CS3233
Competitive Programming

Dr. Steven Halim

Week 01 – Introduction

Outline

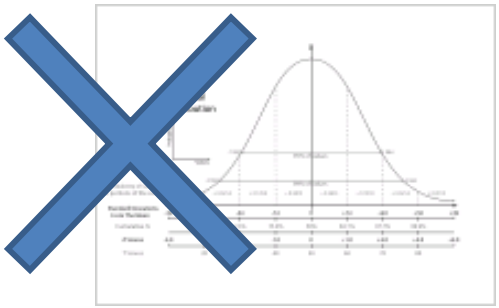
- Course Administration
  - Break 1, Clicker, CP2.9 order (~6.30-6.45pm)
- Competitive Programming Book (2.9th Ed), Ch 1
  - Competitive Programming: Live Demo
  - Tips to be Competitive: Hands on ☺, join me
  - Break 2 (~7.50-8.00pm)
- Mooshak: First Mock Contest & Discussion
  - 45 minutes contest: 2 “easy” + 1 “medium” problems

Course Administration (1)

- Teaching Staffs:
  - Lecturer:
    - Dr. Steven Halim: stevenhalim at gmail
      - Add me in Facebook if you haven't done so
      - www.facebook.com/groups/236210576509653
      - uhunt.felix-halim.net/id/32900
    - Email subject format: "[CS3233]-MESSAGE"
    - Office & Phone: COM2-3-37 & 6516-7361
  - Teaching Assistant:
    - Huang Da: a0091847 at nus edu sg

Course Administration (2)

- Modular Credit: 4
- Not a hard module (to score)*
  - No Final Exam (yippie)
  - "No" bell curve grading system
  - Grade History:



S2 of AY	# Stu	# A+/A/A-	# B+	< B+
2008/09	21	19	1	1
2009/10	12	11	1	0
2010/11	17	13	2	2
2011/12	24	15	6	3

58/74 = 78% students got A- or above ☺

68/74 = 92% students got B+ or above ☺

Course Administration (3)

- Class timetable:
  - Wednesday, 6-9 (or 10*) pm @ **COM1-B-PL2**
  - Week01 to Week13, minus recess week
- Course Website:
  - IVLE, search CS3233 (of S2 AY 2012/13)
    - http://www.comp.nus.edu.sg/~cs3233 is **not** used
  - Details about Syllabus/Lesson Plan/Workload/ Assessment are all there

CS3233 vs CS1010/CS1101S

- In CS1010 (or CG1101)/CS1101S
  - You learn how to create programs
- In CS3233
  - I assume that you are good at that
    - You can use C++ or Java for contests/homework
      - C++ is the main language in CS3233
      - Java is the second language in CS3233
      - However, mastering both is **an advantage** in CS3233
      - Scheme (CS1101S) and Pascal are NOT supported!
    - Please reconsider if you do not like coding!

CS3233 vs CS1020/CS2020 1st half

- In CS1020/CS2020 1st half
  - You learn some well-known linear data structures and algorithms
- In CS3233
  - We only revisit them in the first two weeks++
    - Then, we show how those DSes and algorithms can be coded into computer programs quickly and effectively
    - Please reconsider if you passed this module with difficulty (although you scored A- or above)!

CS3233 vs CS2010/CS2020 2nd half

- In CS2010/CS2020 2nd half
  - You learn one-fifth of CS3233 materials
    - Graph (~4 weeks/lectures)
    - Dynamic Programming (~3 weeks/lectures)
- In CS3233
  - We revisit them in just one and half weeks (Week04 + Help session of Week05)
    - With emphasis on implementation speed…
    - Then we will learn much more ☺…
      - The pre-req of CS3233 is A- in CS2010/CS2020; ***CS3233 is now designed with this assumption*** (verbal details)

CS3233 versus CS3230

- In CS3230
  - You learn more well-known algorithms (mostly analysis/proofs)
- In CS3233
  - We learn how to implement them plus several (lots?) additional topics outside CS3230 (hands-on)
    - We do not discuss their theoretical background in depth!
    - Please reconsider if you are not prepared to learn many new things
  - Side note: It may be good to take both CS3230/CS3233 in the same sem (verbal explanation)

