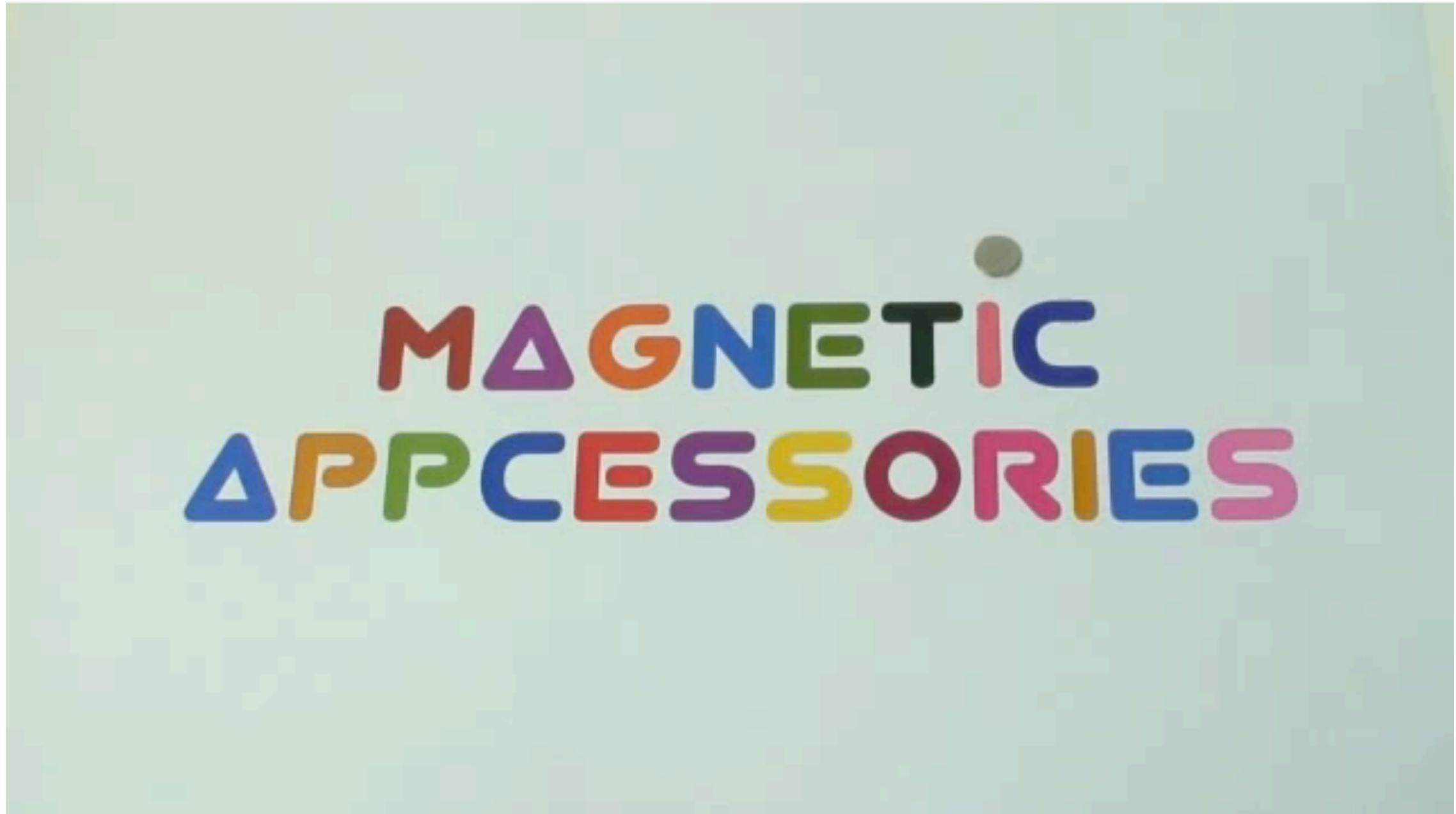
CMMagneticFieldCalibrationAccuracyUncalibrated = -1,
CMMagneticFieldCalibrationAccuracyLow,
CMMagneticFieldCalibrationAccuracyMedium,
CMMagneticFieldCalibrationAccuracyHigh
```



# a cool example

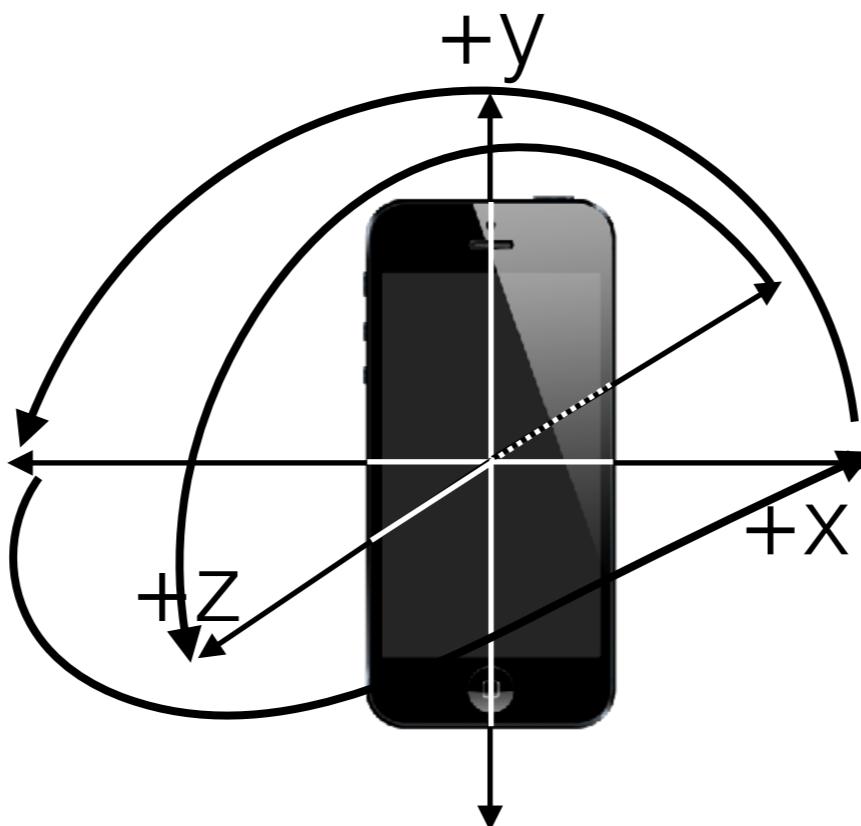


# a cool example



# attitude

- attitude is roll, pitch, and yaw (position)
- these are “fused” measures of the device from
  - the magnetometer (used as a compass)
  - gyroscope (used for detecting quick rotations)
  - accelerometer (used for smoothing out the gyro)



yaw in x/y plane  
pitch in y/z plane  
roll in x/z plane



# getting updates



