

Theory of Computation

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Northeastern University

Course Logistics

- Course Website
- Gradescope
- Canvas
- Piazza
- CCS Github
- Khoury account
- Khoury office hours

Lecture Logistics

- Pre-reading
- Content
- Interactive portions
- Interactive components
- Quiz at the end

Today

- Course Structure Overview
- Course Content Overview
- CLI Crash Course
- Quiz

Is Computer Science “Science?”

Science

From Wikipedia, the free encyclopedia

This article is about a branch of knowledge. For other uses, see [Science \(disambiguation\)](#).

Science (from the [Latin](#) word *scientia*, meaning "knowledge")^[1] is a systematic enterprise that [builds](#) and [organizes knowledge](#) in the form of [testable explanations](#) and [predictions](#) about the [universe](#).^{[2][3]}

Is Political Science?

Is it (applied)

- Engineering?
- Mathematics
- Logic?
- Philosophy?
- Physics?

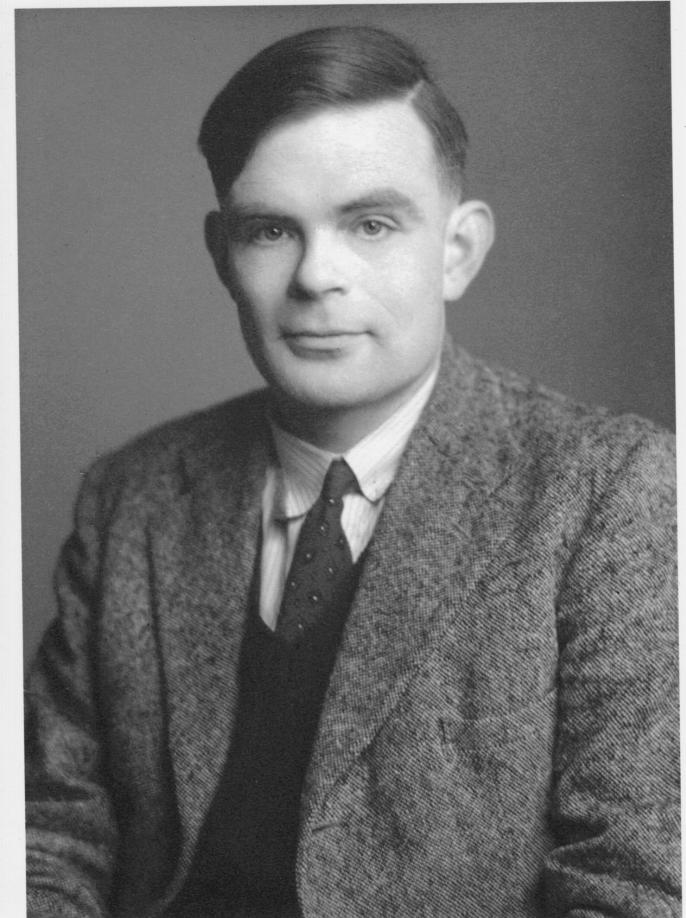
Theory of the practical.

History

- ~1870-1930s – Mathematics introspects
- ~190s-1950s – Implementation and application
- **~1960s** – Emergence as a discipline

Emergence as a Discipline

- Funding
- Practical importance



You will learn

- The Computers of Regular Expressions
- Context-free languages and Parsers, what can they do?
- What's the big deal with Turing-Completeness?
- What makes a problem “**decidable**”?
 - “**Recognizable**”?
 - “**Tractable**”?
- The Halting Problem
- Does $P = NP$?
- What is an NP Complete problem?

Main objective of the course

- Understand what are the powers and limits of computation:
 - a) In principle (i.e. undecidability/uncomputability: computability theory)
 - b) Efficiently/in practice (i.e. complexity theory)
 - c) And what can we do about it?

Intuitive Answers

	tractable problems	intractable problems	uncomputable problems
Description:			
Computable in theory:			
Computable in practice:			
Example:			

Computer ~ Program ~ Algorithm

Civil Service Examinations

The secretary of the Fifth civil service district, Atlanta, Ga., announces the following examinations. Application blanks and additional information concerning them may be obtained from the local civil service board at any first or second class postoffice, the secretary Fifty civil service district, 204 Postoffice building, Atlanta, Ga., or from the civil service commission, Washington, D. C.

