CS131 - Week 9

UCLA Spring 2019
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Announcements

- Project deadline extended - DL next Monday (06/03)
- HW6 deadline extended - DL next Friday (06/07)
- No late submissions after Friday 06/07 for either project/HW6

Today

- Homework 6
- Machine Learning & TensorFlow
- Kotlin

Homework 6

Homework 6

- Due **Friday 6/7**
  - Late submissions close Friday 11:55pm
- A small coding warm-up + a report

Homework 6

- Assume you've built a Python server herd like in your project
- This time, the servers do some machine learning task with TensorFlow
- With a large number of queries, the performance is too slow
  - I.e. Your Python code is the bottleneck
  - Can we improve this by using some other language?
- Compare three alternatives: **Java**, **Ocaml**, **Kotlin**
  - Compare these to each others and Python
- No need to actually implement anything
  - You can include code if you want to, but it is not expected

Report

- 3-page executive summary
  - Write so that it can be understood by someone who doesn't know the specific languages
- What are the challenges when rewriting the server herd on the other languages? Are they any better than Python?
  - If there's e.g. a performance difference, discuss why that is
- Focus on "ease of use, flexibility, generality, performance, reliability"
- Citations!
  - E.g. if you found a nice comparison on performance differences between languages, add a citation to support your claims

Kotlin Warm-up Problem

- Write a function *everyNth(L, N)*
  - Returns a new list that contains every Nth element of list L
  - E.g. List=[1,2,3,4,5,6], N=2 => [2,4,6]
- Write a Makefile
  - Compiles and tests your code with "*make check*"
  - Should work on SEASnet servers

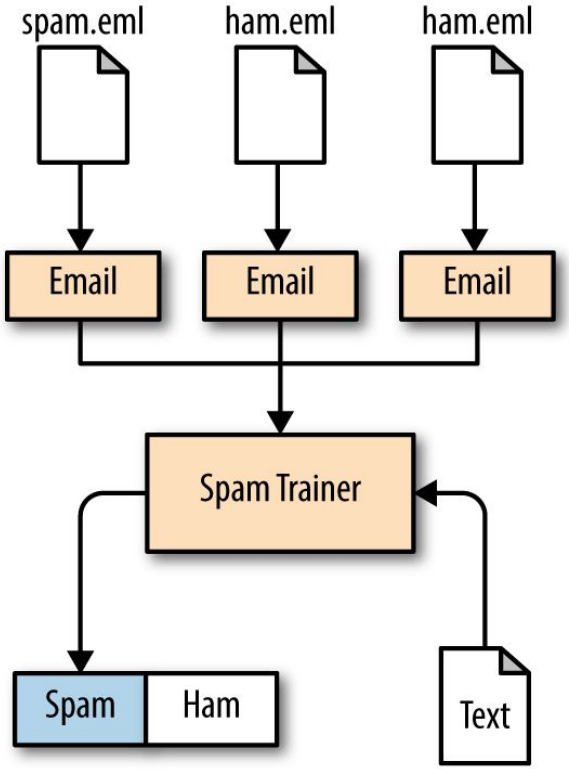
Machine Learning
&
TensorFlow

Machine learning

- Use of algorithms and mathematical models to solve a problem
  - Goal is for the system to improve its performance as it “learns”
  - Compare with your typical programs, where you explicitly define what should happen in each situation
- Three main categories:
  - Supervised learning
  - Unsupervised learning
  - Reinforcement learning

Machine Learning - Supervised Learning

- System tries to learn from examples given to it
- For example, a spam classifier can learn which words are more likely to occur in spam messages than in non-spam messages

