CS10 : The Beauty and Joy of Computing

Lecture #5
Programming Paradigms

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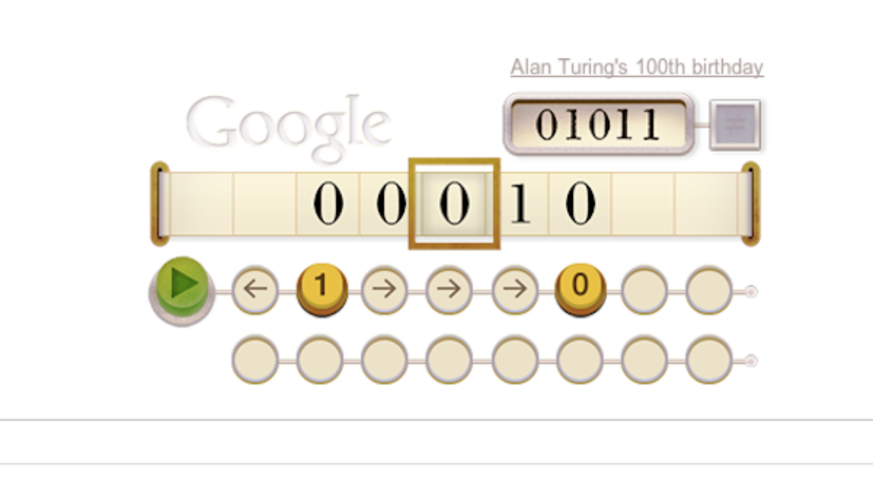
TURING TURNS 100

If you visited google.com on Saturday, you saw a tribute to this founding father of computer science who broke the German Enigma code during WW2.



en.wikipedia.org/wiki/Alan_Turing

Programming Paradigms Overview

- What paradigm is that language?
  - Most are hybrids!
- Four Primary Paradigms
  - Functional
  - Imperative
  - Object-Oriented
    - OOP Example: Skecthpad
  - Declarative
- Turing Completeness
- Summary

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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.

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Of 4 paradigms, how many can BYOB be?

a) 1 (functional)

b) 1 (not functional)

c) 2

d) 3

e) 4

Most Languages Are Hybrids

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

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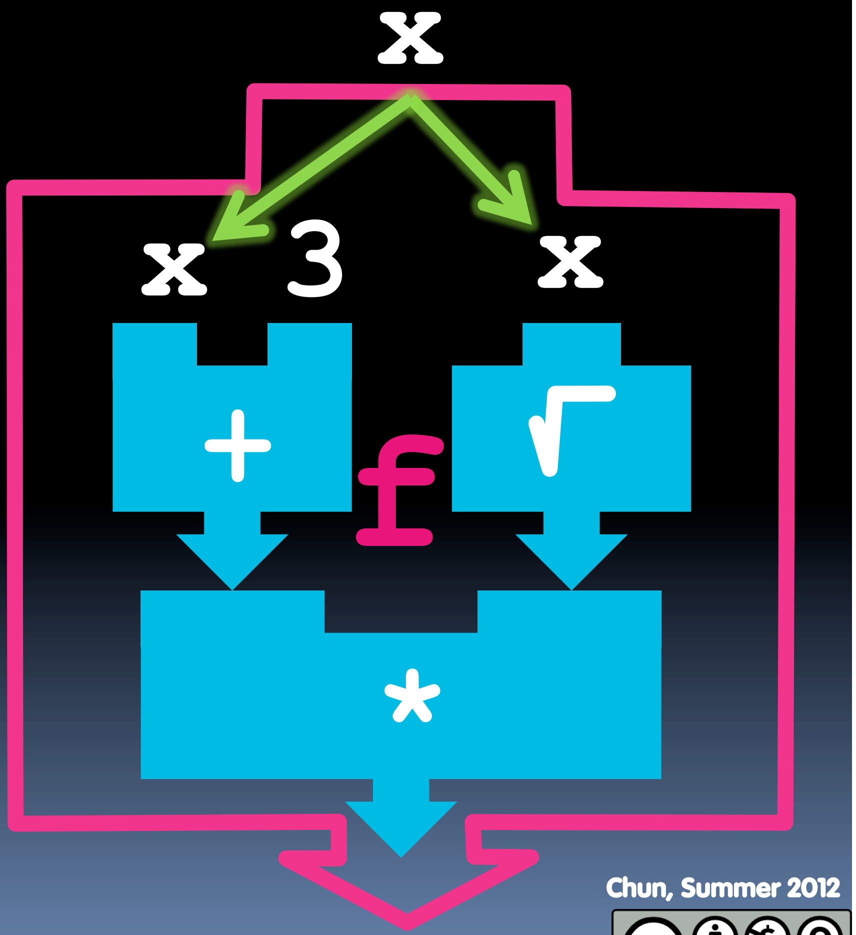
en.wikipedia.org/wiki/Functional_programming