```
// for getting access to the fused motion data (best practice, filtered)  
@property (nonatomic, strong) CMMotionManager *mManager;
```

declare  
instantiate

```
self.mManager = [[CMMotionManager alloc] init];
```

if device is capable

```
[self.mManager setDeviceMotionUpdateInterval:yourSamplingIntervalInSeconds];  
[self.mManager startDeviceMotionUpdatesToQueue:[NSOperationQueue mainQueue]  
withHandler:^(CMDeviceMotion *deviceMotion, NSError *error) {
```

queue to run on  
how often to push  
updates

```
//Access to all the data...  
deviceMotion.attitude,  
deviceMotion.rotationRate,  
deviceMotion.gravity,  
deviceMotion.userAcceleration,  
deviceMotion.magneticField,
```

the data

```
}];
```

# summary

```
CMDDeviceMotion *deviceMotion
```

```
deviceMotion.gravity
```

```
deviceMotion.userAcceleration
```

```
CMAcceleration gravity,
```

```
CMAcceleration userAcceleration
```

```
gravity.x;
```

```
gravity.y;
```

```
gravity.z;
```

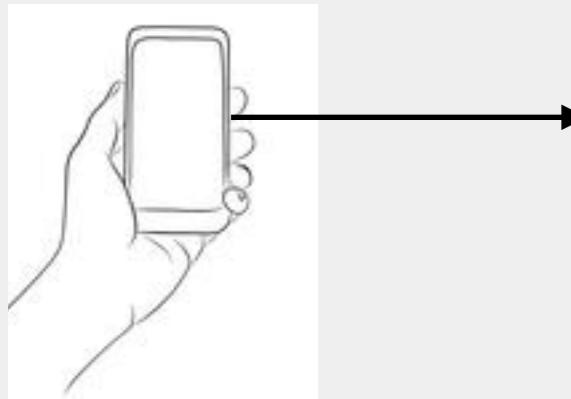


x=+9.81

```
userAcceleration.x;
```

```
userAcceleration.y;
```

```
userAcceleration.z;
```



## acceleration

## rotation velocity

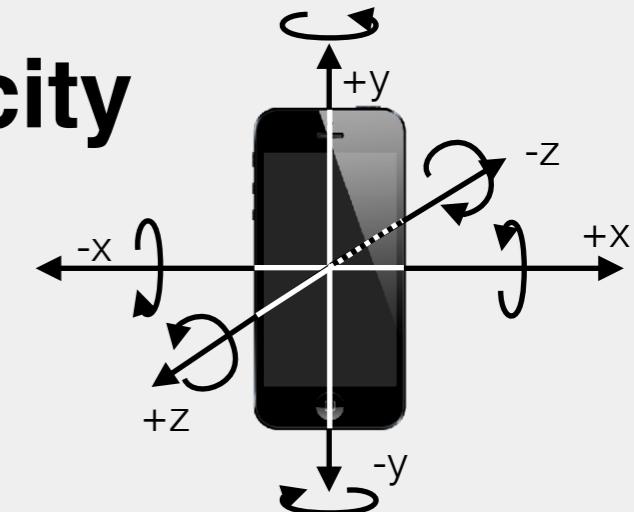
```
deviceMotion.rotationRate
```

```
CMRotationRate rotationRate
```

```
rotX[head] = rotationRate.x;
```

```
rotY[head] = rotationRate.y;
```

```
rotZ[head] = rotationRate.z;
```



```
deviceMotion.magneticField
```

```
CMCalibratedMagneticField magneticField;
```

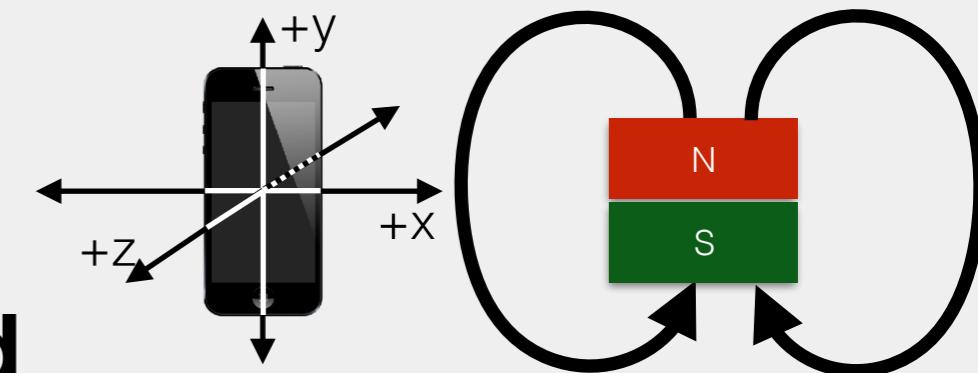
```
magneticField.field.x
```