Master computer (male) \$1,899-\$2,400 computer (male) \$900-\$1,800.

Vacancies in the ordnance department. Applications received at any time until further notice. A college course in mathematics of at least two years necessary. Age under 50. Application 1312.

Elevator conductor (male and female) \$720 or higher. Vacancies in Washington, D. C. Three months' experience necessary. Application

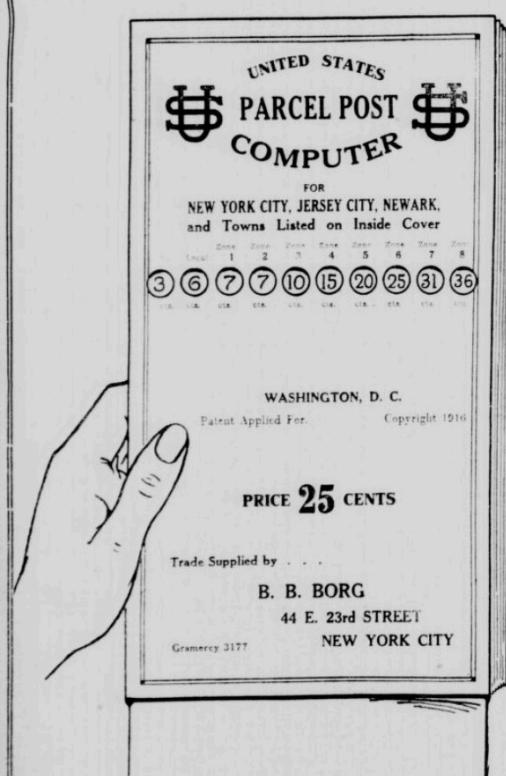
until further notice to fill vacancies in the interstate commerce commission. At least one year's experience required. Age 18 to 50.

Press feeder (male and female) \$2.20 a day to \$840 a year. Vacancies in the government printing office. Three months' experience required. Applications accepted until further notice.

Deputy collector, inspector and agent, antinarcotic act (male) August 6, 1916. \$1,600 and expenses, one year's experience in investigational work or six months' investigating the narcotic drug traffic required. Age 21 to 45. Application 1312.

Coder (male and female) August 7, 1918. \$900-\$1,200. Vacancies in Washington, D. C., in various branches of the service. One month's experience with the Hollerith, Powers, or Pierce tabulating equipment required.

The front of the campaign
The opening of the
The President's speech was as good as gold
The bullet



**DON'T GUESS—
AND GO WRONG!**

←

Our Parcel Post Computer Gives the Exact Postage on Any Package to All Parts of the United States or Foreign Possessions

Just For Example

Suppose you want to send a three-pound parcel to one of the New York soldier boys, stationed at San Antonio. Easy! Open the Computer, and under the heading "Texas" you will find that San Antonio is in Zone No. 7.

Then pull down the index card between the double front cover until the figure "3" appears in the hole marked "Lbs." Glance along the holes to the one marked "Zone 7," and there you will see that the package will cost 31 cents.

Note in the illustration to the left that we have pictured the Computer exactly when it has worked that out for you. So for all weights and all places.

Mighty handy, isn't it? Wait until you commence to send off packages for the holiday season, and it will be your closest friend!

RIGHT UP TO DATE

PRICE 25 CENTS

Trade Supplied by . . .
B. B. BORG
44 E. 23rd STREET
NEW YORK CITY
Gramercy 3177

WASHINGTON, D. C.
Patent Applied For Copyright 1916

FROM NEW YORK AND NEW JERSEY

The Computer is keyed for the uses of every one in New York and New Jersey (in Parcel Post Unit No. 767) and allows the cost of sending a parcel post package of any weight up to the limit allowed of 50 pounds. You simply tell us how much you are told the Zone Numbers, or weight, and immediately turn back to the front cover and there find the cost in a jiffy.

No matter whether you want to send in San Francisco, Calif., or Piney Flats, Tenn., you will find the place there, with its Zone Number.

TO FOREIGN POSSESSIONS, ETC.

You are told in what Zone Number to place packages destined for United States warships in foreign waters, for Canada, Cuba, Alaska, Canal Zone, Guam, Hawaiian Islands, Mexico, Panama, Philippine Islands, Samoa, Porto Rico, Shanghai.

