CS39N
The Beauty and Joy of Computing

Lecture #6 : Programming Paradigms

2009-09-28

UC Berkeley
Computer Science
Lecturer SOE
Dan Garcia

BRITISH PM APOLOGIZES TO TURING

In response to a 30,000+ signature petition, British PM Gordon Brown apologized for the way Britain treated Alan Turing (the "father" of computer science, WWII codebreaker) for being gay.
So on behalf of the British government, …
we're sorry, you deserved so much better.

news.bbc.co.uk/2/hi/technology/8249792.stm
www.number10.gov.uk/Page20571

Programming Paradigms Lecture

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

en.wikipedia.org/wiki/Programming_paradigm

What are Programming Paradigms?

- "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.

Most Languages Are Hybrids!

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

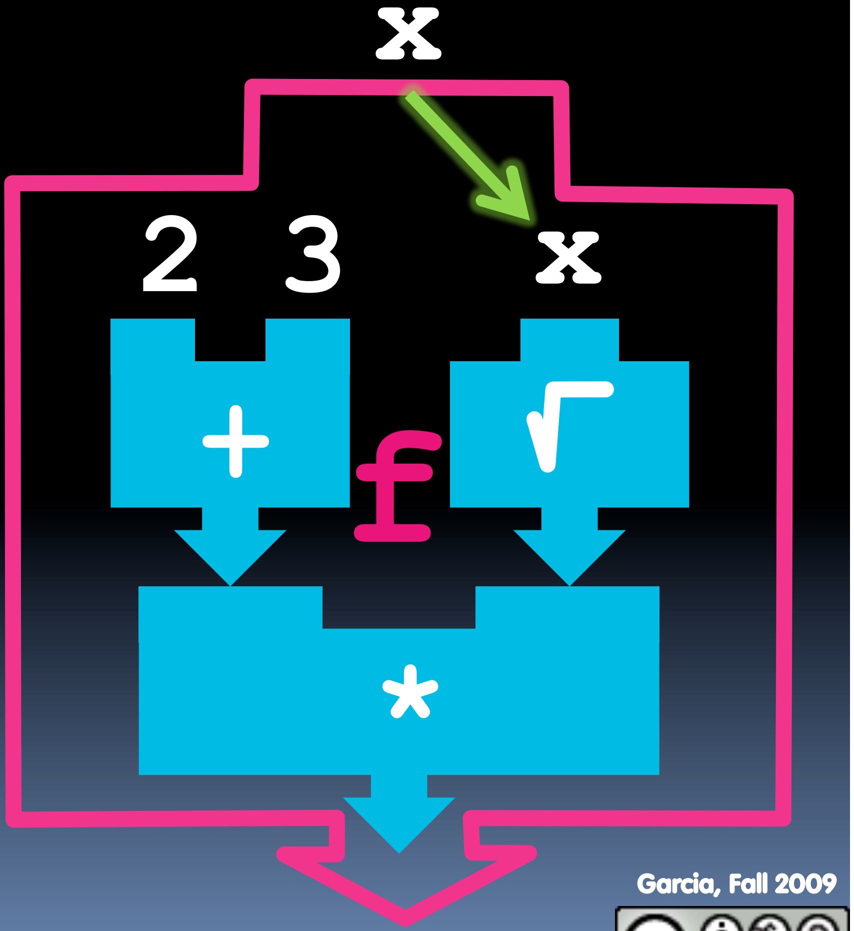
Garcia, Fall 2009

en.wikipedia.org/wiki/Functional_programming

Functional Programming (review)

- Computation is the evaluation of math **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
  - Scheme, Scratch BYOB