CS3233 versus Other Modules

- Obtaining ~52%* (verbal explanation) from total marks is already enough to get a good grade (B+)
  - In normal module, this is usually a 'C+' grade… ☹
  - I repeat, in the last four years:
    - ~78% got at least A- ☺ and ~92% got at least B+ ☺
- Higher chance* to represent NUS in the Annual ACM International Inter-Collegiate Programming Contest (ICPC)
  - Free trip(s) to a few Asian countries^ – Regionals 2013
  - And perhaps to World Finals 2014

In CS3233
but not in other SoC CS modules

- This information is true for S2 AY 2013/2014 version:
  - Heavy usage of bitmask operations (for backtracking, DP, etc)
  - Binary Indexed (Fenwick) Tree
  - State-Space Search
  - Meet in the Middle (Bidirectional Search)
  - Various DP tricks (*much more* than CS3230/2020/2010)
  - Network Flow and Graph Matching (not in CS2020/2010 but maybe in CS5234 – Comb and Graph Algorithms)
  - Various Mathematics algorithms and tricks
  - Suffix Array (CS5238 – Adv Comb Methods in BioInfo)
  - Convex Hull, Cut Polygon (CS5237 – Comp Geo & Apps)
  - And some mysterious stuffs…

CS3233 Lecturer History

- Initiated by Prof Andrew Lim (CUHK): 1999-2001
  - Vacuum in AY 2002/03… ☹
- Between 2004-2006, CS3233 was taught by A/P Leong Hon Wai and A/P Ooi Wei Tsang
  - Another vacuum in AY 2007/08… ☹
- Revived again* on semester 2, 2008/09 ☺
- Note: Each lecturer has different style…
  - Mine is geared towards ICPC (and also IOI) preparation
  - But have now been calibrated to match the level of typical second upper/first class students in NUS

SoC Teams Performance History (1)

- ACM ICPC World Finals
  - 1999: Joint-18
  - 2000: Joint-22
  - 2001: Joint-29
  - 2003: Joint-13
  - 2005: Melvin, Junbin, Yunsong: Hon. Mention
  - 2009/Stockholm, Sweden: Duc, Tien, Phong: Hon. Mention
  - 2010/Harbin, China: Duc, Tien, Phong: Hon. Mention
  - 2011: Miss out by 2 ranks ☹
  - 2012/Warsaw, Poland: Zi Chun*, Harta*, Phuong*: Hon. Mention
  - 2013/St Petersburg, Russia: Harta*, Phuong*, Sy Nguyen*

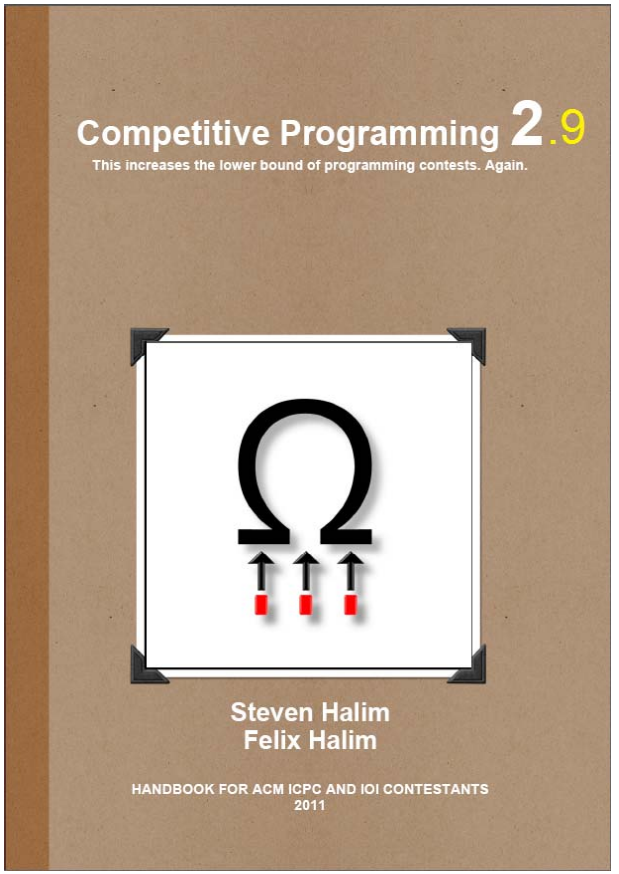
SoC Teams Performance History (2)