```
magneticField.field.y
```

```
magneticField.field.z
```

```
magneticField.accuracy
```

## magnetic field



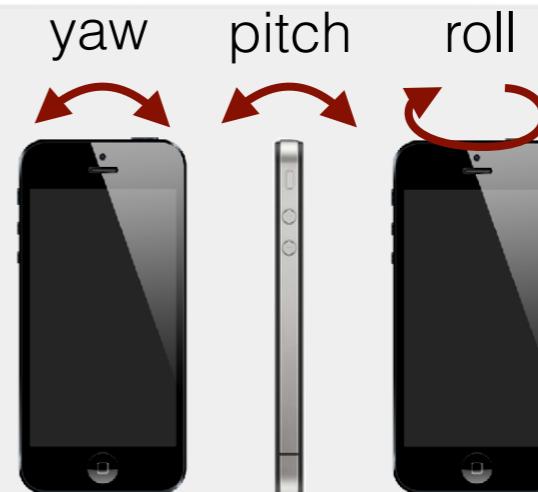
```
deviceMotion.attitude
```

```
CMAcceleration* attitude
```

```
attitude.roll;
```

```
attitude.pitch;
```

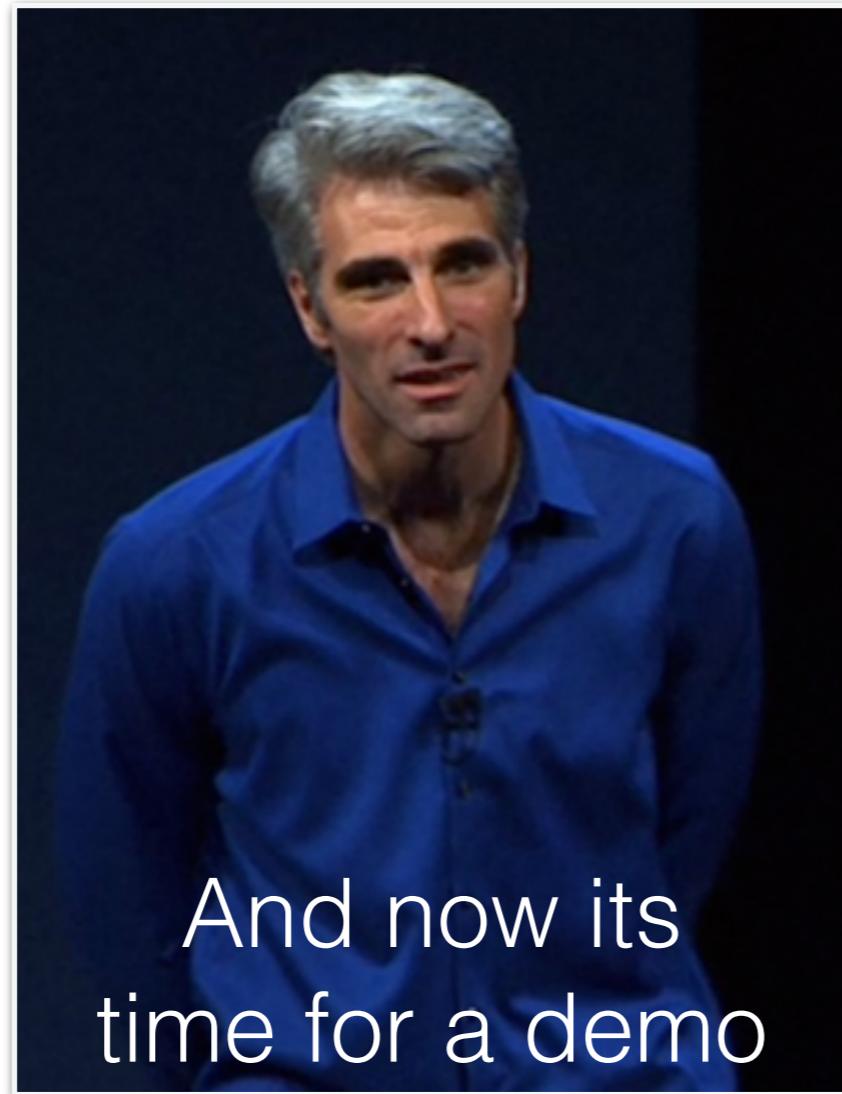
```
attitude.yaw;
```



## device position

# device motion demo

- lets build something
  - to start: take that gravity!



And now its  
time for a demo

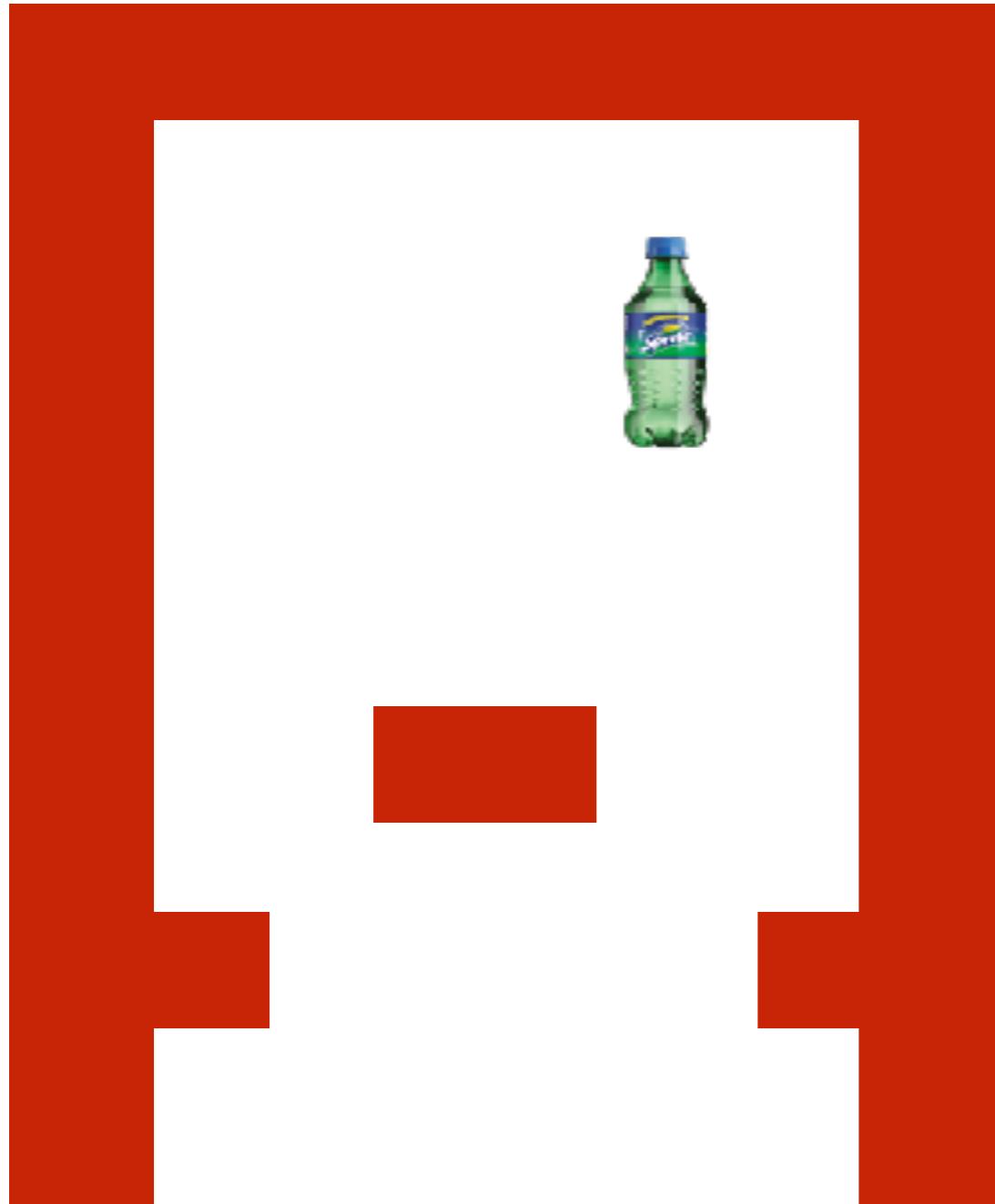
# something more?

- how about a 3D physics engine?
  - Enter SceneKit
