Competitive Programming Syllabus

Geometry

- Graham Scan algorithm for Convex Hull O(n * log(n))
- Online construction of 3-D convex hull in O(n^2)
- Bentley Ottmann algorithm to list all intersection points of n line segments in O((n + I) * logn)
  - Suggested Reading - http://softsurfer.com/Archive/algorithm_0108/algorithm_0108.htm
- Rotating Calipers Technique
  - Suggested Reading - http://cgm.cs.mcgill.ca/~orm/rotcal.html
  - Problems - Refer the article for a list of problems which can be solved using Rotating Calipers technique.
- Line Sweep/Plane Sweep algorithms
- Area/Perimeter of Union of Rectangles.
- Closest pair of points.
  - Suggested Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=lineSweep
  - Problems - Follow the tutorial for list of problems.
- Area of Union of Circles.
- Delaunay Triangulation of n points in O(n * logn).
- Voronoi Diagrams of n points in O(n * logn) using Fortune's algorithm.
- Point in a polygon problem -
  - O(n) solution without preprocessing.
  - O(logn) algorithm with O(n * logn) preprocessing for convex polygons.
- Problems on computational geometry -
  - BSHEEP, BULK, SEGVIS, CONDUIT, RUNAWAY, DIRVS, RAIN1, SHAMAN, TCUTTER, LITEPIPE, RHOMBS, FSHEEP,
    FLBRKLIN, CERC07P, BAC, ALTARS, CERC07C, NECKLACE, CH3D, RECTANGL, POLYSSQ, FOREST2, KPPOLY, RAIN2, SEGMENTS, ARCHPLG, BALLOON, CIRCLES, COMPASS, EOWAMRT, ICERINK on SPOJ.
  - CultureGrowth, PolygonCover on Topcoder.
- Suggested Reading - Computational Geometry: Algorithms and applications. Mark De Burg.

String Algorithms

Substring search

- KnuthMorrisPratt algorithm (Problems - NHAY, PERIOD on SPOJ)
- Suggested Reading - Cormen chapter on Strings.
- http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=stringSearching
- Aho Corasick algorithm
- Problems - WPUZZLES on SPOJ

Suffix Arrays

- O(n^2 * logn) Naive method of suffix array construction
- O(n * logn^2) method of suffix array construction
- O(n * logn) method of suffix array construction
- O(n) method of suffix array construction
- O(n) LCA preprocess on Suffix Arrays to solve a variety of string problems

Suffix Trees

- O(n) construction of Suffix trees using Ukkonon's algorithm
- O(n) construction of Suffix Trees if provided with Suffix Arrays using Farach's algorithm

Other

- Suffix Automata - O(n) Suffix Automaton construction.
- Dictionary Of Basic Factors - O(n * logn) method of DBF construction using Radix Sort.
- Manacher's algorithm to find length of palindromic substring of a string centered at a position for each position in the string. Runtime -> O(n).
- Searching and preprocessing Regular Expressions consisting of '?' and '*'

Multi-dimensional pattern matching

- DISUBSTR, PLD, MSTRING, REPEATS, JEWELS, ARCHIVER, PROPKEY, LITELANG, EMOTICON, WORDS, AMCODES, UCODES, PT07H, MINSEQ, TOPALIN, BWHEELER, BEADS, SARRAY, LCS, LCS2, SUBST1, PHRASES, PRETILE on SPOJ
- http://www.algorithmist.com/index.php/Category:String_algorithms

Graphs

Basic Graphs

- Representation of graphs as adjacency list, adjacency matrix, incidence matrix and edge list and uses of different representations in different scenarios
- Breadth First Search (Problems - PPATH, ONEZERO, WATER on SPOJ)
- Depth First Search
- Strongly Connected Components (TOUR and BOTTOM on SPOJ)
- Biconnected Components, Finding articulation points and bridges (RELINETS, PT07A on SPOJ)
- Dijkstra algorithm (SHPATH on SPOJ)
- Floyd Warshall algorithm (COURIER on SPOJ)
- Minimum Spanning Tree (BLINNET on SPOJ)
- Flood-fill algorithm
- Topological sort
- Bellman-Ford algorithm.
- Euler Tour/Path (WORDS1 on SPOJ)
- Suggested reading for most of the topics in Graph algorithms - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=graphsDataStrucs1.
- Also refer to the tutorial for problems concerning these techniques.
- Cormen chapter 22 to 24.