- Recent ACM ICPC Regional Contests
  - 2008: 6th in Amritapuri; 3rd in Kanpur; Joint-15th & Joint-16th in KL
  - 2009: 7th & 10th in Jakarta; 3rd in Manila; 2nd and 10th in Phuket
  - 2010: 10th in Daejeon; 6th* in Kuala Lumpur; 10th in Tokyo
  - 2011: 7th* in Phuket; 5th* in Kuala Lumpur
  - 2012: 3rd in Jakarta; not so lucky in Hat Yai
  - 2013: YOUR TURN for World Finals 2014 (or 2015)!
- More history in:
  - http://algorithmics.comp.nus.edu.sg/wiki/

SoC Current Strengths

- Teaching Staffs and Seniors:
  - A/P Tan, Dr Steven, Suhendry, Zi Chun*, Harta Wijaya*, Tuan Phuong*, Sy Nguyen*, etc
    - * ex/current-World Finalists currently in SoC
  - Singapore IOI Teams 2010-2012
    - 2 Golds, 4 Silvers, and 5 Bronzes by this team over the past 3 years
  - Leaving/already left/not in SG:
    - Minh Duc (@ FB), Duc Phong, Hoanh Tien, Victor Loh (@ FB), Felix Halim (@ Google), Su Zhan (@ Google)
- Current Students:
  - Many potential students (YOU ALL)…

Textbook



- Competitive Programming 2.9
  - It will be CP3 by May 2013, **with your inputs**
- COMPULSORY!!
- 30 SGD/copy (for fresh purchase)
  (15 SGD discount if you can show me that you already have CP2.5/CP2/CP1)
- You can pre-order tonight, I will print by Week02
  - Ch1.pdf has been sent to you on 1 Jan 2013
- Public version (simplified form), is in:
  http://sites.google.com/site/stevenhalim/home/material

Clicker Distribution + CP2.9 Order (15 Minutes Break)

- During the break:
  - I will distribute clickers
    - In this small class, each of you must take one clicker
  - You can discuss administrative issues with me (i.e. should I take this module or not?, etc)
    - In NUS, drop with 'W' grade is after Week 02!
  - Order "Competitive Programming 2.9" textbook

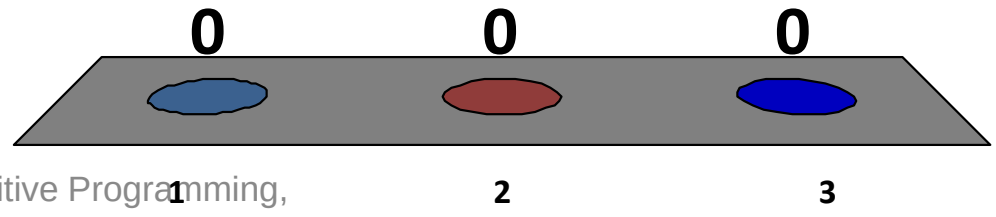
Time Check:
6.30pm

This is the new standard.

COMPETITIVE PROGRAMMING 2.9

Who have read CP2.5/2/1?

1. I have only pre-order CP2.9, so 0 page so far…
2. Most of chapter 4 and a bit of chapter 3 due to CS2020/CS2010 (CP2.5)
3. I have read and understand most of it, but I want to know what are the new stuffs in CP2.9 ☺



Competitive Programming

- Given well-known Computer Science problems, solve them as fast as possible!
  - Not about "software engineering"
  - Solve judge's test data correctly
  - Run fast enough
  - Well-known = not research problems!
  - Problems in our target contests (ACM ICPC & IOI) have this characteristic!

Demo (UVa 10684 – The jackpot)

- This exaggerated demo illustrate contestant's type:
  - The blurry one
  - Give up
  - Slow
  - Competitive programmer
  - Very competitive programmer

CP2.9, Chapter 1
(if you have read ahead, good ☺,
help the rest by answering the pop-quizzes)

TIPS TO BE COMPETITIVE

Tip 1: Type Fast & Correct

- No kidding, this can be important!
- Let's try
  - http://www.typingtest.com
    - ZEBRA – Africa's Striped Horse
  - Mine: ~85-90 wpm
  - Felix's: ~55-65 wpm
- Familiarize yourself with the positions of the following keyboard keys:
  - (,),{,},[,],<,>,',",&,|,!,etc

Tip 2: Identify Problem Types

- Ad Hoc
- Complete Search
- Divide and Conquer
- Greedy
- Dynamic Programming
- Graph
- Mathematics
- String Processing
- Comp. Geometry
- Some Harder Ones

Quick Test – Identification

- What is the type of this problem?
  - And how many minutes that you think you will need to solve this problem?