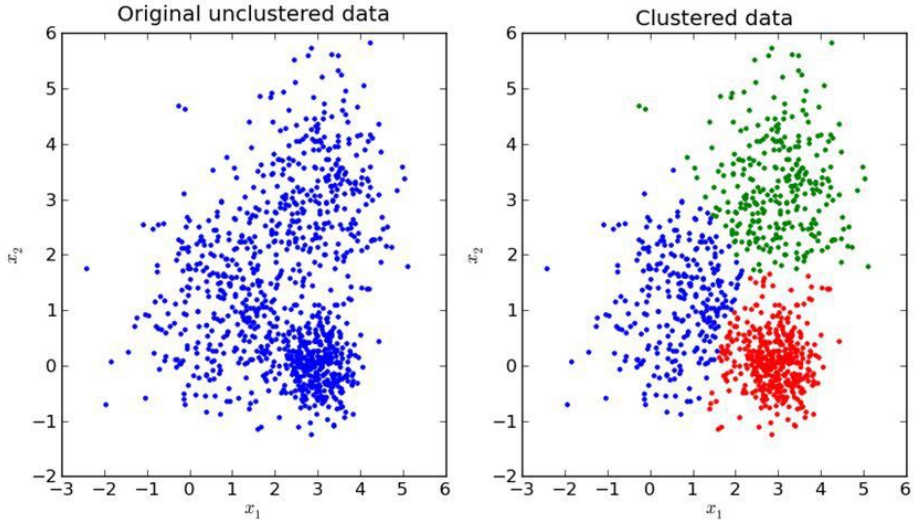


Machine Learning - Supervised Learning

Machine Learning - Supervised Learning

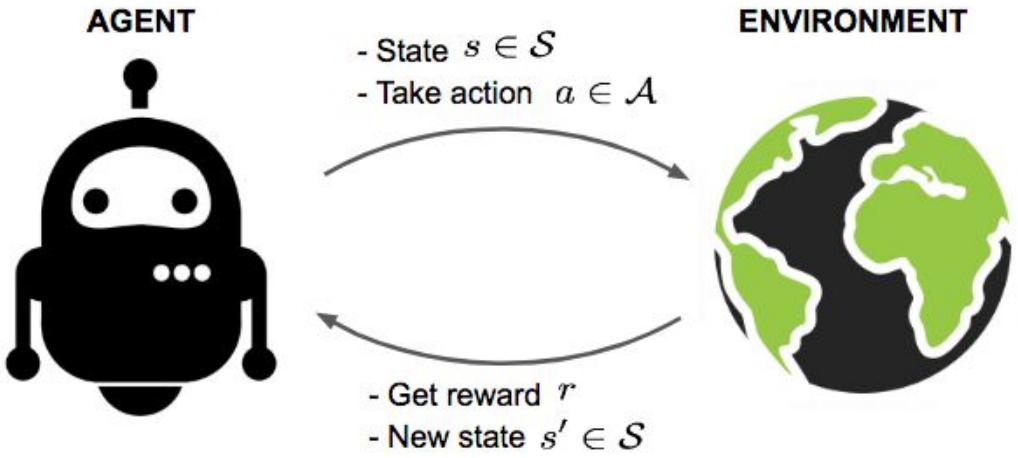
Machine Learning - Unsupervised Learning

- System tries to find structure from data
- For example, which users are likely to enjoy a specific movie on Netflix?
    - Find groups of users and see which groups have lots of people enjoying that movie
- Is a credit card transaction typical for that user, or possibly a fraud? Detect outliers



Machine Learning - Reinforcement Learning

- Try to perform different actions and see what the outcome is
  - Learn from the successes/mistakes
  - For example, a program that can play computer games without having rules explicitly coded into it



