



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](mailto:stevenhalim@gmail.com)
 - 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

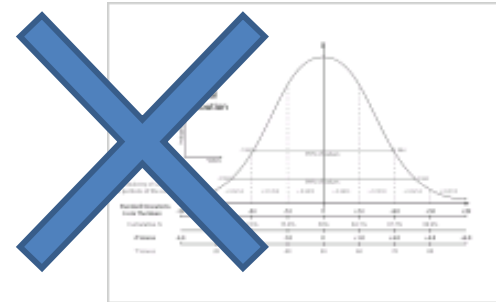
- Teaching Assistant:

- Huang Da: [a0091847 at nus edu sg](mailto:a0091847@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)

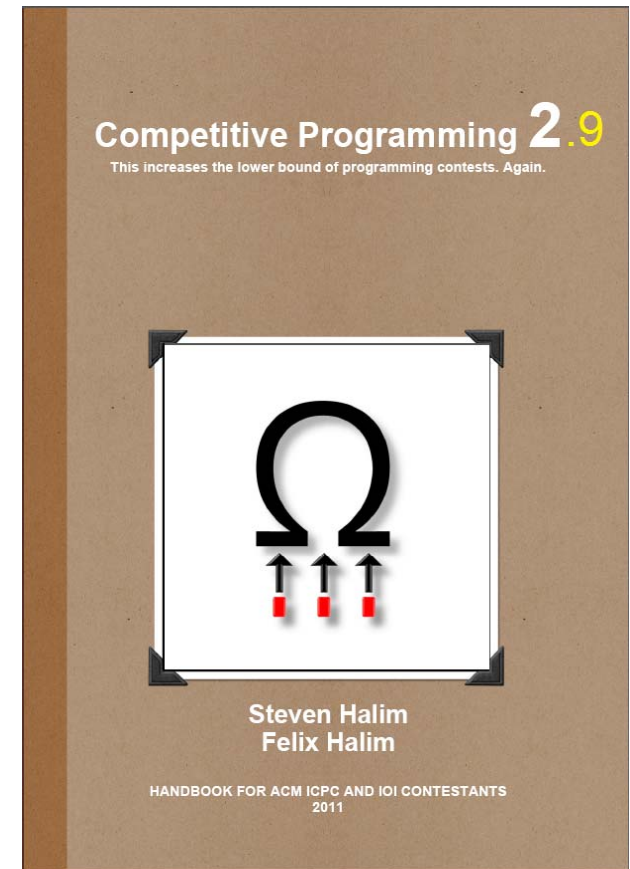
- Recent ACM ICPC Regional Contests
 - 2008: 6th in Amritapuri; 3rd in Kanpur; Joint-15th & Joint-16th in KL
 - 2009: 7th & 10th in Jakarta; 3rd in Manila; 2nd and 10th in Phuket
 - 2010: 10th in Daejeon; 6th* in Kuala Lumpur; 10th in Tokyo
 - 2011: 7th* in Phuket; 5th* in Kuala Lumpur
 - 2012: 3rd in 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)



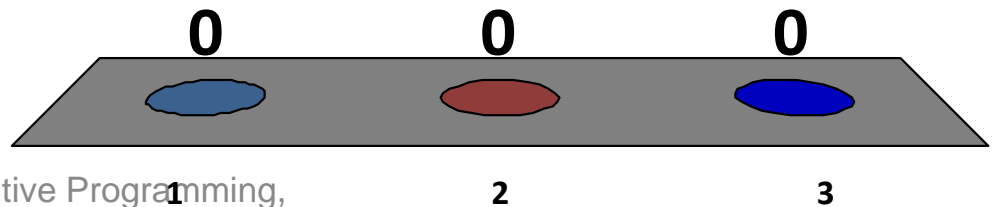
- During the break:
 - I will distribute clickers
 - In this small class, each of you must take one clicker
 - You can discuss administrative issues with me (i.e. should I take this module or not?, etc)
 - In NUS, drop with ‘W’ grade is after Week 02!
 - Order “Competitive Programming 2.9” textbook

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 $M \times N$ **integer** matrix Q ($1 \leq M, N \leq 50$), check if there exists a sub-matrix of Q of size $A \times B$ ($1 \leq A \leq M, 1 \leq B \leq N$) where $\text{mean}(Q) = 7$?

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> ACM-ICPC Live Archive

- MISC: TopCoder



- <http://www.topcoder.com>

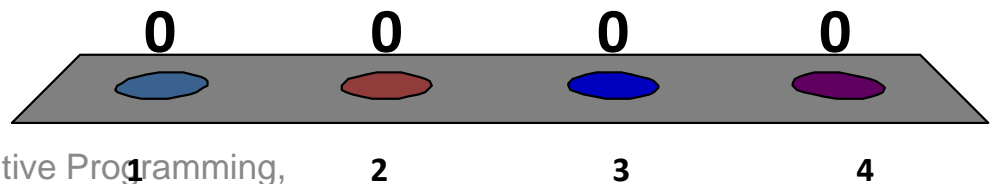
- MISC: USACO

- <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. $A = \{0, 3, 0, 0, 1, 1\} \rightarrow \{0, 0, 0, 1, 1, 3\}$
- What if the given array A has a range of 32-bit unsigned integers, e.g. from $[0..2^{32}-1]$?
 - e.g. $A = \{1, 1000000000, 2\} \rightarrow \{1, 2, 1000000000\}$
- Isn't the lower bound of sorting is $\Omega(n \log n)$?

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 $A = \{1, 5, 1, 3, \underline{5, 10}, 7, 4, 9, 2, 8\}$ 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)

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