FOR WHOLESALER, RETAILER, MANUFACTURER

The Computer gives the Zone of any community, and the price of the postage, at the same time. Think what that means in expediting the shipping of parcels—in the first day it will probably save full cost, and something over!

Many large businesses will want a dozen or more Computers—they are had in every department and they are always exact!

One copy of a factory—one-day legitimate

This is the same system used by the government—the best by all odds that has been produced.

STRIKE OR NOT

If there should be a railroad strike you will

G.S.
THE TRIBUNE
154 Nassau St.
In exchange for this com-

[< Back to front page](#)

Text size [-](#) [+](#)

Introducing Crab Computing

Posted by Josh Rothman April 26, 2012 08:42 AM

[Comments \(\)](#)

[E-mail story](#)

[Print story](#)

If you're tired of artificial, machine-made computers, then check out this new, all-natural computer, designed by computer scientists in Japan and Britain. It's 100% organic: In place of the usual silicon circuits, it uses huge swarms of blue soldier crabs.



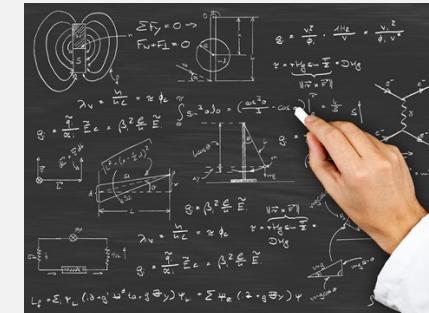
At the outer limits ...

- Microwave?
- Board game?
- Handheld calculator?
- EDVAC?
- Dominoes
- Tiling?

Computer ~ Program ~ Algorithm

Math: The “Language” of Models

- Physics: algebra, calculus, differential eqs
- Biology: probability
- Computer Science:
 - **discrete math, set theory, mathematical logic**
 - See Chapter 0 in the textbook:
 - *Intro to the Theory of Computation*, 3rd ed, by Michael Sipser



This is (mostly) a math course!

About computers and computer programs

Also a course about computer programs

- I.e., making predictions about programs

```
function check(n)
{
    // check if the number n is a prime
    var factor; // if the checked number is not a prime, this is its first factor
    var c;
    factor = 0;
    // try to divide the checked number by all numbers till its square root
    for (c=2 ; (c <= Math.sqrt(n)) ; c++)
    {
        if (n%c == 0) // is n divisible by c ?
            {factor = c; break}
    }
    return (factor);
} // end of check function

function communicate()
{
    // communicate with the user
    var i; // i is the checked number
    var factor; // if the checked number is not a prime, this is its first factor
    i = document.primestest.number.value; // get the checked number
    // is it a valid input?
    if ((isNaN(i)) || (i <= 0) || (Math.floor(i) != i))
        {alert ("The checked object should be a whole positive number");}
    else
    {
        factor = check (i);
        if (factor == 0)
            {alert (i + " is a prime");}
        else
            {alert (i + " is not a prime, " + i + "=" + factor + "X" + i/factor)}
    }
} // end of communicate function
```

(Expect to do some programming)

Why make predictions about computers?

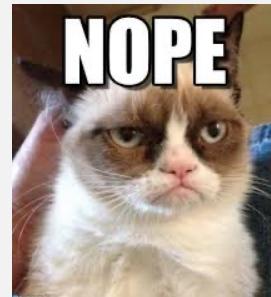
```
function check(n)
{
    // check if the number n is a prime
    var factor; // if the checked number is not a prime, this is its first factor
    var c;
    factor = 0;
    // try to divide the checked number by all numbers till its square root
    for (c=2 ; (c <= Math.sqrt(n)) ; c++)
    {
        if (n*c == 0) // is n divisible by c ?
            {factor = c; break}
    }
    return (factor);
} // end of check function

function communicate()
{
    // communicate with the user
    var i; // i is the checked number
    var factor; // if the checked number is not a prime, this is its first factor
    i = document.getElementById("number").value; // get the checked number
    // is it a valid input?
    if ((i > N(i)) || (i <= 0) || (Math.floor(i) != i))
        {alert ("The checked object should be a whole positive number");}
    else
    {
        factor = check (i);
        if (factor == 1)
            {alert (i + " is a prime");
        else
            {alert (i + " is not a prime. " + i +"=" + factor + "X" + i/factor)}
    }
} // end of communicate function
```



Can we make predictions about computers?

