ARKit and CoreML

Introduction to iOS Development

Background

- ARKit and CoreML released at WWDC 2017
- Both represent a shift in traditional developer model
    - Artist/Researcher creates model
    - Apple takes care of hard part of implementation
    - You just have to connect the above

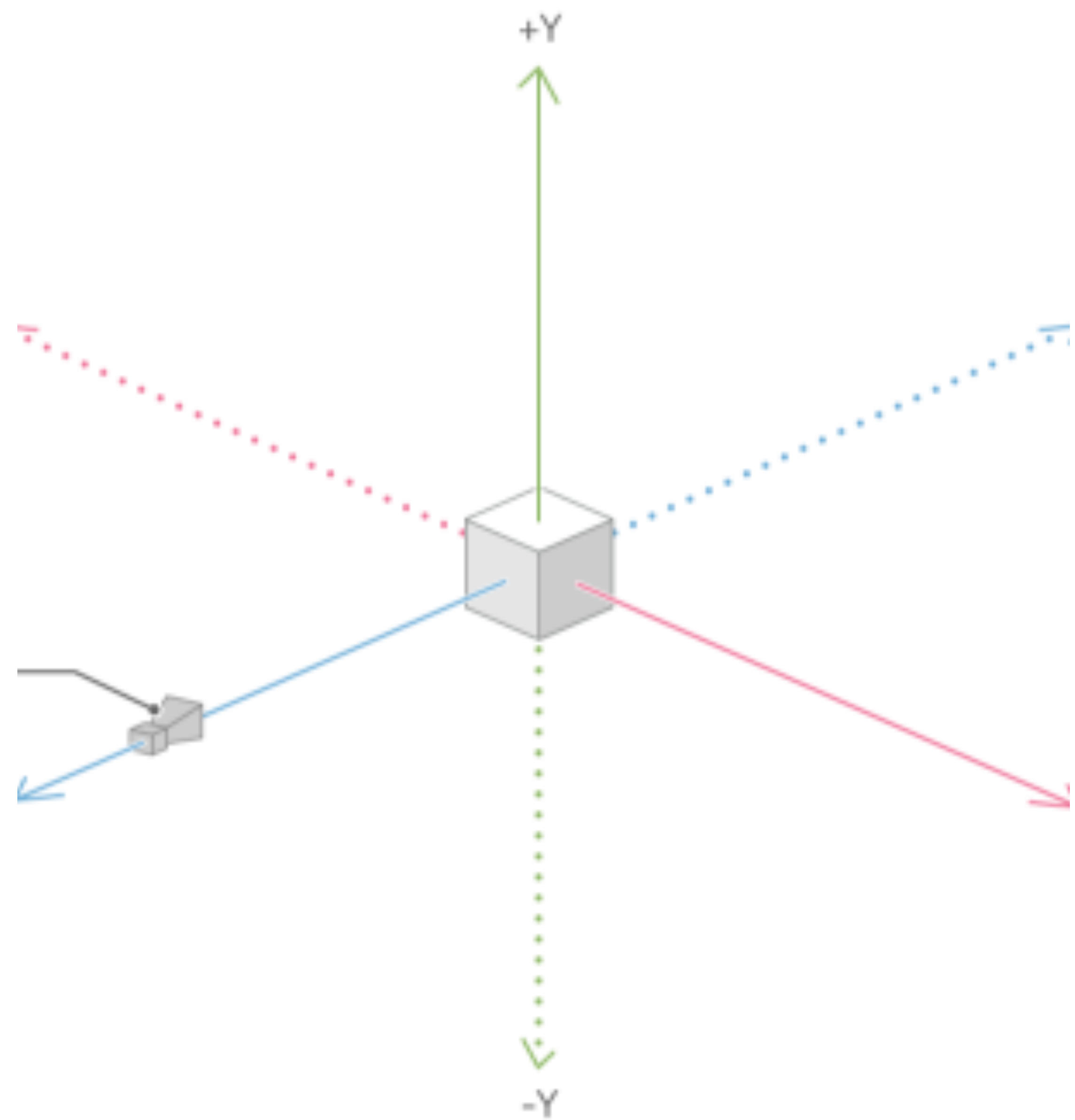
ARKit

- Hard Parts (taken care of):
  - Visual Inertial Odometry (fusion of cameras and motion sensing) to estimate how much device has moved
  - Finding planes and surfaces in surrounding area as well as estimating lighting for simulated objects
  - Detecting faces and matching with 3D characters
- Remember to import!