Flow networks/ matching

- Maximum flow using Ford Fulkerson Method
  - Suggested Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=maxFlow
  - problems - TAXI, POTHOLE, IM, QUEST4, MUDDY, EN, CABLETV, STEAD, NETADMIN, COCONUTS, OPTM on SPOJ.
- Maximum flow using Dinic's Algorithm (PROFIT on spoj)
- Minimum Cost Maximum Flow.
- Successive Shortest path algorithm.
- Cycle Cancelling algorithm - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=minimumCostFlow1
- Maximum weighted Bipartite Matching (Kuhn Munkras algorithm/ Hungarian Method)
  - problems - GREED, SCITIES, TOURS on SPOJ | http://www.topcoder.com/stat?c=problem_statement&pm=8143
- Stoer Wagner min-cut algorithm.
- Hopcroft Karp bipartite matching algorithm (ANGELS on SPOJ)
- Maximum matching in general graph (blossom shrinking)
- Gomory-Hu Trees (MCQUERY on Spoj)
- Chinese Postman Problem
  - problems - http://acm.uva.es/archive/nuevoportal/data/problem.php?p=4039

    - Suggested Reading - http://eie507.eie.polyu.edu.hk/ss-submission/B7a/
- Suggested Reading for the full category ->
- Network flow - Algorithms and Applications by Ahuja
- Cormen book chapter 25.

Dynamic Programming.

- Suggested Reading - Dynamic Programming(DP) as a tabulation method
- Cormen chapter on DP
- Standard problems (you should really feel comfortable with these types)
    - http://www.topcoder.com/stat?c=problem_statement&pm=8570&rd=12012&rm=269199&cr=7581406
    - http://www.topcoder.com/stat?c=problem_statement&pm=10765&rd=14183
- State space reduction
    - http://www.topcoder.com/stat?c=problem_statement&pm=10902
    - http://www.topcoder.com/stat?c=problem_statement&pm=3001
    - http://www.topcoder.com/stat?c=problem_statement&pm=8605&rd=12012&rm=269199&cr=7581406
- Solving in the reverse - easier characterizations looking from the end
    - http://www.spoj.pl/problems/MUSKET
    - http://www.topcoder.com/stat?c=problem_statement&pm=5908
- Counting/optimizing arrangements satisfying some specified properties
    - http://www.topcoder.com/stat?c=problem_statement&pm=8306
    - http://www.topcoder.com/stat?c=problem_statement&pm=784
- Strategies and expected values
    - http://www.topcoder.com/stat?c=problem_statement&pm=10765&rd=14183
    - http://www.topcoder.com/stat?c=problem_statement&pm=10806
    - http://www.topcoder.com/stat?c=problem_statement&pm=7828
    - http://www.topcoder.com/stat?c=problem_statement&pm=7316
- DP on probability spaces
    - http://www.topcoder.com/stat?c=problem_statement&pm=7422
    - http://www.topcoder.com/stat?c=problem_statement&pm=2959
    - http://www.topcoder.com/stat?c=problem_statement&pm=10335
- DP on trees
    - http://www.topcoder.com/stat?c=problem_statement&pm=10800
    - http://www.topcoder.com/stat?c=problem_statement&pm=10737
    - http://www.topcoder.com/stat?c=problem_solution&rm=266678&rd=10958&pm=8266&cr=7581406
    - DP with data structures
    - http://www.spoj.pl/problems/INCSEQ/
    - http://www.spoj.pl/problems/INCDSEQ/
    - http://www.spoj.pl/problems/LIS2/
    - http://www.topcoder.com/stat?c=problem_statement&pm=1986
- Symmetric characterization of DP state
    - http://www.topcoder.com/stat?c=problem_statement&pm=8610
- A good collection of problems
    - http://codeforces.com/blog/entry/325
    - http://problemclassifier.appspot.com/index.jsp?search=dp

Greedy

- Chapter on Greedy algorithms in Cormen
- http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=greedyAlg
- Problems - refer to the topcoder tutorial.