Functional Programming (review)

- 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 (not all pure)
  - Scheme, Scratch, BYOB

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



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en.wikipedia.org/wiki/Imperative_programming

Imperative Programming

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

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

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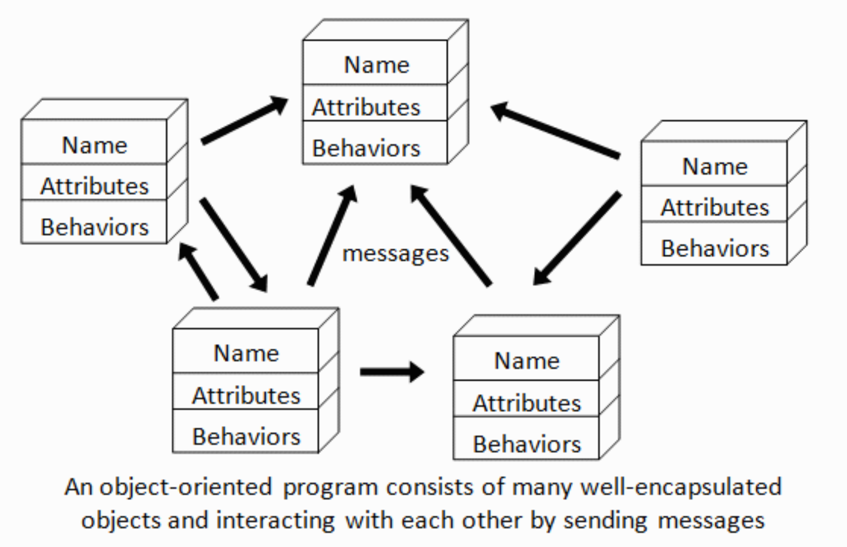
en.wikipedia.org/wiki/Object-oriented_programming

Object-Oriented Programming (OOP)

- **Objects are data structures**
  - With methods you ask of them
    - These are the behaviors
  - With local state, to store info
    - 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., singer is a special case of musician, musician is a special case of person
- **Examples (not all pure)**
  - 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

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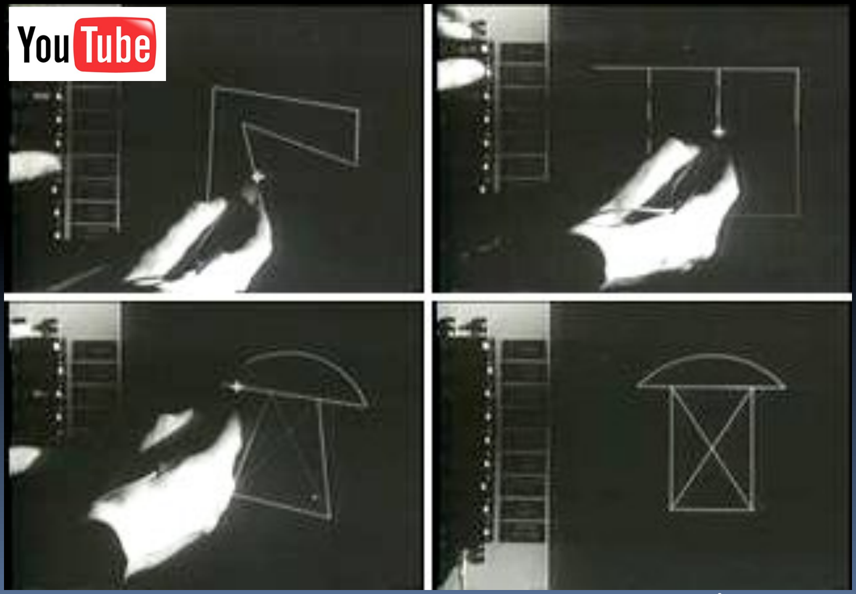
en.wikipedia.org/wiki/Sketchpad