Demo

Coordinates

- Coordinates may not be what you'd expect (x is left-right, y is up-down, z is forward-backwards)
- Camera is at (0, 0, 0)
  - So don't place object there!
- 1 float = 1 meter
- Angles should be specified in radians



Position, Scale, Rotation

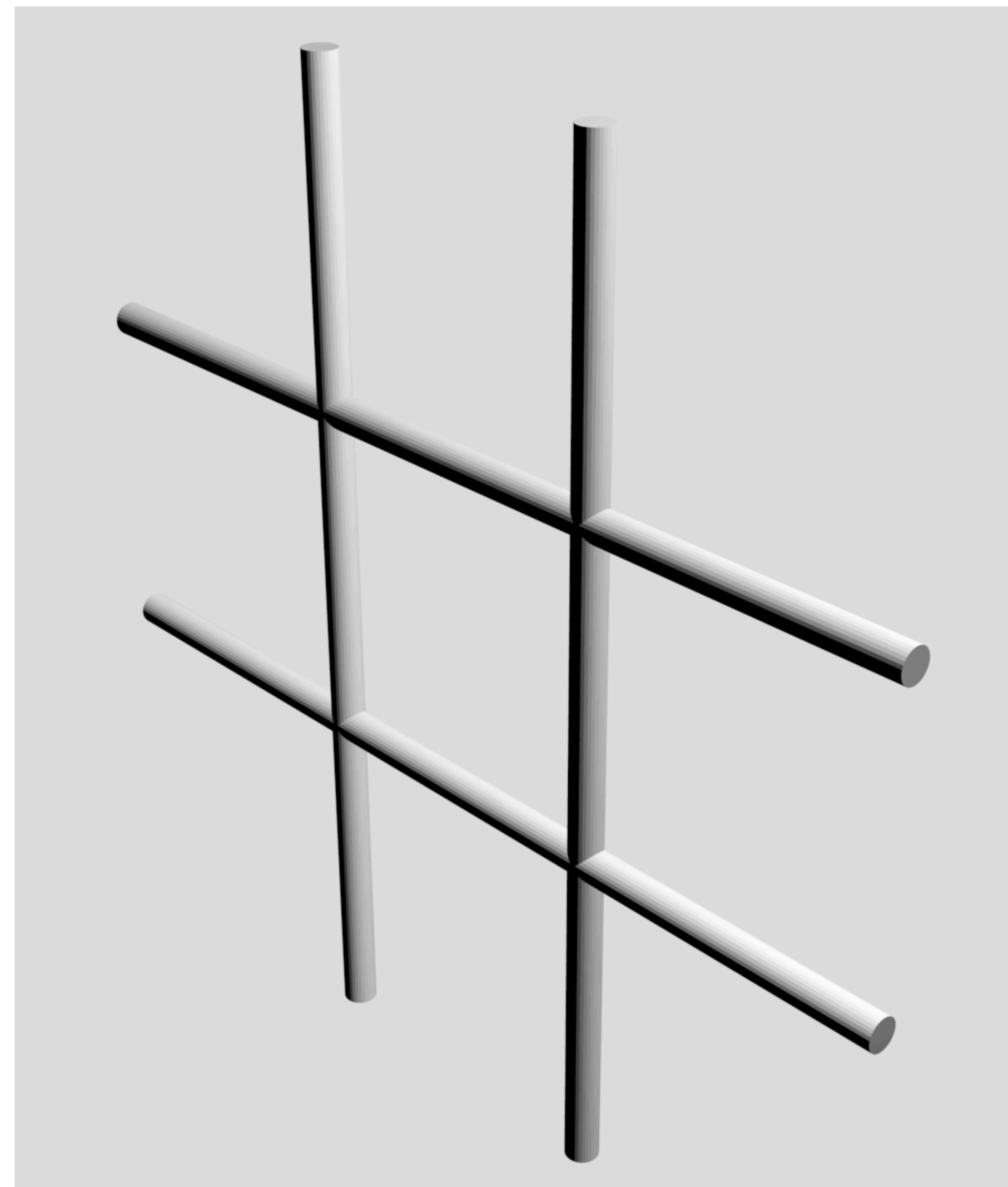
- Position: SCNVector3(x, y, z)
  - z = -0.5 means place object half a meter in front of user (remember coordinate axes)
- Scale: SCNVector3(x, y, z)
  - z = 0.5 means compress in outwards direction to half
- Rotation: SCNVector4(x, y, z, w)
  - x, y, and z correspond to whether the object should be rotated around an axis, w is the angle in radians