- Given an M*N **integer** matrix Q (1 <= M, N <= 50), check if there exists a sub-matrix of Q of size **A*B** (1 <= A <= M, 1 <= B <= N) where mean(Q) = 7?

Tip 3: Do Algorithm Analysis

- This is taught in more details in CS3230!
- In this module, we will just learn the *basics* required for dealing with ICPC/IOI problems
  - See the constraints in the problem statement
  - Conjure the simplest algorithm that works!
  - Do some basic analysis to convince that it will work *before* we start coding…

Tip 4: Master Prog Languages

- You should master at least one (preferably more) programming languages
  - Reduce the amount of time looking at references
  - Use shortcuts, macros, avoid comments
  - Use libraries whenever possible
- Idea: Once you figure out a solution for a problem, you are able to translate it into a bug-free code, and do it fast!

Tip 5: The Art of Testing Code

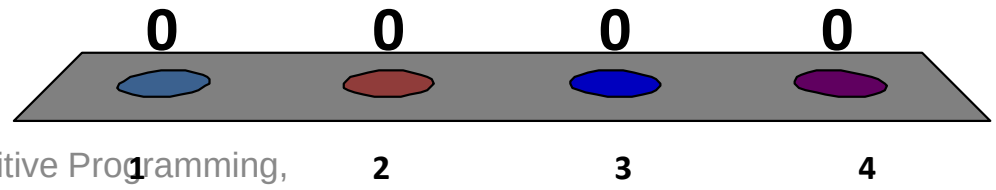
- Ultimately, we want "Accepted (AC)" verdict ☺
  - i.e. Our code passes the judge's secret test data
- However, we may instead be given: ☹
  - Presentation Error (PE)
  - Wrong Answer (WA)
  - Time Limit Exceeded (TLE)
  - Memory Limit Exceeded (MLE)
  - Runtime Error (RTE)

Tip 6: Practice…

- Relevant Online Judges
  - MAIN: University of Valladolid (UVa) Online Judge
    - http://uva.onlinejudge.org (Open with Firefox!)
  - MISC: ACM ICPC Live Archive
    - https://icpcarchive.ecs.baylor.edu
  - MISC: TopCoder
    - http://www.topcoder.com
  - MISC: USACO
    - http://train.usaco.org

I have…

1. Registered a free Uva account but have not solve anything
2. Have solved ≥ 1 UVa problems
3. Have solved ≥ 10 UVa problems
4. Have solved ≥ 40 UVa problems



Tip 7: Team Work (ICPC Only)

- Practice coding on a blank paper
- Submit and print strategy
- Prepare test data challenges
- The X-factor
- You will experience such team work in mid semester and final team contests ☺

LET'S START OUR JOURNEY

Anatomy of a Problem

- Background story/problem description
  - Can be deceiving…
- Input and Output description
  - Usually written in formal manner
  - Most new problems are *multiple test cases* problems
- Sample Input and Sample Output
  - Usually very trivial, you need to come up with stronger/trickier test cases by yourself
- Hints or Footnotes

Quick Note: Ad Hoc Problems

- Read CP2.9 Chapter 1 by yourself
- We will spend our remaining time discussing more interesting stuffs…

Linear Algorithms (1)

- What is an **O(n) solution** for a certain problem?
  - Really just one pass through all n elements
    - e.g. find the min/max element of an array with size n
  - k passes through all n elements, e.g. O(kn), k is 'small'
    - e.g. Find the second (k = 2) smallest element of an array
  - One (or 'a few') pass(es) through all elements with operations that runs in O(n) in *amortized sense*
  - One (or 'a few') pass(es) through all elements, with a help of a logarithmic cost Data Structure/extra component, e.g. O(n log n)
    - Adding a O(log n) component to an O(n)-loop usually does **NOT** significantly increase the runtime under contest settings!
      - You can treat this as "bonus"… (important for IOI)