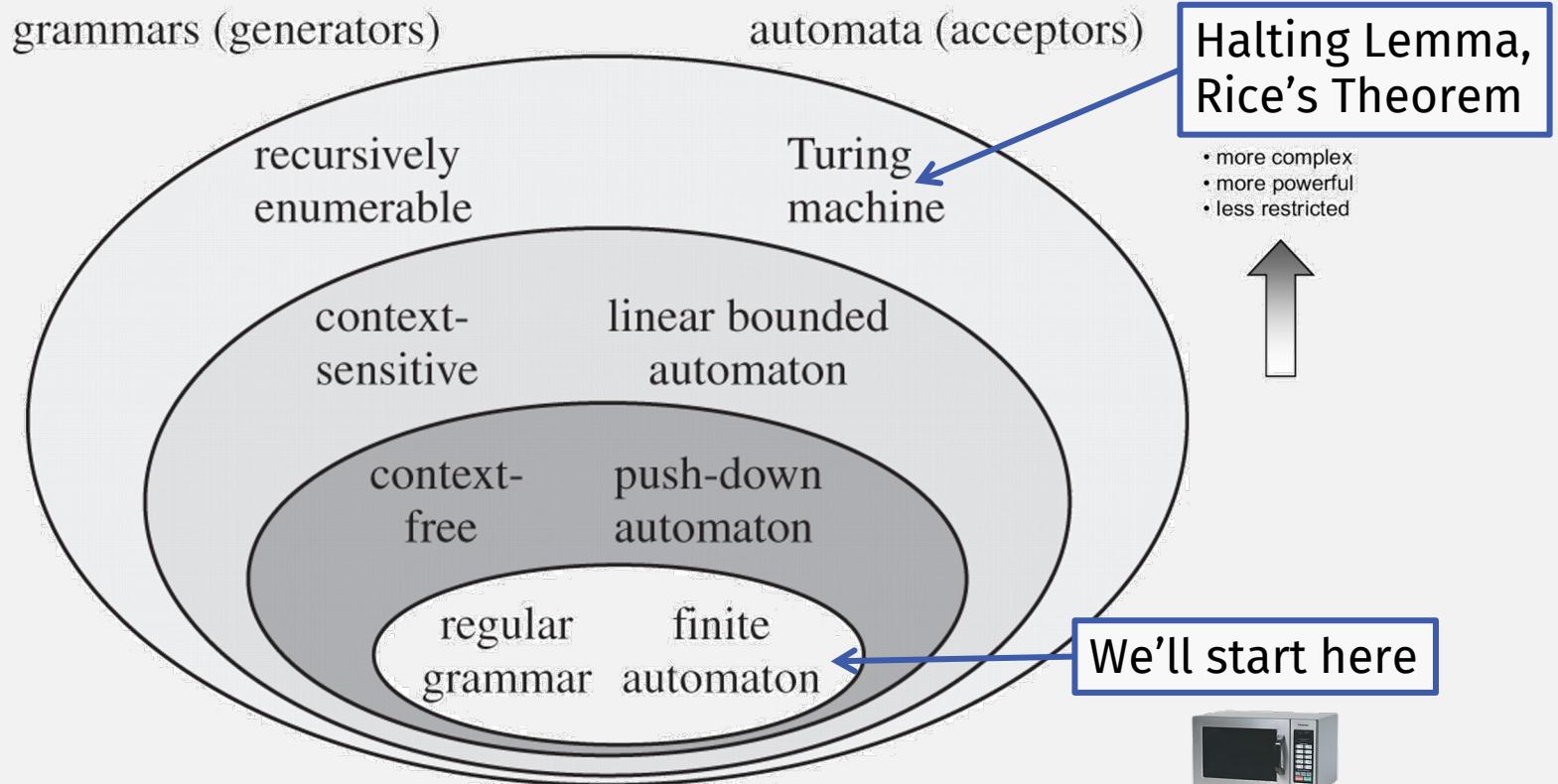
- The **Halting Lemma** says:
- And **Rice's Theorem** says:



- “all non-trivial, semantic properties of programs are undecidable”
- Actually:
 - it depends on the computation model!