Number Theory

Modulus arithmetic

- Basic postulates (Including modular linear equations, Continued fraction and Pell's equation)
- Suggested Reading -
  - Chapter 1 from Number Theory for Computing by SY Yan (Recommended)
  - 31.1, 31.3 and 31.4 from Cormen
  - www.topcoder.com/tc?module=Static&d1=tutorials&d2=primeNumbers
- Problems
  - http://projecteuler.net/index.php?section=problems&id=64
  - http://projecteuler.net/index.php?section=problems&id=65
  - http://projecteuler.net/index.php?section=problems&id=66
  - http://www.topcoder.com/stat?c=problem_statement&pm=6408&rd=9826
  - http://www.topcoder.com/stat?c=problem_statement&pm=2342

Fermat's theorem, Euler Totient theorem (totient function, order, primitive roots)

- Suggested Reading
  - 1.6, 2.2 from Number Theory by SY Yan
  - 31.6 , 31.7 from Cormen
- Problems
  - http://projecteuler.net/index.php?section=problems&id=70
  - http://www.spoj.pl/problems/NDIVPHI/

Chinese remainder theorem

- Suggested Reading
  - 31.5 from Cormen
  - 1.6 from Number Theory by SY Yan
- Problems
  - Project Euler 271
  - http://www.topcoder.com/stat?c=problem_statement&pm=10551&rd=13903

Primality tests

- Deterministic O(sqrt(n)) approach
- Probabilistic primality tests - Fermat primality test, Miller-Rabin Primality test
- Suggested Reading -
  - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=primalityTesting
  - Cormen 31.8
  - 2.2 from Number Theory by SY Yan
- Problems
  - PON, PRIC, SOLSTRAS on SPOJ
  - http://www.topcoder.com/stat?c=problem_statement&pm=4515
- Prime generation techniques - Sieve of Erastothenes (PRIME1 on SPOJ)

GCD using euclidean method

- Suggested Reading - 31.2 Cormen
- Problems
  - GCD on SPOJ
  - http://uva.onlinejudge.org/external/114/11424.html

Logarithmic Exponentiation

- Suggested Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=primalityTesting

Integer Factorization

- Naive O(sqrt(n)) method
- Pollard Rho factorization
- Suggested Reading
  - 2.3 from Number Theory SY Yan
  - 31.9 Cormen
- Problems -
  - http://www.topcoder.com/stat?c=problem_statement&pm=2986&rd=5862
  - http://www.spoj.pl/problems/DIVSUM2/
  - http://www.topcoder.com/stat?c=problem_statement&pm=4481&rd=6538

Other

- Stirling numbers
- Wilson theorem
- nCr % p in O(p) preprocess and O(log n) query
- Lucas Theorem
- Suggested Reading for Number Theory -
  - Number theory for computing by Song Y Yan (Simple book describing concepts in details)
  - Concepts are also superficially covered in Chapter 31 of Introduction to Algorithms by Cormen
  - http://www.codechef.com/wiki/tutorial-number-theory
  - http://www.algorithmist.com/index.php/Category:Number_Theory
- Problems on Number Theory -
  - http://www.algorithmist.com/index.php/Category:Number_Theory
  - http://problemclassifier.appspot.com/index.jsp?search=number&usr=

Math (Probability, Counting, Game Theory, Group Theory, Generating functions, Permutation Cycles, Linear Algebra)