$$f(x) = (2+3) * \sqrt{x}$$



Garcia, Fall 2009

en.wikipedia.org/wiki/Imperative_programming

Imperative Programming

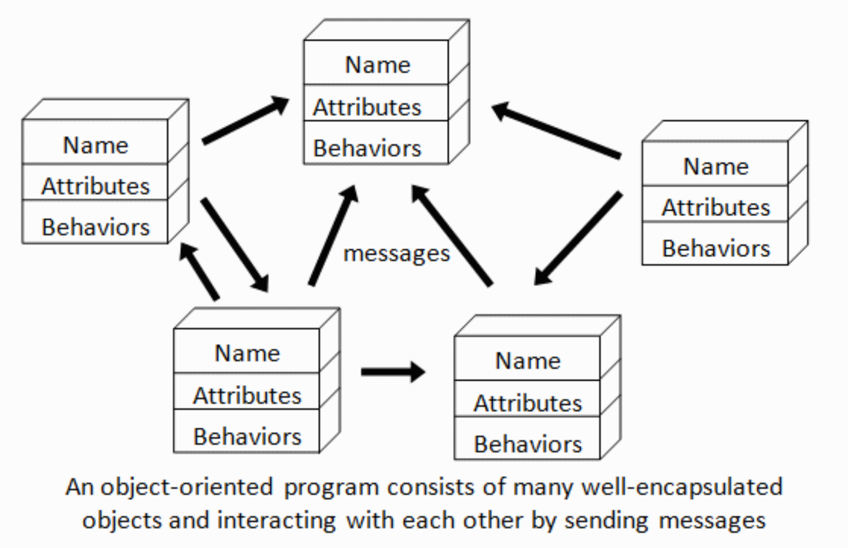
$$f(x)=(2+3)*\sqrt{x}$$

- AKA "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 = (2+3) * ans
  - return ans
- Examples: Pascal, C

en.wikipedia.org/wiki/Object-oriented_programming

Object-Oriented Programming (OOP)

- Objects as data structures
  - With methods you ask of them
    - These are the behavoirs
  - 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: Java, C++



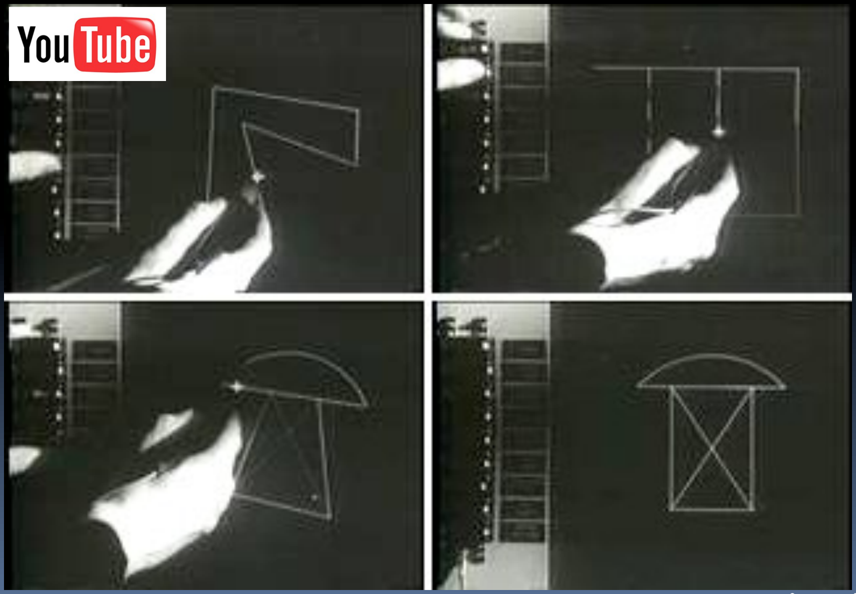
An object-oriented program consists of many well-encapsulated objects and interacting with each other by sending messages

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!