- 2D Physics? Enter SpriteKit:
  - SK abbreviated
  - real time physics engine for game applications
  - ...and 2D games in general

# SpriteKit

- setup game scene
- create sprites
  - color/texture
  - physical properties
    - mass
    - restitution
    - friction
    - awesomeness (not really)
  - physics updated at 60 Hz

# SpriteKit



create “blocks”

create “sides/top”

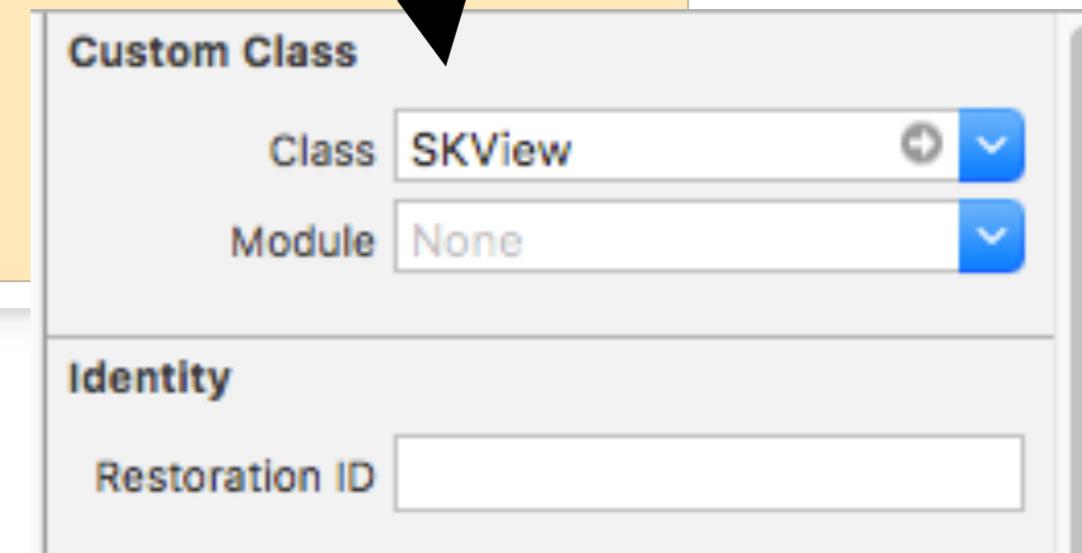
create “bouncy” sprite

make actual gravity  
== game gravity

user must move phone  
to keep sprite bouncing  
on target

# setup view controller