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**
- **It was the first:**
  - Object-oriented system
  - Graphical user interface
  - non-procedural language

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



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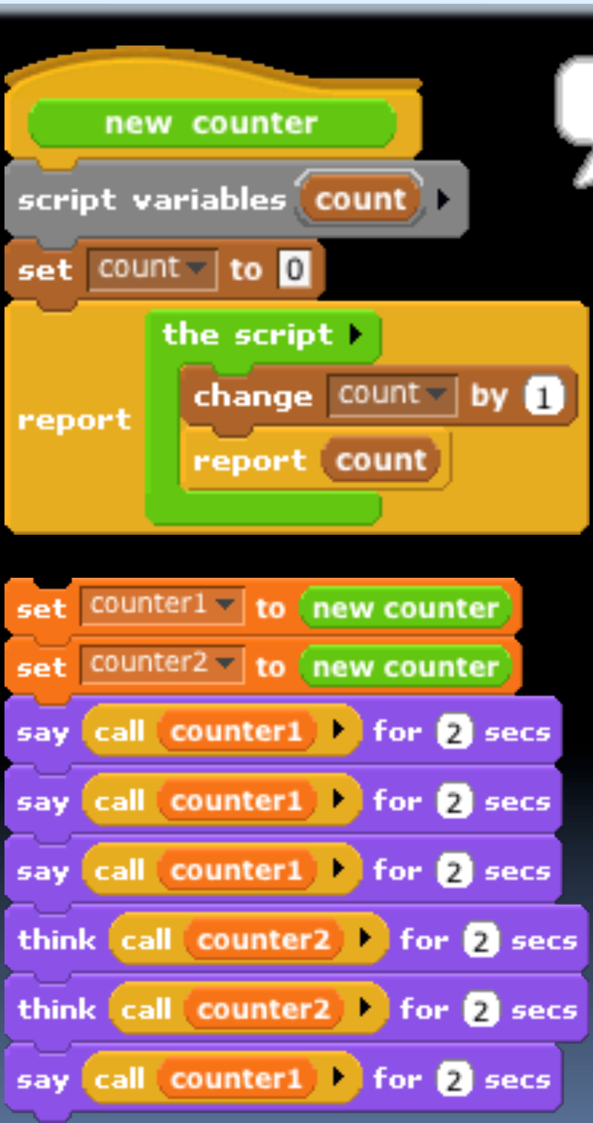
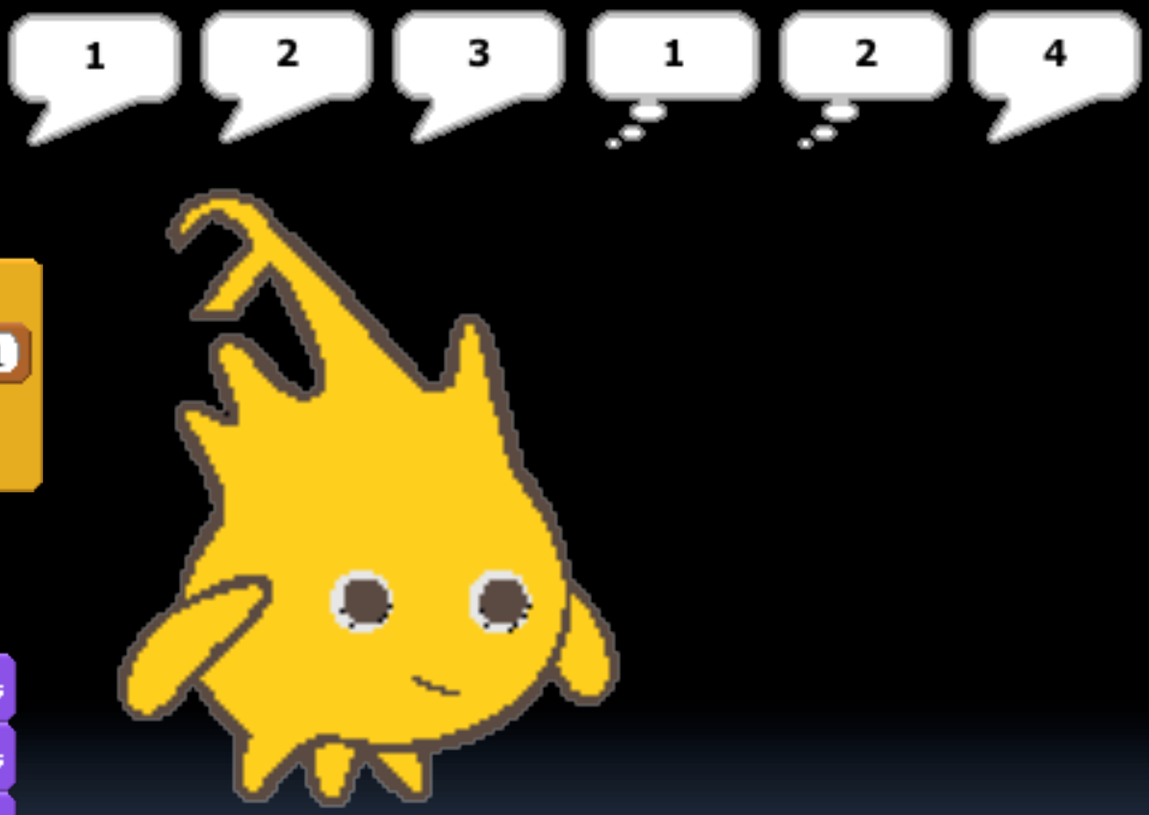
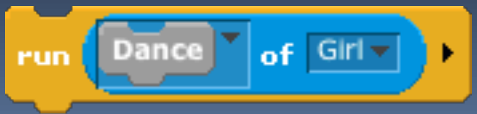
OOP in BYOB



```
new counter
script variables (count)
set count to 0
report (the script
    change count by 1
    report count
)

set counter1 to new counter
set counter2 to new counter
say (call counter1) for 2 secs
say (call counter1) for 2 secs
say (call counter1) for 2 secs
think (call counter2) for 2 secs
think (call counter2) for 2 secs
say (call counter1) for 2 secs
```





```
run (Dance of Girl)
```