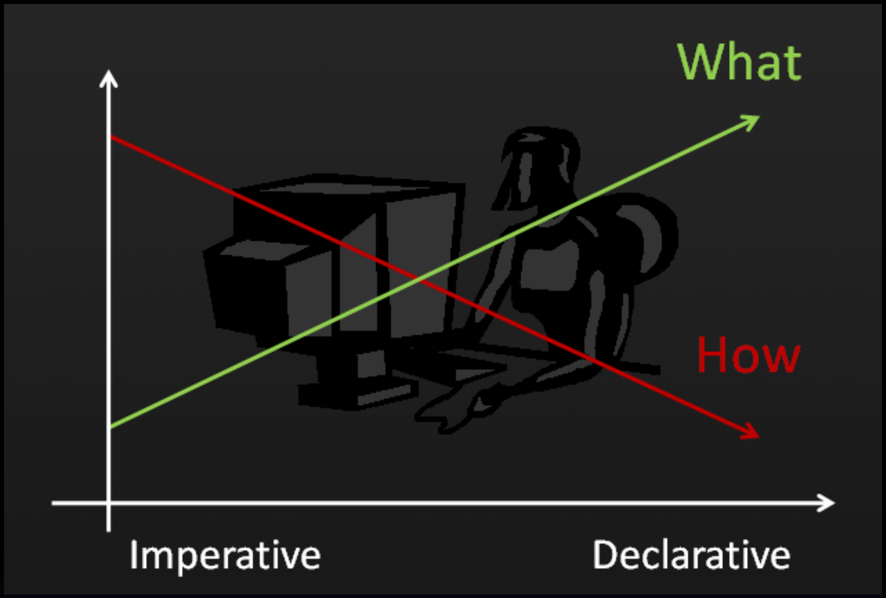


Garcia, Fall 2009

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!
- Examples: Prolog



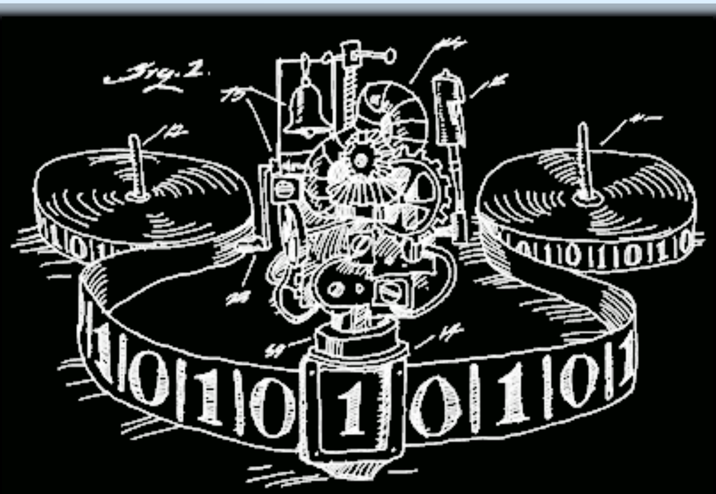
Anders Hejlsberg
"The Future of C#" @ PDC2008
channel9.msdn.com/pdc2008/TL16/

Garcia, Fall 2009

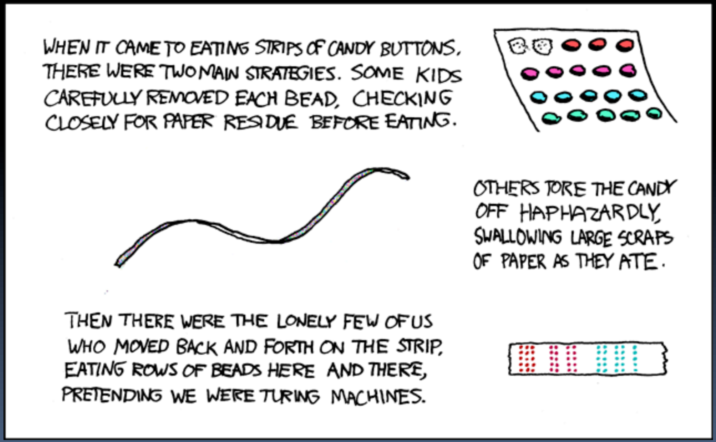
en.wikipedia.org/wiki/Turing_completeness

Turing Completeness

- 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


WHEN IT CAME TO EATING STRIPS OF CANDY BUTTONS, THERE WERE TWO MAIN STRATEGIES. SOME KIDS CAREFULLY REMOVED EACH BEAD, CHECKING CLOSELY FOR PAPER RESIDUE BEFORE EATING.
OTHERS TORE THE CANDY OFF HAPHAZARDLY, SWALLOWING LARGE SCRAPS OF PAPER AS THEY ATE.
THEN THERE WERE THE LONELY FEW OF US WHO MOVED BACK AND FORTH ON THE STRIP, EATING ROWS OF BEADS HERE AND THERE, PRETENDING WE WERE TURING MACHINES.