SceneKit

- Used to handle 3D objects and handles interfacing with ARKit
- Can use SpriteKit to handle 2D objects (see **here** for details)
- Can create simple shapes (cubes, spheres, …) as well as importing more complicated ones

Getting Objects

- Download objects made by artists
    - https://www.turbosquid.com/
    - https://sketchfab.com/
- Create your own
    - https://www.blender.org/
- **.dae** or **.scn** files



Setting the Scene

- Add a **ARSceneView** and add constraints to make it fill the whole screen (recommended by HIG)
- Ask user for permission to use camera
    - Open up Info.plist and add a “Privacy - Camera Usage Description” key
    - Set the value for what text you want to prompt the user with.

Managing a Session

- Usually use **ARWorldTrackingConfiguration** unless you need something more specific
    - Tracks planes, feature points, and 6 degrees of freedom of device

```
override func viewWillAppear(_ animated: Bool) {
    super.viewWillAppear(animated)
    let configuration = ARWorldTrackingConfiguration()
    sceneView.session.run(configuration)
}
override func viewWillDisappear(_ animated: Bool) {
    super.viewWillDisappear(animated)
    sceneView.session.pause()
}
```

Tracking

- Feature points (notable points in the environment that make it easer for us to keep a simulated object stationary) detected automatically

- To detect planes add the following:

```
let configuration = ARWorldTrackingConfiguration()
configuration.planeDetection = .horizontal
sceneView.session.run(configuration)
```

Adding Simple Objects

- Create **SCNNode**
- Create Geometry (**SCN**____) and add to node
- Set position (rotation/scale if necessary) of node
- Add created node as child node of sceneView's root node

```
func addSphere(x: Double, y: Double, z: Double) {
    let sphere = SCNSphere(radius: 0.05)
    let sphereNode = SCNNode()
    sphereNode.geometry = sphere
    sphereNode.position = SCNVector3(x, y, z)
    sceneView.scene.rootNode.addChildNode(sphereNode)

}
```

Adding Complex Objects

- Safely load scene from file
- Create new node
- Add each of the children nodes of the root node of the loaded scene as children nodes of the new node
- Set position (and scale/rotation if necessary) of new node

Adding Complex Objects

- In Code:

```
func addBoard() {
    guard let boardScene = SCNScene(named: "board.dae") else {return}
    let boardNode = SCNNode()
    for childNode in boardScene.rootNode.childNodes {
        boardNode.addChildNode(childNode)
    }
    boardNode.position = SCNVector3(0, 0, -1)
    boardNode.scale = SCNVector3(0.1, 0.1, 0.1)
    boardNode.rotation = SCNVector4(1, 0, 0, Float.pi / 2)
    sceneView.scene.rootNode.addChildNode(boardNode)
}
```

Deleting Objects

- Just remove as child node of root node of sceneView

```
for node in self.sceneView.scene.rootNode.childNodes {
    node.removeFromParentNode()
}
```

Enabling Interaction

- Add Gesture Recognizer to sceneView

```
let tapGestureRecognizer = UITapGestureRecognizer(target: self, action:
    #selector(ViewController.didTap(withGestureRecognizer:)))
sceneView.addGestureRecognizer(tapGestureRecognizer)
```

- And extension to transformation matrix class

```
extension float4x4 {
    var translation: float3 {
        let translation = self.columns.3
        return float3(translation.x, translation.y, translation.z)
    }
}
```

Enabling Interaction

- One can check if we tapped on a feature point to add a node

```
@objc func didTap(withGestureRecognizer recognizer: UIGestureRecognizer) {
    let tapLocation = recognizer.location(in: sceneView)
    let hitTestResultsWithFeaturePoints = sceneView.hitTest(tapLocation, types: .featurePoint)
    if let hitTestResultWithFeaturePoints = hitTestResultsWithFeaturePoints.first {
        let translation = hitTestResultWithFeaturePoints.worldTransform.translation
        addBox(x: translation.x, y: translation.y, z: translation.z)
    }
}
```