```
class GameViewController: UIViewController {  
  
    override func viewDidLoad() {  
        super.viewDidLoad()  
  
        //setup game scene  
        let scene = GameScene(size: view.bounds.size)  
        let skView = view as! SKView // must be an SKView  
        skView.showsFPS = true  
        skView.showsNodeCount = true  
        skView.ignoresSiblingOrder = true  
        scene.scaleMode = .ResizeFill  
        skView.presentScene(scene)  
    }  
}
```



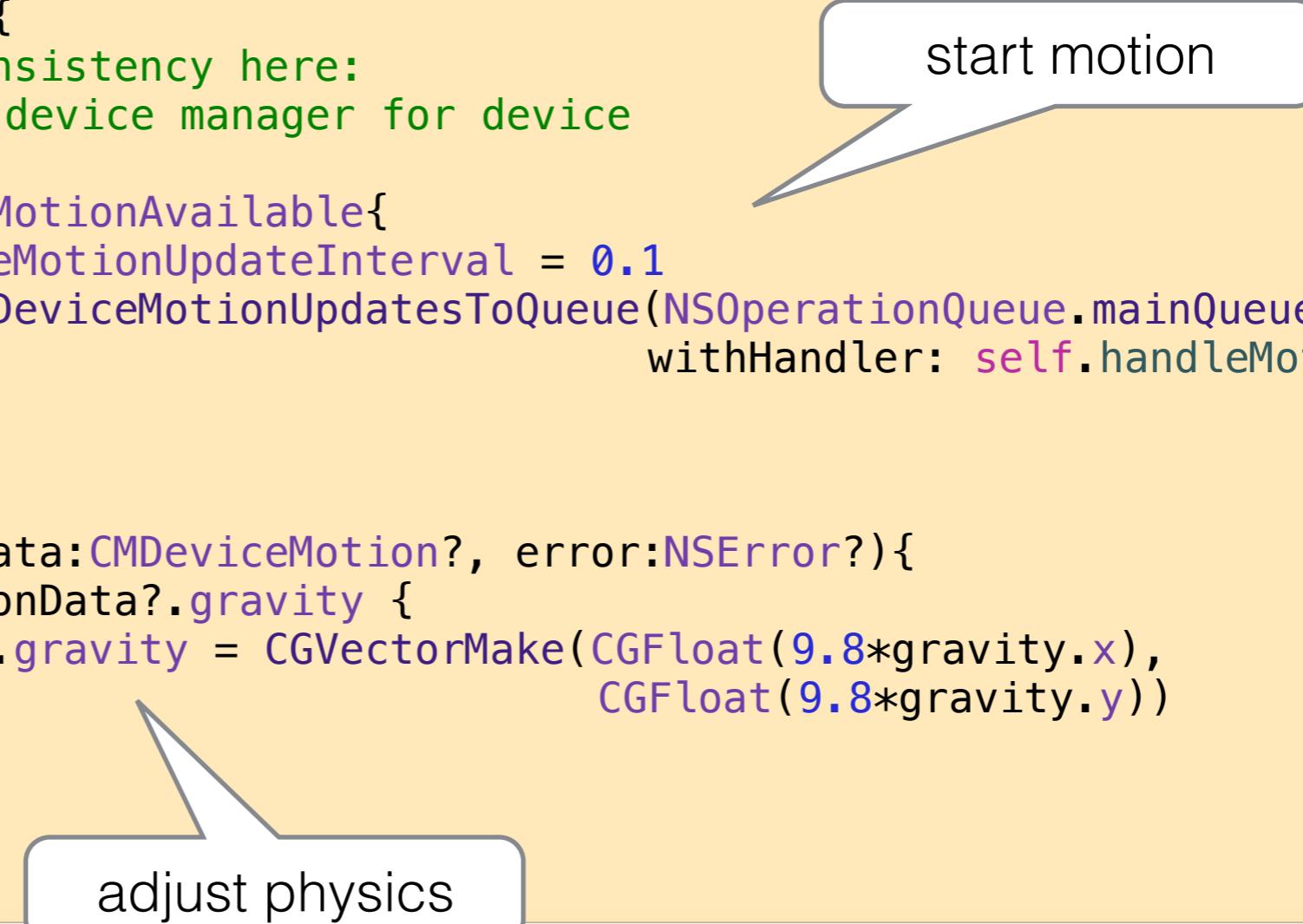
# build sprites (in GameScene)

```
override func didMoveToView(view: SKView) {  
  
    backgroundColor = SKColor.whiteColor()  
  
    // make sides to the screen  
    self.addSidesAndTop() → make border  
  
    // add some stationary blocks  
    self.addStaticBlockAtPoint(CGPoint(x: size.width * 0.1, y: size.height * 0.25))  
    self.addStaticBlockAtPoint(CGPoint(x: size.width * 0.9, y: size.height * 0.25)) → make blocks  
  