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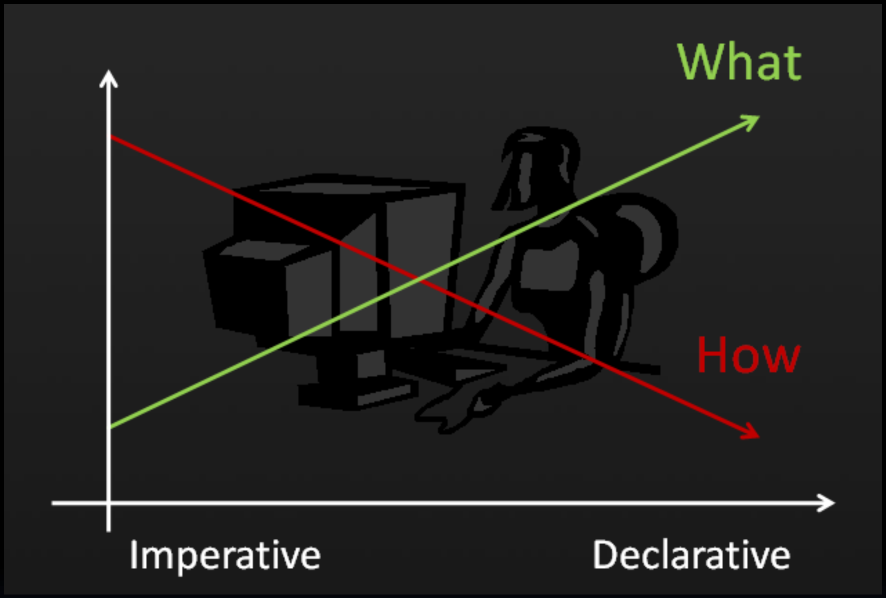
en.wikipedia.org/wiki/Declarative_programming

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/

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mitpress.mit.edu/sicp/full-text/sicp/book/node90.html