- Or can check if we tapped a node that already exists and remove it

```
@objc func didTap(withGestureRecognizer recognizer: UIGestureRecognizer) {
    let tapLocation = recognizer.location(in: sceneView)
    let hitTestResults = sceneView.hitTest(tapLocation)
    guard let node = hitTestResults.first?.node else { return }
    node.removeFromParentNode()
}
```

Adding in Lighting

- Default lighting is probably sufficient unless you want to have some kind of effect (for example, a spotlight on a certain character)

```
func configureLighting() {
    sceneView.autoenablesDefaultLighting = true
    sceneView.automaticallyUpdatesLighting = true
}
```

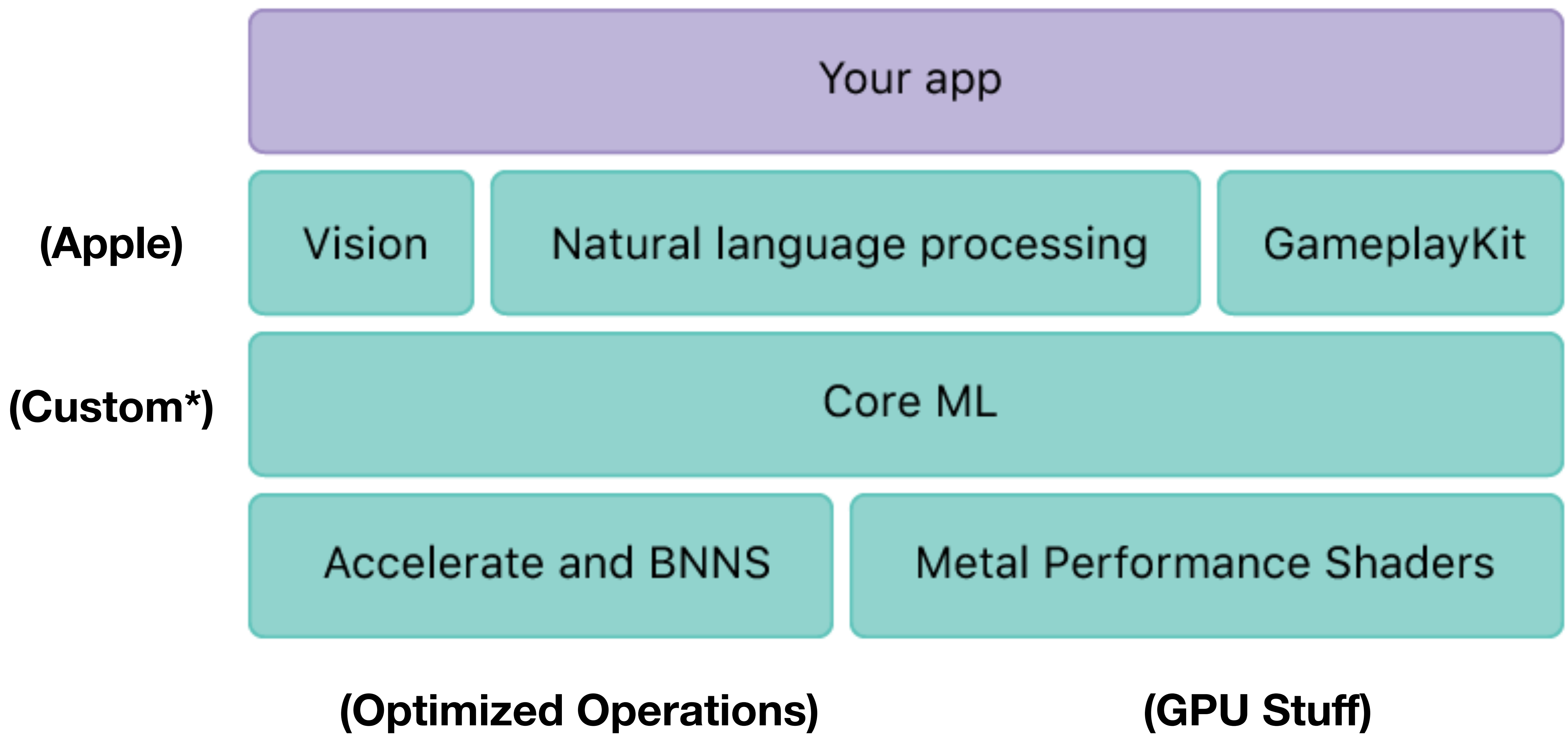
Demo

(Less Cool)