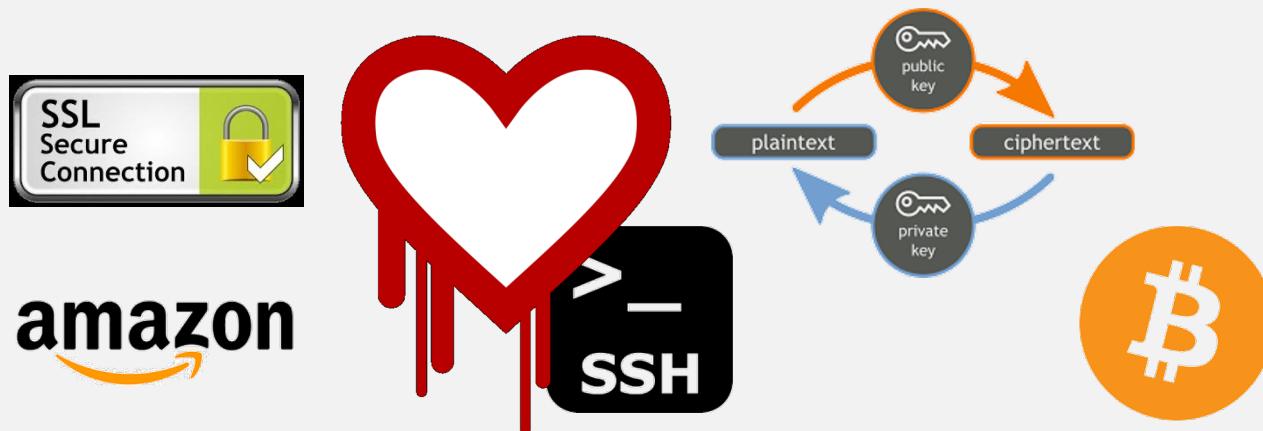


Many levels of computational power



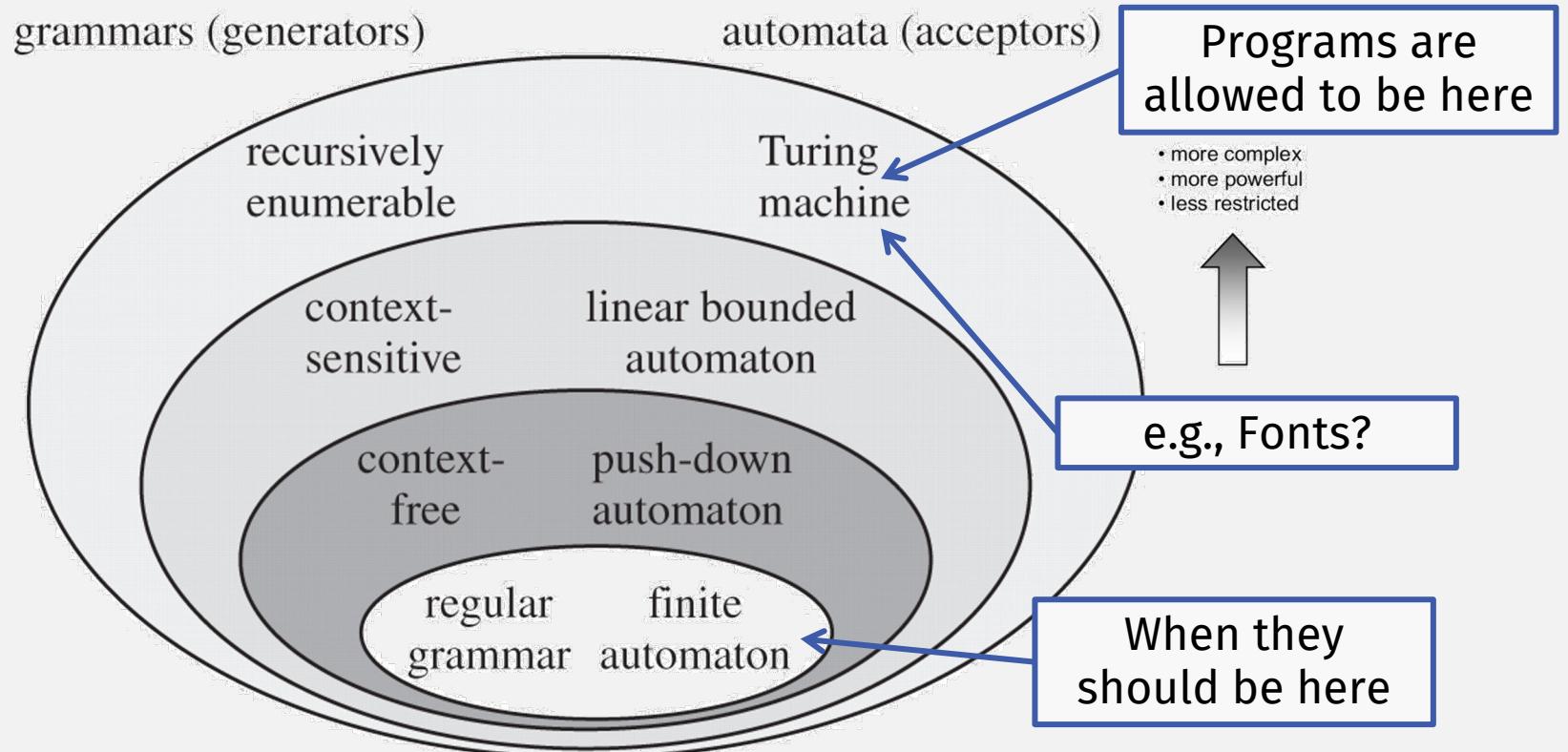
And Knowing What Computers Can't Do is Still Useful!

