UC Berkeley EECS
Lecturer SOE
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CS10 : The Beauty and Joy of Computing

Lecture #5 Programming Paradigms

2012-02-01

DILEMMA OF BEING A CYBORG

Story details the move to Digital of many things precious to us – music, photos, videos. Is there something lost in the process? and what happens when that data is deleted. YOUR backup solution?

http://www.nytimes.com/2012/01/29/magazine/what-happens-when-data-disappears.html

Programming Paradigms Lecture

- What are they?
  - Most are Hybrids!
- The Four Primary ones
  - Functional
  - Imperative
  - Object-Oriented
    - OOP Example: Skecthpad
  - Declarative
- Turing Completeness
- Summary

What are Programming Paradigms?

en.wikipedia.org/wiki/Programming_paradigm

- "The concepts and abstractions used to represent the elements of a program (e.g., objects, functions, variables, constraints, etc.) and the steps that compose a computation (assignation, evaluation, continuations, data flows, etc.)."
- Or, a way to classify the style of programming.

Of 4 paradigms, how many can BYOB be?

byob.berkeley.edu

a) 1 (functional)
b) 1 (not functional)
c) 2
d) 3
e) 4

Most Languages Are Hybrids!

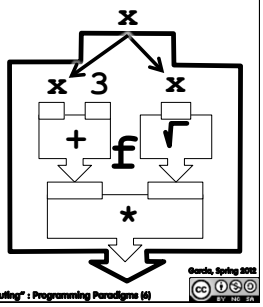
- This makes it hard to teach to students, because most languages have facets of several paradigms!
  - Called "Multi-paradigm" languages
  - Scratch too!
- It's like giving someone a juice drink (with many fruit in it) and asking to taste just one fruit!

Functional Programming (review)

en.wikipedia.org/wiki/Functional_programming

- Computation is the evaluation of functions
  - Plugging pipes together
  - Each pipe, or function, has exactly 1 output
  - Functions can be input!
- Features
  - No state
    - E.g., variable assignments
  - No mutation
    - E.g., changing variable values
  - No side effects
- Examples (tho not pure)
  - Scheme, Scratch BYOB

$f(x) = (x+3) * \sqrt{x}$



en.wikipedia.org/wiki/Imperative_programming

Imperative Programming

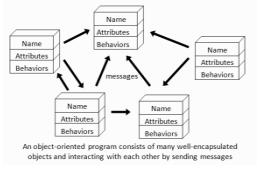
- "Sequential" Programming
- Computation a series of steps
  - Assignment allowed
    - Setting variables
  - Mutation allowed
    - Changing variables
- Like following a recipe. E.g.,
- Procedure f(x)
  - ans = x
  - ans = $\sqrt{\text{ans}}$
  - ans = (x+3) * ans
  - return ans
- Examples: (tho not pure)
  - Pascal, C

$f(x) = (x+3) * \sqrt{x}$

en.wikipedia.org/wiki/Object-oriented_programming

Object-Oriented Programming (OOP)

- Objects as data structures
  - With methods you ask of them
    - These are the behaviors
  - With local state, to remember
    - These are the attributes
- Classes & Instances
  - Instance an example of class
  - E.g., Fluffy is instance of Dog
- Inheritance saves code
  - Hierarchical classes
  - E.g., pianist special case of musician, a special case of performer
- Examples (tho not pure)
  - Java, C++



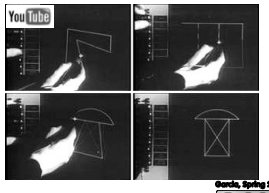
www3.ntu.edu.sg/home/ehchua/programming/java/images/OOP-Objects.gif