Machine Learning - Phases

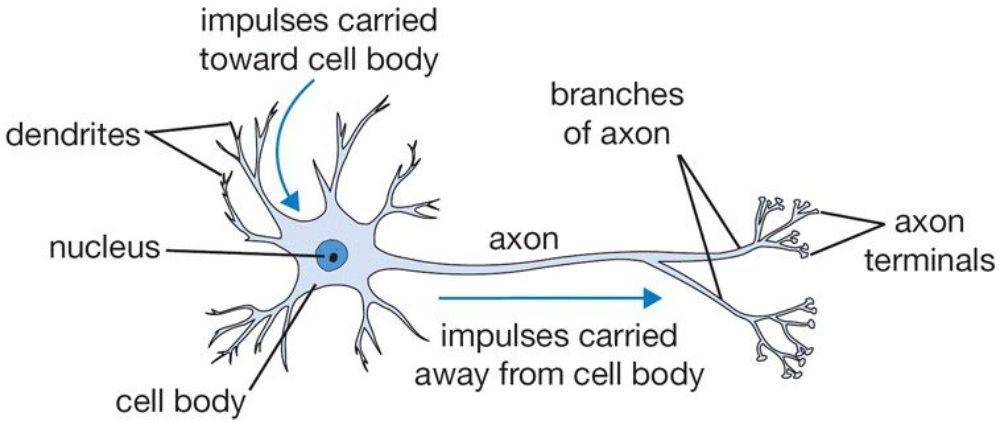
- Training phase
  - Preprocess data, extract features
  - Give features and labels to some learning algorithm
  - Algorithm produces a model (typically very slow)
- Testing / Prediction phase
  - Preprocess data, extract features (exactly the same way as in the training phase)
  - Give features to the model
  - Model gives predictions (typically quite fast)

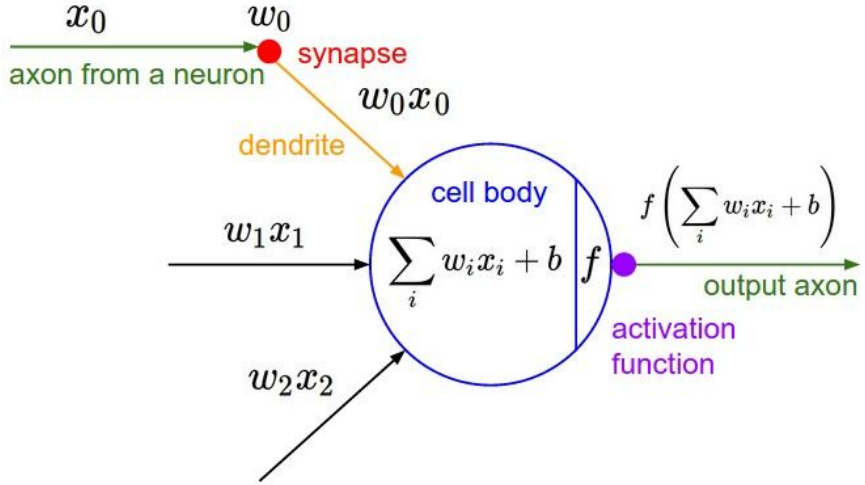
TensorFlow

- Library for symbolic mathematics and neural networks
- Initially meant for Google’s internal use, released for the public 2015
- Easy to define neural networks, TensorFlow takes care of running it efficiently on multiple CPUs or GPUs

Neural networks

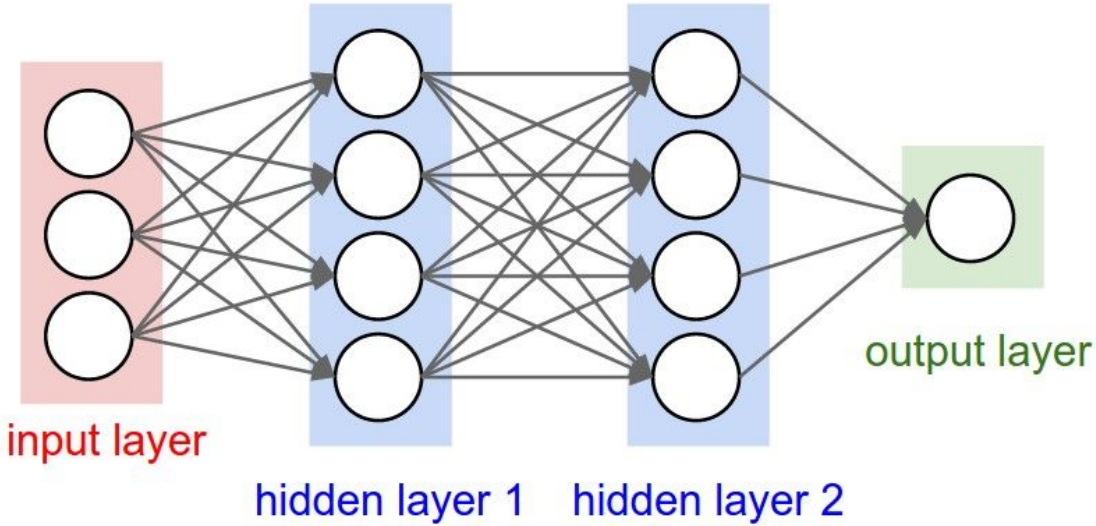
- Powerful machine learning approach, has been shown to have great performance on tasks such as image recognition or signal processing
- Challenges: computationally heavy, difficult to reason about