CoreML

- An even bigger buzzword
- Lets you convert ML code written in Python into a **.mlmodel** file can be dropped directly into your app
- Hard part: optimizes code for iOS devices
- Some helpful preprocessing included
- Does not currently support on-device training

Architecture



* = don’t use a custom model unless Apple doesn’t cover your use case or you’re Andrew Ng

Vision

- Allows you to do many things (detect face landmarks, OCR, scan barcodes, optical flow)
- Slower but more accurate than CoreImage and AVFoundation
- Three Steps
  - Call **VNRequestHandler**
  - Which executes a **VNRequest**
  - And returns some **VNObservation** for you to process

Vision: Code

- Be sure to add Camera Usage Description to Info.plist and import Vision

```
func detectText(image: UIImage){
    let textRequest = VNDetectTextRectanglesRequest(completionHandler: self.detectTextCompletionHandler)
    let textRequestHandler = VNImageRequestHandler(cgImage: image.cgImage!, options: [:])
    do {
        try textRequestHandler.perform([textRequest])
    } catch {
        print(error)
    }
}

func detectTextCompletionHandler(request: VNRequest, error: Error?){
    guard let results = request.results as? [VNTextObservation] else {return}
    var boxes = [VNRectangleObservation]()
    for result in results {
        if let characterBoxes = result.characterBoxes {
            for box in characterBoxes {
                boxes.append(box)
            }
        }
    }
    // do something here with boxes
}
```

Demo

NSLinguisticTagger

- Hello NS my old friend
- On device processing so no privacy worries
- Can identify language, tokenize (split up into chunks), lemmatize (give root form of word), and detect named entities (nonstandard words that may be important)
- Two Steps
  - Create **NSLinguisticTagger** with tagSchemes set to application
  - Set **tagger.string** to the text to be analyzed.

NSLinguisticTagger: Code

- For example, to detect dominant language:

```
let tagger = NSLinguisticTagger(tagSchemes: [.language], options: 0)
tagger.string = "NSLinguisticTagger provides text processing APIs."
let language = tagger.dominantLanguage
```

- For all use case sample code, check out **this link**

Custom Models

- A couple popular models already converted by Apple **here**
- In general, find code on Github or on **arXiv**
- Use python 2.7 package coremltools to convert code to .mlmodel format
- Then, instantiate instance of generated class and use **model.prediction()** method

coremltools Sources

Table 1 Models and third-party tools supported by Core ML Tools

Model type	Supported models	Supported tools
Neural networks	Feedforward, convolutional, recurrent	Caffe v1 Keras 1.2.2+
Tree ensembles	Random forests, boosted trees, decision trees	scikit-learn 0.18 XGBoost 0.6
Support vector machines	Scalar regression, multiclass classification	scikit-learn 0.18 LIBSVM 3.22
Generalized linear models	Linear regression, logistic regression	scikit-learn 0.18
Feature engineering	Sparse vectorization, dense vectorization, categorical processing	scikit-learn 0.18
Pipeline models	Sequentially chained models	scikit-learn 0.18

Python Package Setup

- Need to be in python 2.7
- pip install virtualenv
- virtualenv --python=/usr/bin/python2.7 py2.7
- source py2.7/bin/activate
- pip install numpy
- pip install scipy
- pip install sklearn
- pip install coremltools

Spam Detection

- SMS Spam Detection is a mostly solved problem that can effectively treated without using neural networks
- We’re going to train a classifier to detect spam based on a provided dataset
- We’ll be using the Naive Bayes, Support Vector Machine, and Random Forest classifiers

Loading the Data

- We'll be using data from **here**
  - In machine learning, getting good and clean data is often the hardest part
- First, we load and split our data

```
raw_data = open('./smsspamcollection/SMSSpamCollection.txt', 'r')
sms_data = []
for line in raw_data:
    split_line = line.split("\t")
    sms_data.append(split_line)

sms_data = np.array(sms_data)
X = [x.lower() for x in sms_data[:, 1]]
y = sms_data[:, 0]
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=13)
```