- In Cryptography:
 - Perfect secrecy is impossible in practice
 - But with slightly imperfect secrecy
(i.e., a computationally bounded adversary):

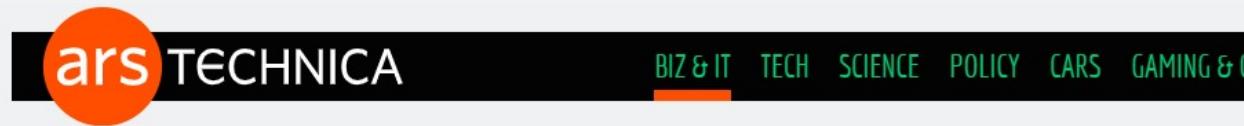


- But even if foundations are mathematically sound, problems remain:
 - E.g., with users, with implementors

Programs running programs: How much power to give?



What computing power should fonts have?



IN THE WILD —

Windows code-execution zero-day is under active exploit, Microsoft warns

There's no patch available now. Here's what to do until Microsoft issues one.

DAN GOODIN - 3/23/2020, 3:40 PM

The font-parsing remote code-execution vulnerability is being used in "limited targeted attacks," against Windows 7 systems, the software maker said in an [advisory published on Monday morning](#). The security flaw exists in the Adobe Type Manager Library, a Windows DLL file that a wide variety of apps use to manage and render fonts available from Adobe Systems. The vulnerability consists of two code-execution flaws that can be triggered by the improper handling of maliciously crafted master fonts in the Adobe Type 1 Postscript format. Attackers can exploit them by convincing a target to open a booby-trapped document or viewing it in the Windows preview pane.

What power should smart contracts have?



The New York Times

A Hacking of More Than \$50 Million Dashes Hopes in the World of Virtual Currency

By Nathaniel Popper

June 17, 2016

The specific mechanism the hackers used is known as a recursive call vulnerability, — essentially a malicious transaction that moves money away from the D.A.O. into a side fund in an endlessly repeating loop.

What computing power should ____ have?

- More computing power = more possibilities
 - But also less secure, because it's harder to predict all scenarios

NEWS

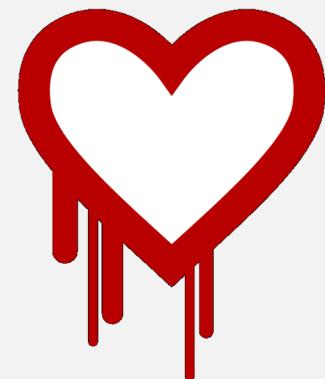
Understanding the
Rosetta Flash
vulnerability

14 August 2014 by Ange Albertini

Android 'Master Key' Security Hole Puts 99% Of Devices At Risk Of Exploitation

Natasha Lomas @riptari 9:20 am EDT • July 4, 2013

 Comment



Efficient algorithms

Big O (complexity) is such an important concept that we dedicate the longest chapter in the book to it.