Neural networks

- Neural networks consist of a large number of neurons, each performing a simple mathematical operation on its input values



TensorFlow Example

- Example

TensorFlow - Minimal Example

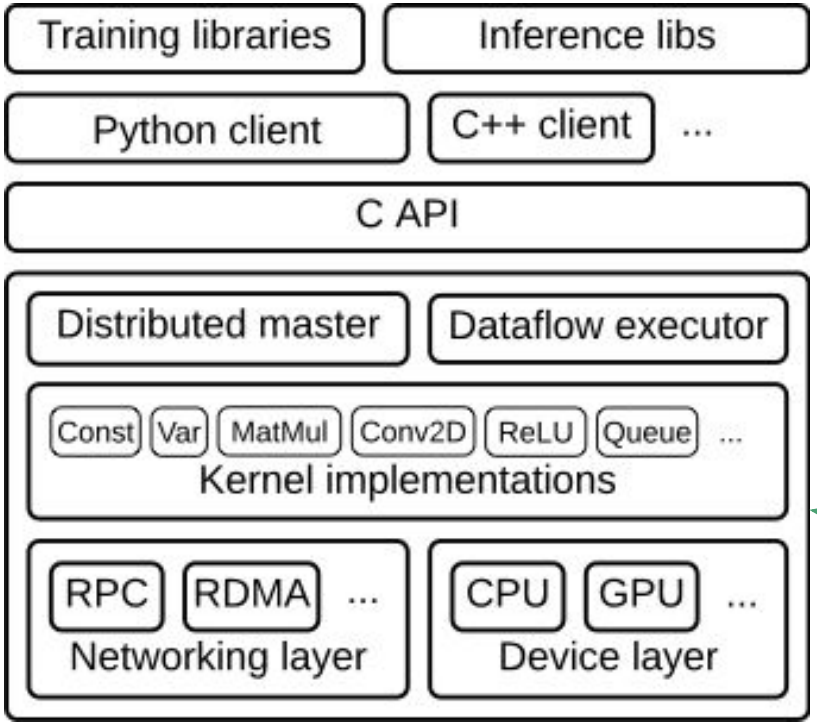
```
# Define network structure
model = Sequential()
model.add(Dense(4, input_dim=8, activation='relu'))
model.add(Dense(2, activation='relu'))
model.add(Dense(1, activation='sigmoid'))

# Define parameters that are needed to learn the model
model.compile(loss='binary_crossentropy', optimizer='adam', metrics=['accuracy'])

# Learn the parameters
model.fit(X, Y, epochs=150, batch_size=10)

# Make predictions
predictions = model.predict(X)
```

TensorFlow Architecture (see documentation)



Defines the computational graph

Provides access to the TensorFlow core

TensorFlow core
(Implemented in C++)

TensorFlow Bindings

- Bindings allow you to call another language's code
  - Usually high-level languages (Python, Java, ...) call low-level libraries (C, C++, ...)
    - Plenty of libraries available
    - Better performance
  - Challenges
    - Different languages have different data types -> Might need to convert
    - Memory management
- For details on how bindings work, see e.g. Python CFFI documentation
- TensorFlow's focus has been on Python, but there are bindings for other languages as well
  - JavaScript, C++, Java, Go, Swift, C#, Haskell, Julia, Ruby, Rust, OCaml, Scala, ...
  - Not all features are available for all languages...
  - Some of these provided by TensorFlow team, some not

TensorFlow & Python

- TensorFlow handles all the heavy mathematical operations etc
  - Can use multiple CPUs/GPUs to make it very fast
- Python needs to preprocess the data to a format that TensorFlow can handle
- Python is used to define the computational graphs etc
- In your homework, assume that TensorFlow is not the bottleneck

Kotlin

History of Kotlin

- Released 2011 by JetBrains (developer of IntelliJ IDEA)
- Designed to be “better than Java” while still interoperable with existing Java code
  - Easy migration from old Java code
- Originally designed for Java Virtual Machine (JVM)
  - Like Java, Scala, Clojure, Groovy, ...
  - Language designers get all the benefits of JVM without having to put any effort into it!
    - Garbage collection
    - JIT compilation
    - ...