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

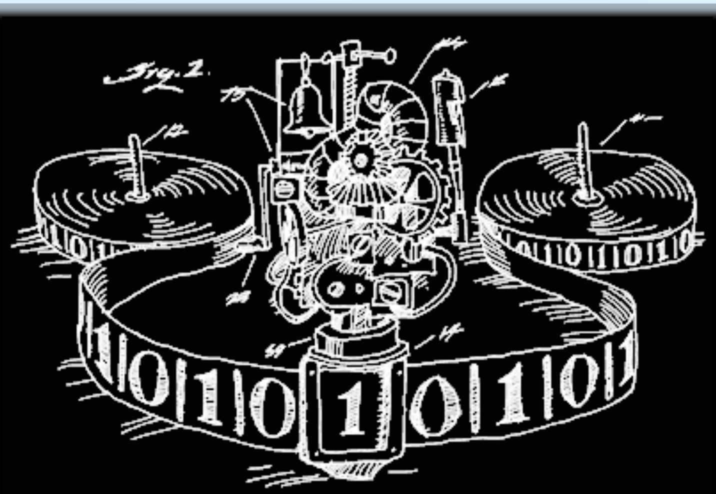
Of 4 paradigms, what's the most powerful?

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

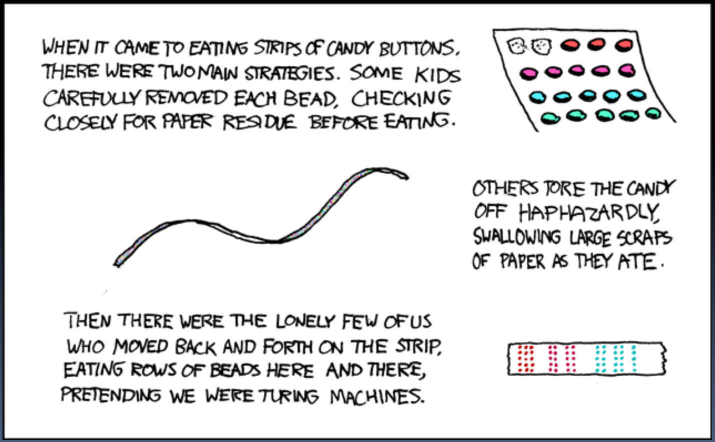
en.wikipedia.org/wiki/Turing_completeness
ironphoenix.org/tril/tm/

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"

en.wikipedia.org/wiki/Programming_paradigm

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

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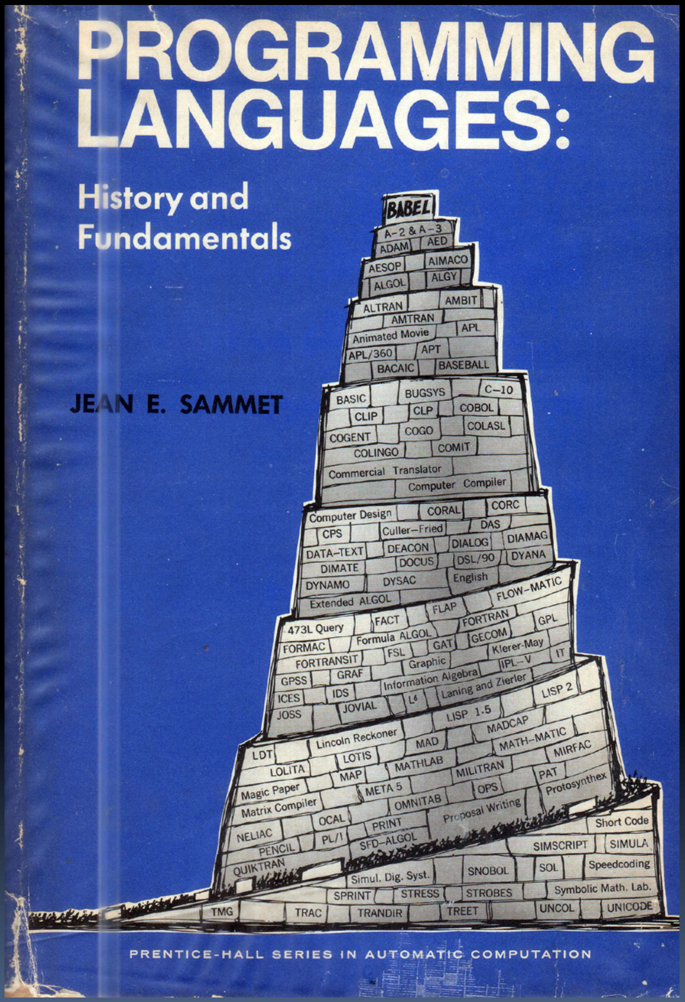
Summary

- **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



PROGRAMMING LANGUAGES:

History and Fundamentals

JEAN E. SAMMET

PRENTICE-HALL SERIES IN AUTOMATIC COMPUTATION