    // add a spinning block  
    self.addBlockAtPoint(CGPoint(x: size.width * 0.5, y: size.height * 0.35))  
  
    self.addSprite() → add bouncy sprite  
}  
  
func addSprite(){
```

```
    let spriteA = SKSpriteNode(imageNamed: "sprite") // this is a sprite bottle  
  
    spriteA.size = CGSize(width:size.width*0.1,height:size.height * 0.1)  
    spriteA.position = CGPoint(x: size.width * 0.1, y: size.height * 0.75) → size & position  
  
    spriteA.physicsBody = SKPhysicsBody(rectangleOfSize:spriteA.size)  
    spriteA.physicsBody?.restitution = 1.5  
    spriteA.physicsBody?.dynamic = true → interaction physics  
  
    self.addChild(spriteA) → add to scene  
}
```

# set gravity

```
let motion = CMMotionManager()  
func startMotionUpdates(){  
    // some internal inconsistency here:  
    // we need to ask the device manager for device  
  
    if self.motion.deviceMotionAvailable{  
        self.motion.deviceMotionUpdateInterval = 0.1  
        self.motion.startDeviceMotionUpdatesToQueue(NSOperationQueue.mainQueue(),  
                                         withHandler: self.handleMotion)  
    }  
}  
  
func handleMotion(motionData:CMDeviceMotion?, error:NSError?){  
    if let gravity = motionData?.gravity {  
        self.physicsWorld.gravity = CGVectorMake(CGFloat(9.8*gravity.x),  