Design principles

- Conciseness
  - Taking inspiration from functional programming
- Safety
  - Collections are immutable by default (e.g. *List* vs *MutableList*)
  - Immutable data types preferred in general (*val* vs *var*)
  - Variable can contain null only if it is defined to be nullable (more on this later)
  - Static typing -> Many errors caught at compile-time
- Interoperability
  - Using existing libraries (e.g. Java libraries)

Who uses Kotlin?

Pinterest

Pinterest has successfully introduced Kotlin into their application, used by 150M people every month.

Gradle

Gradle is introducing Kotlin as a language for writing build scripts.

Evernote

Evernote recently integrated Kotlin into their Android client

Uber

Uber team uses Kotlin for building internal tools

Corda

is an open-source distributed ledger platform, supported by major banks, and built entirely in Kotlin.

Coursera

Coursera Android app is partially written in Kotlin

Pivotal

Spring makes use of Kotlin's language features to offer more concise APIs

Atlassian

All new code in the Trello Android app is in Kotlin.

Kotlin Uses

- Android
- Server-side
- Native
- JavaScript

Uses - Android Development

- Android used old version of Java for a long time -> Kotlin provided a nicer alternative for developers
  - Compiles like Java code, so could be used on Android even without Google’s support
- Google made it one of the official Android languages in 2017
  - Android Studio has a full support for it, in addition to Java and C++

Uses - Server-side Development

- Can be deployed anywhere where running Java is possible
  - AWS, Google Cloud Platform, Heroku, ...
- Can use existing Java libraries
- Many server-side libraries support Kotlin specifically
  - Easier development

Uses - Native Development (Kotlin/Native)

- Sometimes running JVM is not possible -> compile native code instead
- Kotlin/Native can be compiled to following architectures:
  - iOS
  - MacOS
  - Android
  - Windows
  - Linux
  - WebAssembly
- Kotlin/Native can use C libraries and Swift / Objective-C frameworks

Uses - JavaScript Development

- Transpiling = Compiling source code into another language's source code
- Your Kotlin code and Kotlin standard library can be transpiled into JavaScript
  - Excludes every other Java library!
- Client-side JavaScript
  - Interacting with DOM elements (your webpage's elements)
  - Creating graphical elements using WebGL
- Server-side JavaScript
  - Can interact with e.g. Node.js

Installation

- Included in IntelliJ IDEA, Android Studio
- Available as a plugin for Eclipse
- Can install the compiler and use any text editor
  - See http://kotlinlang.org for instructions
  - Already on SEASnet Linux servers

Hello, World!

```
fun main(args: Array<String>) {
        val scope = "World"
        println("Hello, $scope!")
}
```

- Compare to Java:
  - No class needed
  - No semi-colons
  - Type after argument name
  - Variable inside string
  - val => immutable variable

Compilation / Interactive Shell

```
$ kotlinc hello.kt -include-runtime -d hello.jar
$ java -jar hello.jar
Hello, World!
```

```
$ kotlinc-jvm
Welcome to Kotlin version 1.3.21 (JRE 1.8.0_151-b12)
Type :help for help, :quit for quit
>>> println("Hello, World!")
Hello, World!
```

Variables

- Type inference
- *val* defines immutable variables, *var* defines mutable variables

```
>>> val a = 5
>>> a
res2: kotlin.Int = 5
>>> a = 6
error: val cannot be reassigned

>>> var b = 5
>>> b = 6
>>> b
res5: kotlin.Int = 6
```