Big O time is the language and metric we use to describe the efficiency of algorithms. Not understanding it thoroughly can really hurt you in developing an algorithm. Not only might you be judged harshly for not really understanding Big O, but you will also struggle to judge when your algorithm is getting faster or slower.

Master this concept.

Gayle Laakmann, “Cracking the Coding Interview”

Why study the theory of computation?

- When using computers to solve problems, it's often important to understand whether a given problem is computable and/or tractable.
- If it's not tractable, is there a suitable variant or approximation that is tractable?
- How do we compare the efficiency and effectiveness of proposed methods for solving the problem?
- Certain specific techniques have practical applications, including reductions, regular expressions, and automata theory
- Idealized models give we programmers insights

Programming in Linux: Basics

(15 minute crash course)

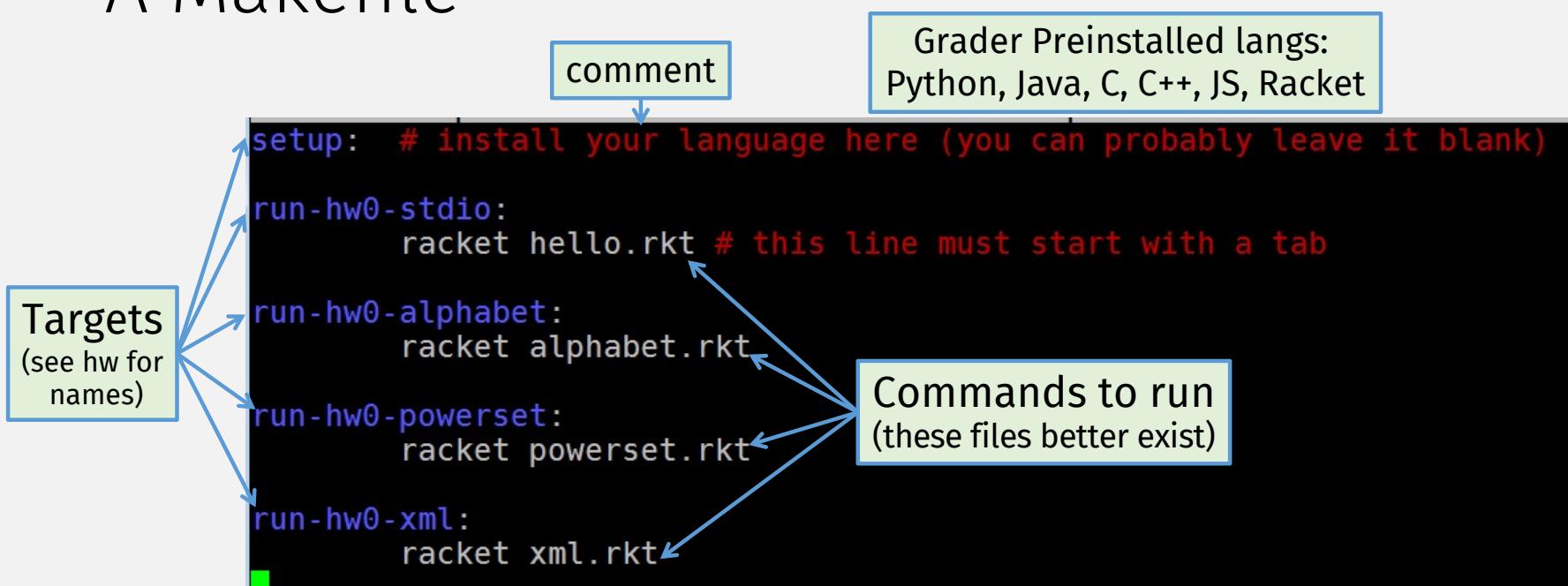
Code Demo

- `stdin`, `stdout`
- command line
- command line scripts
- `Makefiles`

Why makefiles?

Two reasons.

A Makefile



HW 0 Questions?

Check-In Quiz (see gradescope)