Probability

- Basic probability and Conditional probability
  - http://www.spoj.pl/problems/CT16E/
  - http://www.spoj.pl/problems/CHICAGO/
- Random variables, probability generating functions
- Mathematical expectation + Linearity of expectation
  - http://www.spoj.pl/problems/FAVDICE/
  - http://www.topcoder.com/stat?c=problem_statement&pm=10744
- Special discrete and continuous probability distributions
  - Bernoulli, Binomial, Poisson, normal distribution
  - http://acm.sgu.ru/problem.php?contest=0&problem=498
- Suggested Readings
  - Cormen appendix C (very basic)
  - Topcoder probabilty tutorial http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=probabilities
  - http://en.wikipedia.org/wiki/Random_variable
  - http://en.wikipedia.org/wiki/Expected_value
  - William Feller, An introduction to probability theory and its applications

Counting

- Basic principles - Pigeon hole principle, addition, multiplication rules
- Problems
  - http://acm.timus.ru/problem.aspx?space=1&num=1690

    - http://www.topcoder.com/stat?c=problem_statement&pm=10805
- Suggested readings
    - http://en.wikipedia.org/wiki/Combinatorial_principles
    - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=combinatorics
    - http://www.maa.org/editorial/knot/pigeonhole.html
- Inclusion-exclusion
    - http://en.wikipedia.org/wiki/Inclusion–exclusion_principle
    - http://www.topcoder.com/stat?c=problem_statement&pm=4463&rd=6536
    - http://www.topcoder.com/stat?c=problem_statement&pm=10238

Special numbers

- Stirling, eurlerian, harmonic, bernoulli, fibonnacci numbers
- http://en.wikipedia.org/wiki/Stirling_number
- http://en.wikipedia.org/wiki/Eulerian_numbers
- http://en.wikipedia.org/wiki/Harmonic_series_(mathematics)
- http://en.wikipedia.org/wiki/Bernoulli_number
- http://en.wikipedia.org/wiki/Fibonnaci_numbers
- Concrete mathematics by Knuth
- Suggested problems
    - http://www.topcoder.com/stat?c=problem_statement&pm=1643
    - http://www.topcoder.com/stat?c=problem_statement&pm=8202&rd=11125
    - http://www.topcoder.com/stat?c=problem_statement&pm=8725
    - http://www.topcoder.com/stat?c=problem_statement&pm=2292&rd=10709

Advanced counting techniques - Polya counting, burnsides lemma

- Suggested reading
    - http://en.wikipedia.org/wiki/Burnside's_lemma
    - http://petr-mitrichev.blogspot.com/2008/11/burnsides-lemma.html
- Problems
    - http://www.topcoder.com/stat?c=problem_statement&pm=9975
    - http://www.spoj.pl/problems/TRANSP/

Game theory

- Basic principles and Nim game
- Sprague grundy theorem, grundy numbers
- Suggested readings
    - http://en.wikipedia.org/wiki/Sprague%E2%80%93Grundy_theorem
    - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=algorithmGames
    - http://www.ams.org/samplings/feature-column/fcarc-games1
    - http://www.codechef.com/wiki/tutorial-game-theory
- Suggested problems
    - http://www.topcoder.com/stat?c=problem_statement&pm=3491&rd=6517
    - http://www.topcoder.com/stat?c=problem_statement&pm=3491&rd=6517
- Hackenbush
    - http://en.wikipedia.org/wiki/Hackenbush
    - http://www.ams.org/samplings/feature-column/fcarc-partizan1
- Suggested problems
    - http://www.cs.caltech.edu/ipsc/problems/g.html
    - http://www.spoj.pl/problems/PT07A/

Linear Algebra

Matrix Operations

- Addition and subtraction of matrices
  - Cormen 28.1
- Multiplication (Strassen's algorithm), logarithmic exponentiation
  - Cormen 28.2
  - Linear Algebra by Kenneth Hoffman Section 1.6
- Problems
  - http://uva.onlinejudge.org/external/111/11149.html