Functions

- Return type comes **after** function name and arguments
  - Can be omitted if the type is *Unit* (similar to *void*)
- No need for curly braces if we only have one expression:

```
fun foo(): Int {
        <Do things here>
        return 1
}

fun len(x: String) = x.length
```

Lambda functions

- Lambda functions defined with curly braces: *{ arg : argType -> expression }*

```
>>> { s: String -> println(s) } ("Hello")
Hello
```

```
fun executeLambda(f: (s: String) -> Unit) {
        f("Hello")
}

>>> executeLambda({ s : String -> println(s) })
Hello
```

Lists & List Operations

```
>>> val myList = listOf(1, 2, 3, 4, 5, 6, 7, 8, 9, 10)
>>> myList.map { x -> x*2 }
res3: kotlin.collections.List<kotlin.Int> = [2, 4, 6, 8, 10]

>>> myList.map { it*2 }
res4: kotlin.collections.List<kotlin.Int> = [2, 4, 6, 8, 10]

>>> myList.filter { it < 5 }
res5: kotlin.collections.List<kotlin.Int> = [1, 2, 3, 4]
```

- By convention, function calls with a lambda argument do not use parentheses
- List iteration can directly use iterator (*it*) without declaring it as a parameter

List Indices

```
>>> myList.withIndex().forEach { (index, value) -> println("$index: $value") }
0: 1
1: 2
2: 3
3: 4
4: 5

>>> myList.forEachIndexed { index, value -> println("$index: $value") }
0: 1
1: 2
2: 3
3: 4
4: 5
```

Data Classes

- Meant for classes whose main purpose is to store data
    - Creates getters/setters automatically, provides equals()/copy()/toString() methods

```
data class Person(val name: String, val age: Int) {
        fun printName() { println(name) }
}


>>> val person = Person("John", 53)
>>> person.toString()
res50: kotlin.String = Person(name=John, age=53)
>>> person.name
res51: kotlin.String = John
>>> person.printName()
John
```

Extension Methods

- Ability to add new functionality to existing classes without inheritance

```
package MyStringExtensions

fun String.lastChar(): Char = get(length - 1)

>>> println("Kotlin".lastChar())
n
```

Coroutines

- Similar to Python's *async*/*await*

```
import kotlinx.coroutines.*

fun main() = runBlocking {
    launch { doWorld() }
    println("Hello,")
}

suspend fun doWorld() {
    delay(1000L)
    println("World!")
}
```

Nullable Data Types

- Nullable values must be defined with *?*
- Safe navigation operator: *?.*
  - Access a method/field only if the variable is not null, otherwise return null
- Null coalescing operator: *?:*
  - Also known as Elvis Operator
  - Return the nullable value if it is not null, otherwise return an alternative value

```
>>> val name: String? = null
>>> name?.length
res5: kotlin.Int? = null

>>> val my_var = name ?: "Name was null"
>>> my_var
res9: kotlin.String = Name was null
```

Safe casting

- Typical way of casting variables will throw an exception if the types are not compatible
- Safe casting will set the result variable null instead

```
>>> val y = 5
>>> val x: String = y as String
java.lang.ClassCastException: java.lang.Integer cannot be cast to java.lang.String
>>> val x: String? = y as? String
>>> x
res10: kotlin.String? = null
```

Smart Casting

- If we check the type of a variable, it will cast itself to the desired type:

```
fun len(obj: Any): Int? {
        if (obj is String) {
                return obj.length
        }

        return null
}

>>> len(5)
res18: kotlin.Int? = null
>>> len("Hello")
res19: kotlin.Int? = 5
```

```
fun len(obj: Any): Int? {
        if (obj !is String) return null

        return obj.length
}

>>> len(5)
res25: kotlin.Int? = null
>>> len("Hello")
res26: kotlin.Int? = 5
```

Resources

- Kotlin Playground
- Kotlin Koans
- Kotlin Reference

Reminders

- Course feedback is open
  - Please fill it, shouldn’t take more than a few minutes
  - Did we not cover something that you wish was covered? Should something be taught differently? How would you change this course?
- All homeworks must be submitted by next **Friday 11:55pm**
  - **LATE SUBMISSIONS WILL NOT BE GRADED**

Questions?