Xkcd comic “Candy Button Paper”

Ways to Remember the Paradigms

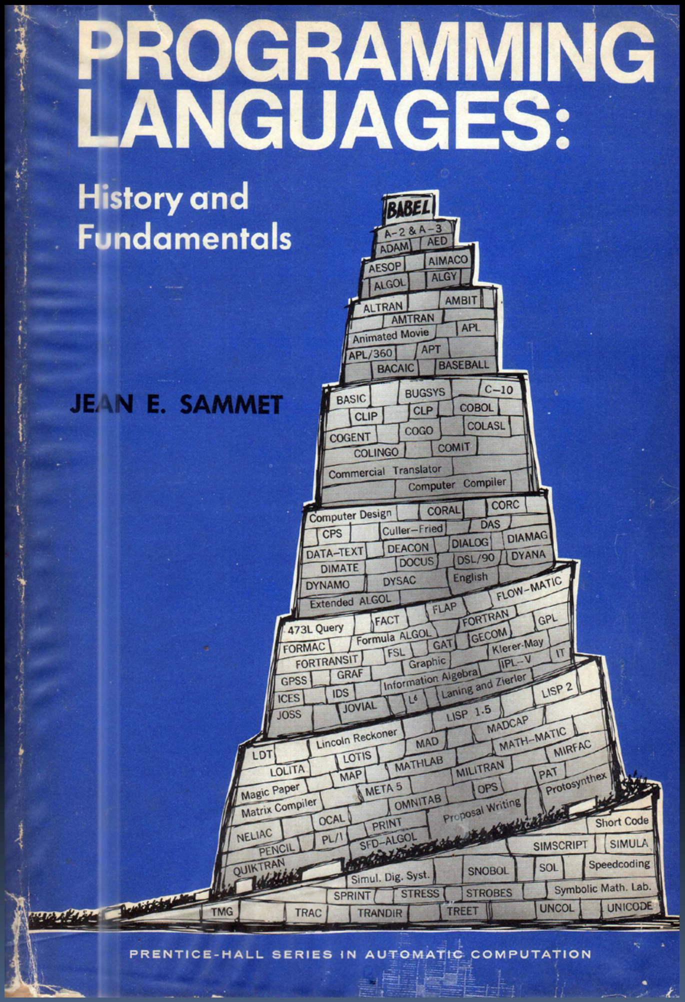
- **Functional**
  - Evaluate an expression and use the resulting value for something
- **Object-oriented**
  - Send messages between objects to simulate the temporal evolution of a set of real world phenomena
- **Imperative**
  - First *do this* and next *do that*
- **Declarative**
  - Answer a question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

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

Garcia, Fall 2009

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!


PROGRAMMING LANGUAGES:
History and Fundamentals
JEAN E. SAMMET
BABEL
A-2 & A-3
ADAM
AED
AESOP
AIMACO
ALGOL
ALGY
ALTRAN
AMBIT
AMTRAN
Animated Movie
APL
APL/360
APT
BACAIC
BASEBALL
BASIC
BUGSYS
C-10
CLIP
CLP
COBOL
COGENT
COGO
COLASL
COLINGO
COMIT
Commercial Translator
Computer Compiler
Computer Design
CORAL
CORC
CPS
Culler-Fried
DAS
DATA-TEXT
DEACON
DIALOG
DIAMAG
DIMATE
DOCUS
DSL/90
DYANA
DYNAMO
DYSAC
English
Extended ALGOL
FLAP
FLOW-MATIC
473L Query
FACT
FORTRAN
GPL
FORMAC
Formula ALGOL
GAT
GECOM
Klerer-May
FORTRANSIT
FSL
Graphic
IPL-V
IT
GPSS
GRAF
Information Algebra
ICES
IDS
L6
Laning and Zierler
LISP 2
JOSS
JOVIAL
LISP 1.5
MADCAP
LDT
Lincoln Reckoner
MAD
MATH-MATIC
LOLITA
LOTIS
MATHLAB
MIRFAC
MAP
MILITRAN
PAT
Magic Paper
META 5
OPS
Protosynthex
Matrix Compiler
OMNITAB
Proposal Writing
OCAL
PRINT
Short Code
NELIAC
PL/I
SFD-ALGOL
SIMSCRIPT
SIMULA
PENCIL
QUIKTRAN
Simul. Dig. Syst.
SNOBOL
SOL
Speedcoding
SPRINT
STRESS
STROBES
Symbolic Math. Lab.
TMG
TRAC
TRANDIR
TREET
UNCOL
UNICODE
PRENTICE-HALL SERIES IN AUTOMATIC COMPUTATION