Matrix transformations (Transpose, Rotation of Matrix, Representing Linear transformations using matrix)

- Suggested Reading - Linear Algebra By Kenneth Hoffman Section 3.1,3.2,3.4,3.7
- Problems
  - http://www.topcoder.com/stat?c=problem_statement&pm=6877
  - JPIX on Spoj
- Determinant, Rank and Inverse of Matrix (Gaussean Elimination , Gauss Jordan Elimination)
  - 28.4 Cormen
  - Linear Algebra by Kenneth Chapter 1
- Problems
  - http://www.topcoder.com/stat?c=problem_statement&pm=8174
  - http://www.topcoder.com/stat?c=problem_statement&pm=6407&rd=9986
  - http://www.topcoder.com/stat?c=problem_statement&pm=8587
  - HIGH on Spoj

Solving system of linear equations

- Suggested Reading
  - 28.3 Cormen
  - Linear Algebra by Kenneth Chapter 1
- Problems
  - http://www.topcoder.com/stat?c=problem_statement&pm=3942&rd=6520

Using matrix exponentiation to solve recurrences

- Suggested Reading
  - http://www.topcoder.com/tc?module=Static&d1=features&d2=010408
- Problems
  - REC, RABBIT1, PLHOP on spoj
  - http://www.topcoder.com/stat?c=problem_statement&pm=6386
  - http://www.topcoder.com/stat?c=problem_statement&pm=7262
  - http://www.topcoder.com/stat?c=problem_statement&pm=6877

Eigen values and Eigen vectors

- Problems - http://www.topcoder.com/stat?c=problem_statement&pm=2423&rd=4780

Polynomials

- Roots of a polynomial (Prime factorization of a polynomial, Integer roots of a polynomial, All real roots of a polynomial)
  - http://www.topcoder.com/stat?c=problem_statement&pm=8273&rd=10798
  - POLYEQ , ROOTCIPH on Spoj
- Lagrange Interpolation
  - http://www.topcoder.com/stat?c=problem_statement&pm=10239

- http://www.topcoder.com/stat?c=problem_statement&pm=8725

Permutation cycles

- Suggested Reading - Art of Computer Programming by Knuth Vol. 3
- Problems - ShuffleMethod, Permutation and WordGame on topcoder.

Group Theory

- Burnside Lemma
- Polya's theorem
- Suggested Reading
  - Hernstein's topics in algebra
  - http://petr-mitrichev.blogspot.com/2008/11/burnsides-lemma.html
- Problems
  - TRANSP on spoj
  - http://www.topcoder.com/stat?c=problem_statement&pm=9975

Generating functions

- Suggested Reading
  - Herbert Wilf's generating functionology
  - Robert Sedgewick and Flajoulet's Combinatorial analysis

Data Structures

Basic

- Arrays/Stacks/Queues
- Problems
  - https://www.spoj.pl/problems/STPAR/
  - https://www.spoj.pl/problems/SHOP/
  - https://www.spoj.pl/problems/WATER/
- Reading:
  - CLRS: section 10.1
  - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=dataStructures

Singly/Doubly Linked List

- Problems - https://www.spoj.pl/problems/POSTERS/
- Reading: CLRS: section 10.2, Mark Allen Weies Chapter 3

Hash Tables

- Problems
  - https://www.spoj.pl/problems/HASHIT/
  - https://www.spoj.pl/problems/CUCKOO/
- Reading: CLRS: Chapter 11, Mark Allen Weies Chapter 5

Circular linked list / queue

- Problems - https://www.spoj.pl/problems/CTRICK/

Binary/n-ary trees

- Reading
  - CLRS: section 10.4
  - CLRS: Chapter 12
  - Mark Allen Weies Chapter 4
  - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=binarySearchRedBlack

Heaps

- Problems
  - https://www.spoj.pl/problems/PRO/
  - https://www.spoj.pl/problems/EXPEDI/
- Reading : Mark Allen Weies Chapter 6

