What is Computer Science at Duke?

Did you mean: duke computer science

Computer Science - Duke University
The Department of Computer Science at Duke University excels in learning, and engages with the broader community at www.cs.duke.edu/ - 9k - Cached - Similar pages - Note this
Big Ideas in Computer Science

● “Mathematics is the Queen of the Sciences”
  Carl Friedrich Gauss

● What is Computer Science?
  ➢ Why study it, what is it, why is it interesting (or not)?

● Historically
  ➢ What can we program, what can we program efficiently

● Present
  ➢ Lots of data, lots of connectivity, lots of inferences

● Future
  ➢ Where do we go from here?
What can be programmed?

- **What class of problems can be solved?**
  - G5, 1000Mhz Pentium III, Cray, pencil?
  - Alan Turing proved some things, hypothesized others
    - Halting problem, Church-Turing thesis

- **What class of problems can be solved efficiently?**
  - Problems with no practical solution
    - What does practical mean?
  - Problems for which we can’t find a practical solution
    - Solving one solves them all
    - Would you rather be rich or famous?
Schedule students, minimize conflicts

- **Given student requests, available teachers**
  - write a program that schedules classes
  - Minimize conflicts

- **Add a GUI too**
  - Web interface
  - ...
  - ...

I can’t write this program because I’m too dumb
One better scenario

I can’t write this program because it’s provably impossible
Another possible scenario

I can’t write this program but neither can all these famous people
Entscheidungsproblem

- What can we program?

- What can't we program?

- Can we write a program that will determine if any program $P$ will halt when run on input $S$?
  - Input to halt: $P$ and $S$
  - Output: yes/no halts
What Computers Can’t Do?

Digitizing Books One Word at a Time

Type the two words:

Submit

The words above come from scanned books. By typing them, you help to digitize old texts.
Good sites: [http://del.icio.us/](http://del.icio.us/)

- **What is social bookmarking?**
  - Why is del.icio.us interesting?
  - Who posts, who visits?

- **What about a website of interesting websites?**
  - What would you expect to find there?
  - Would the site list itself?

- **What about sites that list/link to themselves?**
  - What about a site with all sites that list themselves?
Bad sites: http://haz.ardo.us

- Sites listing bad sites (don't visit them?)
  - Where would this be useful?
  - What about censorship (internationally?)
  - Is this a good site or a bad site?

- What about sites that list/link themselves?
  - Is haz.ardo.us there?

- Website of all the sites that don't list themselves?
  - Is notlisted.com listed on notlisted.com?
The halting problem: writing doesHalt

```java
public class ProgramUtils {
    /**
     * Returns true if progname halts on input,
     * otherwise returns false (progname loops)
     */
    public static boolean doesHalt(String progname, String input) {
    }
}
```

- A compiler is a program that reads other programs as input
  - Can a word counting program count its own words?
- The `doesHalt` method might simulate, analyze, ...
  - One program/function that works for any program/input
How to tell if Foo stops on 123 456

```java
public static void main(String[] args) {
    String prog = "Foo.java";
    String input = "123 456"
    if (ProgramUtils.doesHalt(prog,input)){
        System.out.println(prog+" stops");
    }
    else {
        System.out.println(prog+" 4ever");
    }
}

- Can user enter name of program? Input?
  - What's the problem with this program?
```
Consider the class *Confuse.java*

```java
public static void main(String[] args){
    String prog = "Foo.java";
    if (ProgramUtils.doesHalt(prog, prog)) {
        while (true) {
            // do nothing forever
        }
    }
}
```

- **We want to show writing `doesHalt` is impossible**
  - Proof by contradiction:
    - Assume possible, show impossible situation results

- **Can a program read a program? Itself?**
Can we write Confuse.java?

- Legal if doesHalt exists
  - What have we assumed?
- What are consequences of running confuse on itself?
  - Trouble?

```
P
\rightarrow
\text{DoesHalt}
\rightarrow
S
```

```
\text{confuse}
\rightarrow
\text{confuse}
\rightarrow
\text{if DoesHalt(.,.,.) loop}
\rightarrow
\text{else exit}
\rightarrow
```
Not impossible, but impractical

- **Towers of Hanoi**
  - How long to move n disks?

- **What combination of switches turns the light on?**
  - Try all combinations, how many are there?
  - Is there a better way?
Travelling Salesperson

- Visit every city exactly once
- Minimize cost of travel or distance
- Is there a tour for under $2,000? less than 6,000 miles?
- Is close good enough?
  - Within 10% of optimal
  - Within 50% of optimal
  - ...

Try all paths, from every starting point -- how long does this take?

a, b, c, d, e, f, g
b, a, c, d, e, f, g ...
Travelling Salesman: XKCD 399

BRUTE-FORCE SOLUTION: \(O(n!)\)

DYNAMIC PROGRAMMING ALGORITHMS: \(O(n^2 2^n)\)

SELLING ON EBAY: \(O(1)\)

STILL WORKING ON YOUR ROUTE?

SHUT THE HELL UP.
Are hard problems easy?

- $P$ = easy problems, $NP$ = "hard" problems
  - $P$ means solvable in polynomial time
  - Difference between $N, N^2, N^{10}$?
  - $NP$ means non-deterministic, polynomial time
    - guess a solution and verify it efficiently
- Question: $P = NP$?
  - if yes, a whole class of difficult problems, the NP-complete problems, can be solved efficiently
  - if no, none of the hard problems can be solved efficiently
  - showing the first problem was NP complete was an exercise in intellectual bootstrapping, satisfiability/Cook/(1971)
Theory and Practice

- **Number theory: pure mathematics**
  - How many prime numbers are there?
  - How do we factor?
  - How do we determine primeness?

- **Computer Science**
  - Primality is “easy”
  - Factoring is “hard”
  - Encryption is possible

public-key cryptography
randomized primality testing
Useful Computer Science

How does this work?

- [http://tinyurl.com/2t57jc](http://tinyurl.com/2t57jc)
In Re Boucher 2007 WL 4246473
Courses of Study

- What do you take first?
- What’s next?
- In between?
- Who teaches what?