                                                CGFloat(9.8*gravity.y))  
    }  
}
```

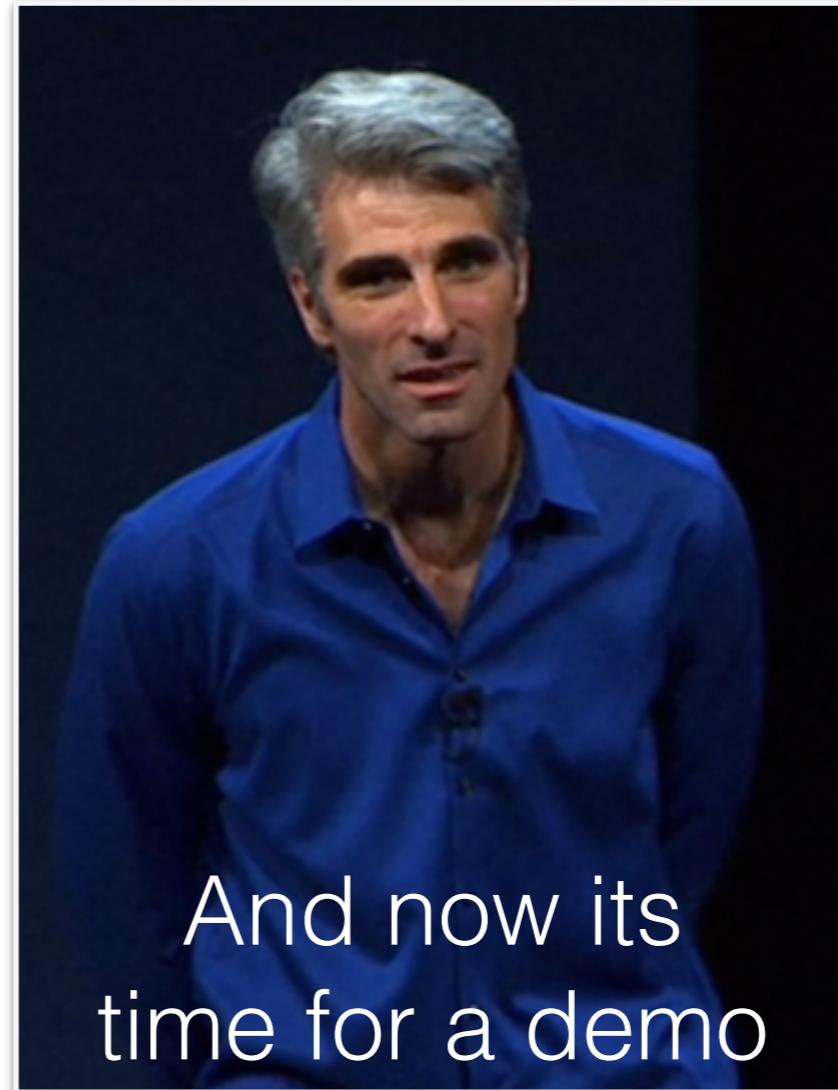


start motion

adjust physics

# device motion demo 2

- lemon lime bounce
- pre-made demo



And now its  
time for a demo

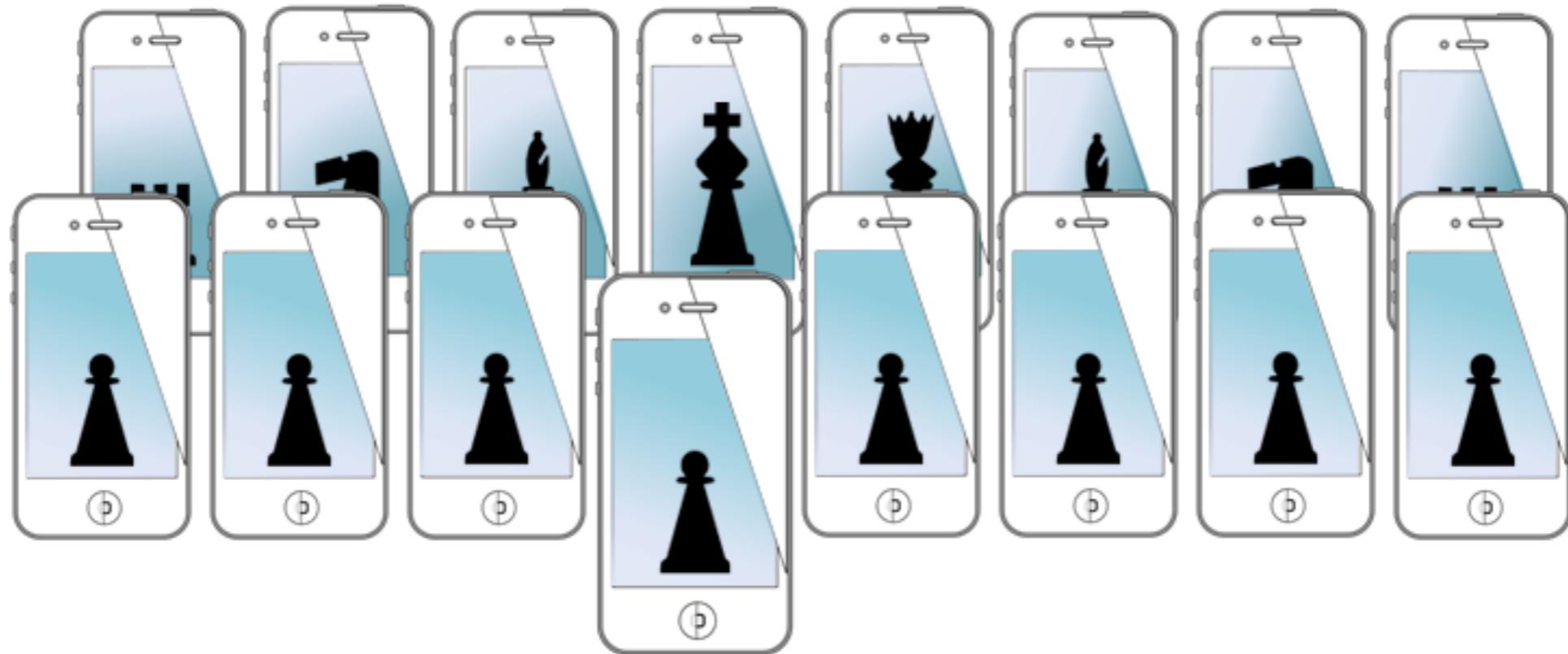
# the end of motion...

- before moving on...
- one week lab next time...
- assignment posted

# for next time...

- Image processing!

# MOBILE SENSING LEARNING

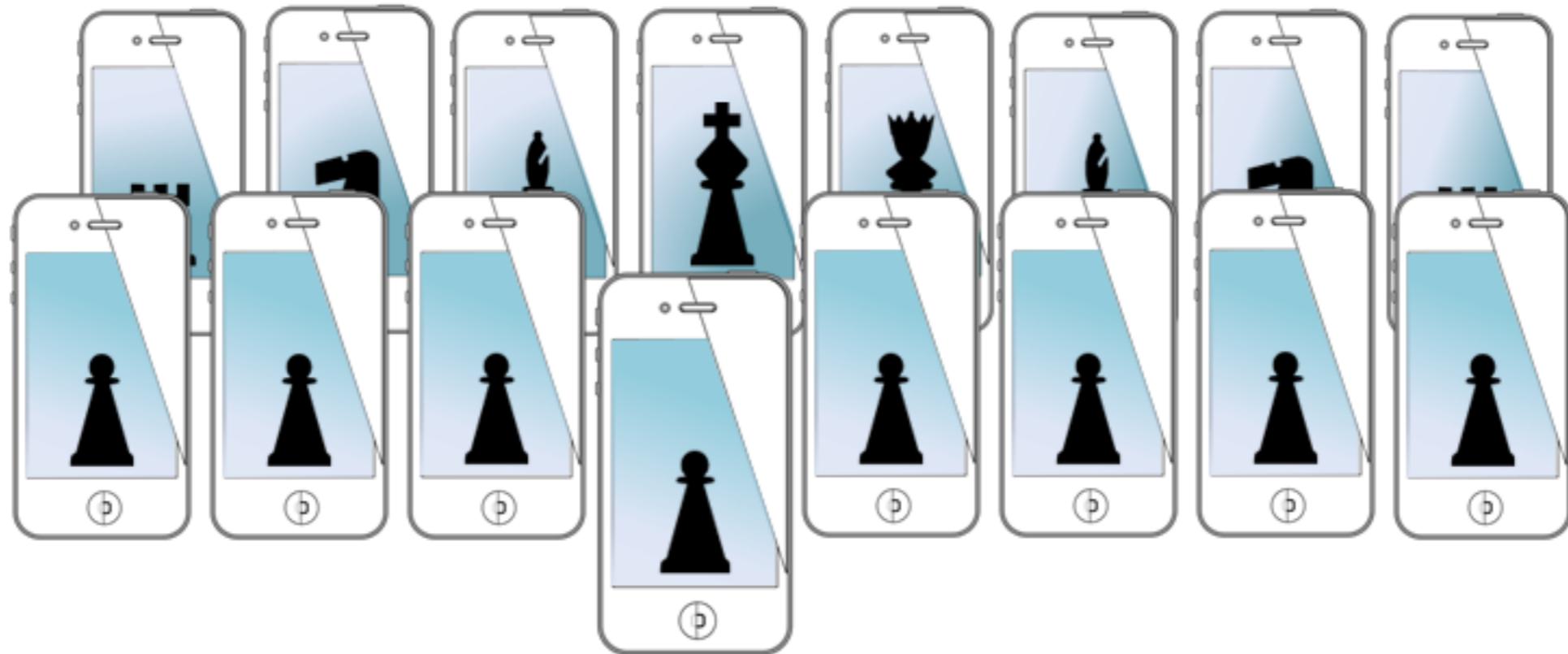


**CSE5323 & 7323**  
Mobile Sensing and Learning

week 5 lecture b: activity, pedometers, and motion sensing

Eric C. Larson, Lyle School of Engineering,  
Computer Science and Engineering, Southern Methodist University

# MOBILE SENSING LEARNING



**CSE5323 & 7323**  
Mobile Sensing and Learning

Supplemental Slides: vector trajectory and profiling

Eric C. Larson, Lyle School of Engineering,  
Computer Science and Engineering, Southern Methodist University

# supplemental slides

- vector trajectory

# phone trajectory

- what direction is the phone (user) headed?

- direction could be:

- cardinal {N, S, E, W}

GPS and magnetometer

- altitude {sea level, +30 feet, etc.}

GPS

- relative altitude {up, down}

motion sensors