Trie

- Problems
  - https://www.spoj.pl/problems/MORSE/
  - https://www.spoj.pl/problems/EMOTICON/
- Reading

Interval trees / Segment Trees

- Problems
  - https://www.spoj.pl/problems/ORDERS/
  - https://www.spoj.pl/problems/FREQUENT/
- Reading

Fenwick (Binary Indexed) trees

- Problems - https://www.spoj.pl/problems/MATSUM/
- Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=binaryIndexedTrees

Disjoint data structures

- Problems
  - https://www.spoj.pl/problems/BLINNET/
  - https://www.spoj.pl/problems/CHAIN/
- Reading:
  - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=disjointDataStructure
  - Mark Allen Weies Chapter 8

Range minimum Query (RMQ)

- Problems
  - https://www.spoj.pl/problems/GSS1/
- Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=lowestCommonAncestor

Customized interval/segment trees (Augmented DS)

- Problems
  - https://www.spoj.pl/problems/GSS3/
  - https://www.spoj.pl/problems/RRSCHED/
- Reading: CLRS: Chapter 14 (augmented DS)

AVL Trees

- Problem - https://www.spoj.pl/problems/ORDERS/

Miscellaneous

- Splay Trees
- B/B+ Trees
- k-d Trees
- Red-black Trees
- Skip List
- Binomial/ Fibonacci heaps

Exercices

- https://www.spoj.pl/problems/LAZYPROG/ (Hint: Heaps)
- https://www.spoj.pl/problems/HELPR2D2/ (Hint: Interval Trees)
- https://www.spoj.pl/problems/SAM/ (Hint: Heaps)
- https://www.spoj.pl/problems/PRHYME/ (Hint: Trie)
- https://www.spoj.pl/problems/HEAPULM/ (Hint: Interval Trees)
- https://www.spoj.pl/problems/CORNET/ (Hint: Disjoint)
- https://www.spoj.pl/problems/EXPAND/
- https://www.spoj.pl/problems/WPUZZLES/
- https://www.spoj.pl/problems/LIS2/

Search Techniques/Bruteforce writing techniques/Randomized algorithms.

Backtracking (beginner)

- N queens problems
- Knights Tour
- Sudoku Problem
- Tiling Problem
- 15 puzzle.

Dancing Links and Algorithm X given by Knuth (advanced)

- problems - PRLGAME, SUDOKU, NQUEEN on SPOJ
- Suggested reading - http://www-cs-faculty.stanford.edu/~uno/papers/dancing-color.ps.gz

Binary Search (beginner)

- problems - AGGRCOW on SPOJ. Refer the tutorial for more problems.
- finding all real roots of a polynomial using binary search (intermediate)
- Suggested Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=binarySearch

Ternary Search (intermediate)

- Problems
  - http://www.spoj.pl/problems/KPPOLY/
  - http://www.codechef.com/DEC09/problems/K1/
  - http://www.topcoder.com/stat?c=problem_statement&pm=4705&rd=7993
  - http://www.topcoder.com/stat?c=problem_statement&pm=7741&rd=10671

    - http://www.topcoder.com/stat?c=problem_statement&pm=6464&rd=9994
    - http://www.topcoder.com/stat?c=problem_statement&pm=3501&rd=6529
    - http://www.topcoder.com/stat?c=problem_statement&pm=4567&rd=6539

Meet in the middle (Intermediate)

- problems - http://www.spoj.pl/problems/MAXISET/

Hill Climbing (Advanced)

Regular Iteration to reach a fixed point (Advanced)

- Newton-Raphson method to find root of a mathematical function.
- Iterations to solve linear non homogeneous system of equations.

Representing sets with bitmasks and manipulating bitmasks (Beginner)

- Suggested Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=bitManipulation
- problems - refer to the tutorial link in Suggested reading section.

General programming issues in contests

- Arithmetic Precision (Beginner)
- Suggested Reading - http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=integersReals