Deconstructing OCaml

What makes up a language

PL Dimensions

- Wide variety of programming languages
- How do they differ?
- along certain dimensions...
- What are these dimensions?

PL Dimensions (discussion)

Dimension: Syntax

- Languages have different syntax
  - But the difference in syntax can be superficial
  - C# and Java have different syntax, but are very similar
- In this class, will look beyond superficial syntax to understand the underlying principles

Dimension: Computation model

- Functional: Lisp, OCaml, ML
- Imperative: Fortran, Pascal, C
- Object oriented: Smalltalk, C++, Java, C#
- Constraint-based: Prolog, CLP(R)

Dimension: Memory model

- Explicit allocation-deallocation: C, C++
- Garbage collection: Smalltalk, Java, C#
- Regions: safe versions of C (e.g. Cyclone)
  - allocate in a region, deallocate entire region at once
  - more efficient than GC, but no dangling ptrs

Dimension: Typing model

- Statically typed: Java, C, C++, C#
- Dynamically typed: Lisp, Scheme, Perl, Smalltalk
- Strongly typed (Java) vs. weakly typed (C, C++)

Dimension: Execution model

- Compiled: C, C++
- Interpreted: Perl, shell scripting PLs
- Hybrid: Java
- Is this really a property of the language? Or the language implementation?
- Depends...

Key components of a lang

- Computation model
- Typing model
- Memory model

Computation model

In OCaml

In OCaml

- Expressions that evaluate to values
- Everything is an expression
  - int, bool, real
  - if-then-else
  - let-in
  - match
  - fun x -> x+1
  - e1 e2
- Functions are first class

In Java/Python

In Java/Python

- Store and update commands
- Message sends

Types

Types

- Used to classify things created by the programmer
- Classification used to check what can be done with/to those things

In OCaml: Static typing

- Types are assigned statically at compile time
- Without computing values

In OCaml: Static typing

- How can one reuse code for different types?
  - parametric types: ‘a * ‘b -> ‘b * ‘a
  - implicit forall
- Type “discovered” (inferred) automatically from code
  - less burden on the programmer

In Python: Dynamic typing

- Types assigned to values/objects as they are computed, ie: dynamically
- Before an operation is performed, check that operands are compatible with operation

In Python: Dynamic typing

- More programs are accepted by compiler
- More flexible, but find errors late

```
[1, "abc", 1.8, [ "efg", 20]]
```

```
let x = if b then 1 else "abc"
let y = if b then x + 1 else x ^ "efg"
```

Dynamic vs. Static, OO vs. Func

	Statically typed	Dynamically typed
OO		
Functional		

Dynamic vs. Static, OO vs. Func

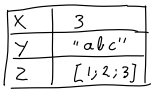
	Statically typed	Dynamically typed
OO	Java	Python, Smalltalk
Functional	Ocaml, Haskell	Lisp/Scheme

Memory/Data model

aka: what do variables refer to?

Data model in functional langs

- Environment of bindings (phonebook)



- Never change a binding
  - add new bindings at the end of the phonebook

Data model in functional langs

- Variables are names that refer into the phonebook
- Most recent entry looked up during evaluation
- Environment "frozen" inside function value so that the behavior of the function cannot be changed later on (easier reasoning)

Data model in OO langs

- Variables are cells in memory
- Can change them by assigning into them
- Variables point to objects on the heap
- x = x + 10

Final words on functional programming

What's the point of all this?

Advantages of functional progs

- Functional programming more concise
  "one line of lisp can replace 20 lines of C"
  (quote from http://www.ddj.com/dept/architect/184414500?pgno=3)
- Recall reverse function in OCaml:

```
let reverse = fold (::) [];;
```

- How many lines in C, C++?

Can better reason about progs

- No side effects. Call a function twice with same params, produces same value
- As a result, computations can be reordered more easily
- They can also be parallelized more easily

So what?

- From the authors of map reduce: "Inspired by similar primitives in LISP and other languages"
  http://research.google.com/archive/mapreduce-osdi04-slides/index-auto-0003.html
- The point is this: programmers who only know Java/C/C++ would probably not have come up with this idea
- Many other similar examples in industry

This stuff is for real: F#

F# = Microsoft's Ocaml-on-steroids

http://channel9.msdn.com/pdc2008/TL11/

- Why FP is way cool
- How FP works with Objects (C#)
- How FP allows you to write parallel code

… all with an extremely engaging speaker

And: Jane Street Capital

- Trading company
- Software does the trading
- Use Ocaml exclusively because
  - Ocaml brevity make code reviews easier
  - Ocaml immutability makes code more understandable
  - Static typing prevents bugs

And many others!