en.wikipedia.org/wiki/Sketchpad

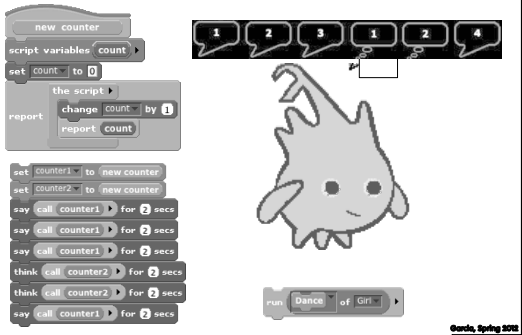
OOP Example : SketchPad

- Dr. Ivan Sutherland
  - "Father of Computer Graphics"
  - 1988 Turing Award ("Nobel prize" for CS)
  - Wrote Sketchpad for his foundational 1963 thesis
- The most impressive software ever written
- First…
  - Object-oriented system
  - Graphical user interface
  - non-procedural language

Spent the past few years doing research @ Berkeley in EECS dept!



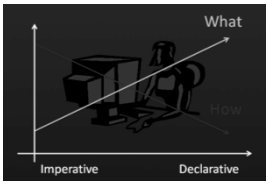
OOP in BYOB



en.wikipedia.org/wiki/Declarative_programming

Declarative Programming

- Express what computation desired without specifying how it carries it out
  - Often a series of assertions and queries
  - Feels like magic!
- Sub-categories
  - Logic
  - Constraint
    - We saw in Sketchpad!
- Example: Prolog



Anders Hejlsberg
"The Future of C#" @ PDC2008
channel9.msdn.com/pdc2008/TL16/

Declarative Programming Example

- Five schoolgirls sat for an examination. Their parents – so they thought – showed an undue degree of interest in the result. They therefore agreed that, in writing home about the examination, each girl should make one true statement and one untrue one. The following are the relevant passages from their letters:
  - Betty
    - Kitty was 2nd
    - I was 3rd
  - Ethel
    - I was on top
    - Joan was 2nd
  - Joan
    - I was 3rd
    - Ethel was last
  - Kitty
    - I came out 2nd
    - Mary was only 4th
  - Mary
    - I was 4th
    - Betty was 1st

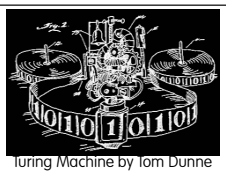
Of 4 paradigms, what's the most powerful?

a) Functional
b) Imperative
c) OOP
d) Declarative
e) All equally powerful

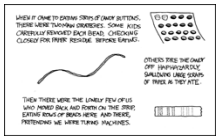
Turing Completeness

en.wikipedia.org/wiki/Turing_completeness
ironphoenix.org/tril/tm/

- A Turing Machine has an infinite tape of 1s and 0s and instructions that say whether to move the tape left, right, read, or write it
  - Can simulate any computer algorithm!
- A Universal Turing Machine is one that can simulate a Turing machine on any input
- A language is considered Turing Complete if it can simulate a Universal Turing Machine
  - A way to decide that one programming language or paradigm is just as powerful as another



Turing Machine by Tom Dunne



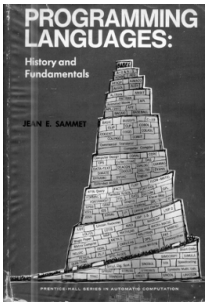
Xkcd comic "Candy Button Paper"

Ways to Remember the Paradigms

en.wikipedia.org/wiki/Programming_paradigm

- **Functional**
  - Evaluate an expression and use the resulting value for something
- **Object-oriented**
  - Send messages between objects to simulate the temporal evolution of a set of real world phenomena
- **Imperative**
  - First *do this* and next *do that*
- **Declarative**
  - Answer a question via search for a solution

www.cs.aau.dk/~normark/prog3-03/html/notes/paradigms_themes-paradigm-overview-section.html

Summary

- **Each paradigm has its unique benefits**
  - If a language is Turing complete, it is equally powerful
  - Paradigms vary in efficiency, scalability, overhead, fun, "how" vs "what" to specify, etc.
- **Modern languages usually take the best from all**
  - E.g., Scratch
    - Can be functional
    - Can be imperative
    - Can be object-oriented
    - Can be declarative