- relative trajectory {left, right, straight}

motion sensors

- how should we sense each of these?

# up/down movement

- questions:
  - are we accelerating?
  - in what direction are we accelerating?
  - are we accelerating opposite of gravity?

which way is gravity?

`deviceMotion.gravity.{x,y,z}`

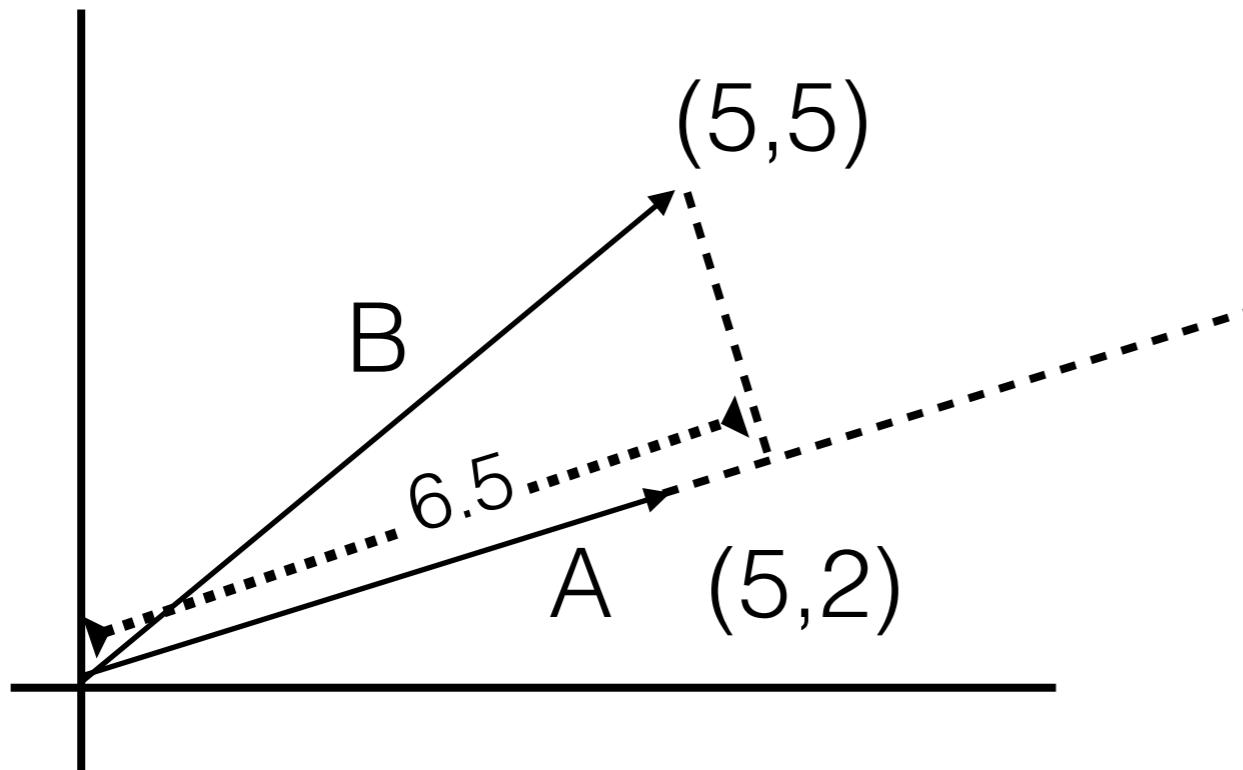
vectors

which way is the phone accelerating?

`deviceMotion.userAcceleration.{x,y,z}`

# vector direction

- how much of one vector is in the direction of another?
- projections



$$\frac{\mathbf{A} \cdot \mathbf{B}}{|\mathbf{A}|}$$

$$(5,5) \bullet (5,2)$$

$$|(5,2)|$$

$$5 \cdot 5 + 5 \cdot 2$$

$$\frac{\sqrt{(5^2+2^2)}}{= 35/\sqrt{29}} \sim 6.5$$

# vector direction

- acceleration of the user towards or away from gravity?

CMAcceleration gravity, CMAcceleration userAccel

```
float dotProduct =  
    gravity.x*userAccel.x + gravity.y*userAccel.y + gravity.z*userAccel.z;
```

```
float normDotProd =  
    dotProduct / (gravity.x*gravity.x + gravity.y*gravity.y + gravity.z*gravity.z);
```

positive acceleration is speeding up  
negative acceleration is slowing down

# vector acceleration demo

- don't drop it!

# profiling demo

- using the instruments panel in Xcode
  - memory leaks
  - general efficiency
  - excellent integration with iOS