Linear Algorithms (2)

- Several "rare" topics solvable with O(n) algorithms:
  1. Bracket Matching
  2. Postfix Calculator and Conversion (Shunting yard)
  3. (Static) Selection Problem
  4. Sorting in Linear Time
  5. Sliding Window
- I will present these problems *briefly*
- For more details about the solutions,
  please read Chapter 9 of CP2.9 on your own ☺

Bracket Matching

- ‘(())’, ‘({})’, ‘(){}[]’ are correctly matched braces
- ‘(()’, ‘(}’, ‘)(’ are NOT correct
- Can we detect if a given expression of braces are correctly matched in O(n)?

Postfix Calculator

- There are three well-known types of algebraic expressions:
  - Infix (our default setting), e.g. 2 + 6 * 3, (2 + 6) * 3
  - Prefix (Polish), e.g. + 2 * 6 3, * + 2 6 3
  - Postfix (Reverse Polish), e.g. 2 6 3 * +, 2 6 + 3 *
- Can we evaluate a Postfix expression in O(n)?

Postfix Conversion

- Given an infix expression (that may contain parentheses), e.g. (2 + 6) * 3,
  can we compute the equivalent postfix expression,
  e.g. 2 6 + 3 * in O(n)?

Static Selection Problem

- Given a static (unchanged) array A of n elements, can we find the k-th smallest element of A in O(n)?
  - e.g. for A = {2, 8, 7, 1, 5, 4, 6, 3}, n = 8,
    the 4-th smallest element is 4,
    the 8-th smallest element is 8, etc

Special-Purpose Sorting

- Given an array A of n small integers (each integer is between [0..100]), can we sort them in O(n)?
  - e.g. A = {0, 3, 0, 0, 1, 1} → {0, 0, 0, 1, 1, 3}
- What if the given array A has a range of 32-bit unsigned integers, e.g. from [0..2^{32}-1]?
  - e.g. A = {1, 1000000000, 2} → {1, 2, 1000000000}
- Isn't the lower bound of sorting is Ω(n log n)?

Sliding Window

- Given an array of n elements, can we find a smallest sub-array size so that the sum of the sub-array is greater than or equal to a certain constant S in O(n)?
  - e.g. for A = {1, 5, 1, 3, [**5, 10**], 7, 4, 9, 2, 8} and S = 15, the answer is 2 as highlighted
- Given an array of n elements, find the minimum of each possible sub-arrays with size K in O(n)!
  - e.g. for A = {0, 5, 5, 3, 10, 0, 4}, n = 7, and K = 3, we have 5 possible sub-arrays: {0, 5, 5}, {5, 5, 3}, {5, 3, 10}, {3, 10, 0}, and {10, 0, 4}. The minimum of each sub-array is 0, 3, 3, 0, 0, respectively

Next Week

- **CH2: Data Structures and Libraries**
  - Focus on bit manipulation and Binary Indexed (Fenwick) Tree
- No homework yet, but please try UVa!

skillset.xls Survey

- I want to measure your skillset (NUS students only)
  - But this is an optional task
- Download the file from:
  - https://sites.google.com/site/stevenhalim/home/material
  - See Week01
  - Fill it, rename it to “skillset-yourname.xls”
  - Upload to IVLE Workbin
- To save time, let’s do this at home
  - I will send a reminder ☺

10 Minutes Break

- In the last part of our first introductory class, you will familiarize yourself with **Linux controlled environment** in this PL2 and the **Mooshak system**, the internal online judge used for CS3233 this sem
  - Mock contest with 2 “easy” + 1 “medium” problems
  - Not graded yet ☺, enjoy it for fun
    (and to help you decide if you should take CS3233)

Time Check:
7.50pm

Mooshak

- Let's try this system
  - Open with **Firefox**
    (does not work well with most other browsers ☹):
    - http://algorithmics.comp.nus.edu.sg
  - Click "Online Judge (Login)" at the top left corner
  - Try "Mini0 (16 Jan 2013)"
  - Use user ids that have been emailed to you
    - For new participants use dummy IDs where pwd = uid
      - team01, team02, team03, …
      - I will tell who use which id