- We train on the train data and check accuracy on test data

Testing our Models

- Use library you've selected and create models to solve your problem (each of the models hear include a preprocessing vectorizer and then a classifier)

- Train the models on the test, predict on the test set and compare to the true output for the test set to get accuracy

```
pipeline_1 = Pipeline([('vect', CountVectorizer()),('clf', MultinomialNB())])
pipeline_2 = Pipeline([('vect', CountVectorizer()),('clf', LinearSVC())])
pipeline_3 = Pipeline([('vect', CountVectorizer()),('clf', RandomForestClassifier())])
pipelines = [pipeline_1, pipeline_2, pipeline_3]

for pipeline in pipelines:
    pipeline.fit(X_train, y_train)
    y_pred = pipeline.predict(X_test)
    print(classification_report(y_test, y_pred, target_names=["ham", "spam"]))
```

Converting a Model

- Train an instance of the best model on all the data (not just the training set)
- Use appropriate coremltools converter for your chosen framework (see **here** for full documentation)
- Save the model as a .mlmodel file

```
import coremltools

vectorizer = CountVectorizer()
vectorized = vectorizer.fit_transform(X)
model = LinearSVC()
model.fit(vectorized, y)

coreml_model = coremltools.converters.sklearn.convert(model, "message", "label")
coreml_model.save('SpamDetector.mlmodel')
```

Using an .mlmodel in Your App

- Drag and drop the file into your project
- Import CoreML
- Format your data as an **MLMultiArray** and pass it into the model.prediction() method
- Pick outputs from prediction (for example: most likely class, class probabilities)

Spam Detection: Code

```swift
func isSpam(message: String) -> Bool {
    let wordsFile = Bundle.main.path(forResource: "words_ordered", ofType: "txt")
    let message = "You have won the GRAND PRIZE reply to claim your FREE MONEY"
    do {
        let wordsFileText = try String(contentsOfFile: wordsFile!, encoding: String.Encoding.utf8)
        var wordsData = wordsFileText.components(separatedBy: .newlines)
        wordsData.removeLast() // Trailing newline.
        var wordsDict: [String: Int] = [:]
        for (idx, word) in wordsData.enumerated() {
            wordsDict[word] = idx
        }

        let posVect = vectorize(message: message, mapping: wordsDict)
        if let vect = posVect {
            let model = SpamDetector()
            let prediction = try model.prediction(message: vect)
            if prediction.label == "ham" {
                return false
            } else {
                return true
            }
        }

    }
    catch {
        print("ERROR")
    }
    return true
}
```

Vectorization: Code

```
func vectorize(message: String, mapping: [String: Int]) -> MLMultiArray? {
    var message = message
    message = message.lowercased()
    var vector = [Double](repeating: 0.0, count: mapping.count)
    for word in message.split(separator: " "){
        if let index = mapping[String(word)] {
            vector[index] += 1.0
        }
    }
    do {
        let formatted = try MLMultiArray(shape: [NSNumber(integerLiteral: vector.count)], dataType: .double)
        for (idx, elem) in vector.enumerated() {
            formatted[idx] = NSNumber(value: elem)
        }
        return formatted
    } catch {
        return nil
    }
}
```

Demo

Spam Detection: Closing Points

- Check out my **blog** if you're curious for how to integrate the code so far into an iMessage App
- Nowadays, this kind of problem is solved using neural networks (see **here** if curious)
- Convolutional Neural Networks work very well with text classification (see **here** and **here** if curious)
- We'd use k-fold cross validation to tune hyper-parameters as well as tf-idf vectorization if we were to do this irl
- Additionally, we'd use a much larger and more diverse dataset

Machine Learning

- If you’d like to learn more, check out the following resources
  - **ML@B Blog** by Geng and Shih
  - **STATS 385** Cheat Sheet
  - **CS 189** by Sahai
  - **CS 231n** by Karpathy
  - **Deep Learning** by Goodfellow and Bengio

Conclusion

- iOS devices are capable of some pretty awesome stuff
- Team up with people who are amazing at what they do (researchers, artists, …) to build more complex apps
- You’ve learned how to build awesome things that people all around the world can use
    - So start making and never stop!