- Facebook: Infer program analysis tool implemented in Ocaml
- Facebook: Sigma malware detection tool implemented in Haskell
- Google: map reduce, need we say more?
- Twitter: uses Scala for their back-end (Scala has roots in FP and OO)

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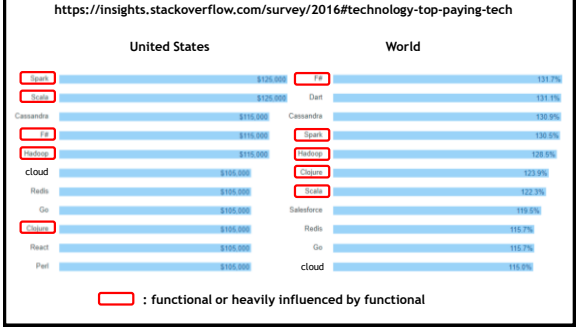
Stack Overflow Survey

https://insights.stackoverflow.com/survey/2016#technology-top-paying-tech



Remember

- The next time you use google, think of how functional programming has inspired some of the technical ideas behind their engine
- And of course:

"Free your mind"

-Morpheus

Recap of the course so far

- 4 weeks of functional with Ocaml
- Next: 4 weeks of OO with Python
- After that: 1 week of constraint logic programming with Prolog

OO at the highest level

- What is OO programming?

OO at the highest level

- What is OO programming?
- Answer:
  - objects
  - message sends
  - dynamic dispatch

Just to whet your appetite

- Say we have objects, like `cars`, `ducks`, `pig`, `cell_phones`
- Say we have a message name: `make_some_noise`

Just to whet your appetite

- Each object has its own implementation for `make_some_noise`: these are traditionally called methods.
- `car`: vroom vroom, `pig` : oink oink, `duck`: quack quack
- We can send `make_some_noise` to any object. Depending on the actually run-time object, we'll get a different noise!

OO programming

- Message: the name of an operation
- Method: the implementation of an operation
- Dynamic dispatch: the act of determining at based on the dynamic type which method should be run for a given message send.
- These are the core ideas of OO

This brings us to Python...

- We'll use Python as our vehicle for OO programming
- Fun and useful language
- Let's compare with OCaml along some of the dimensions we saw last time

OCaml/Python comparison

	ML	Python
PL paradigm		
Basic unit		
Types		
DataModel		

OCaml/Python comparison

	ML	Python
PL paradigm	functional	OO/imperative
Basic unit	Expr/value	Objects/ messages
Types	statically	dynamicaclly
DataModel	env lookup	"pointers" to mutable objs

Python

- Python has a very relaxed philosophy
  - if something "can be done" then it is allowed.
- Combination of dynamic types + everything is an object makes for very flexible, very intuitive code.

No static types

- No static type system to "prohibit" operations.
- No more of that OCaml compiler giving you hard-to-decypher error messages!
- And... No need to formally define the type system (although still need to define the dynamic semantics somehow)

No static types: but what instead?

- Dynamic typing
- At runtime, every "operation" is translated to a method call on the appropriate object.
- If the object supports the method, then the computation proceeds.
- Duck-typing: if it looks like a duck, quacks like a duck, then it is a duck!

Dynamic typing

- This loose, comfortable, free-style, philosophy is at the heart of python.
- But... beware, can get burned...
- One way to think about it:
  - Dynamic types good for quick prototyping
  - Static types good for large systems
  - Although…
  - Gmail in Javascript?

Similarities to Ocaml

- Uniform model: everything is an object, including functions
- Can pass functions around just as with objects
- Supports functional programming style with map and fold

Other cool things about Python

- A lot of stuff that you may first think is a "language feature" is actually just translated under the hood to a method call...
- Very widely used, supported.
- Has libraries for all sorts of things.

Ok, let's start playing with Python!

- Like Perl, python is a "managed" or "interpreted" language that runs under the python environment, i.e. not compiled to machine code.
- Makes it convenient to rapidly write and test code!

Ways to run Python code

- At an interactive Python prompt: like "read-eval-print" loop of ML,
- As shell scripts,
- As stand-alone programs run from the shell.

Let’s fire it up!

- Ok, let’s give it a try...
- See py file for the rest...