Programming Syllabus For advance Level In CCS(CUET Computer Society)

Geometry

1. Computational Geometry
   a. Graham scan algorithm for convex Hull $O(n^*(\log(n)))$
   b. Online construction of 3-D convex Hull in $O(n^2)$
   c. Bentley otmann algorithm to list all intersecting points of n line segments in $O((n+i)*\log(n))$
      - [http://softsurfer.com/Archive/algorithm_0108/algorithm_0108.htm](http://softsurfer.com/Archive/algorithm_0108/algorithm_0108.htm)
   d. Rotating Calipers Technique
      - Problem refer to Rotating calipers technique
   e. Line sweep/ Plane sweep algorithms
      - Area / Perimeter of Union of Rectangles.
      - Closet Pair of Points.
      - [http://community.topcoder.com/tc?module=Static&d1=tutorials&d2=lineSweep](http://community.topcoder.com/tc?module=Static&d1=tutorials&d2=lineSweep)
   f. Area of Union of Circles
   g. Delaunay Triangulation of n points in $O(n^* \log(n))$
   h. Voronoi Diagrams of n points in $O(n^* \log(n))$ using Fortunes algorithm
   i. points in a polygon problem –
      - $O(n)$ solution without preprocessing
      - $O(\log n)$ algorithm with $O(n^* \log(n))$ preprocessing for convex polygons
   j. Problems under this catagory-
      - BSHEEP, BLUX, CONDUIT, RUNAWAY, SHAMAN, TCUTTER, LITEPIPE, FSHEEP, FLBRKLIN, BAC, COMPASS, CIRCLES, SEGMENTS, RAIN2, KPPOLY, RECTANGL on SPOJ
      - CultureGrowth, PolygonCover on Topcoder

String Algorithm

- Dictionary of Basic Factors
  - $O(n^*\log(n))$ method of DBT construction using Radix sort
- Manachar's algorithm to find Length of palindromeic substring of a string centered at a position for each position in the string
  - Runtime -> $O(n)$
- Multi-dimentional pattern matching

- Problems on Strings [can be solved with a variety of techniques]
  - DISUBSTER, PLD, MSTRING, REPREATS, JEWELS, ARCHIVER, PROPXLEY, LITELANG, EMOTICON, WORDS, AMCODES, TOPALIN, BEADS, SARRY, LCS, LCS2, SUBSTR on SPOJ
Graph

- Euler Tour/Path
  - problems - WORDS1 on SPOJ
- Hamiltonian Cycle
- Kth Shortest Path
- Suggested reading for most of the topics in graph algorithm -
  - http://community.topcoder.com/tc?module=Static&d1=tutorials&d2=graphsDataStructs1

Flow Networks/Matching

a. Maximum flow using Ford Fulkerson Method
   - Suggested reading -
     http://community.topcoder.com/tc?module=Static&d1=tutorials&d2=maxFlow
   - Problems - TAXI, POTHOLE, TM QUEST4, MUDDY, EN STEAD, COCONUTS on SPOJ
b. Maximum flow using Dinics Algorithm
   - problems - PROFIT on SPOJ
c. Minimum Cost Maximum Flow
   - Successive Shortest path algorithm
   - Cycle Cancelling algorithm
   - Suggested reading -
     http://community.topcoder.com/tc?module=Static&d1=tutorials&d2=minimumCostFlow1

d. Maximum Weighted Bipartite Matching (Kuhn Munkres algorithm/Hungarian algorithm)
   - problems - GREED, SCITIES, TOURS on SPOJ
e. Stoer wagner min-cut algorithm
f. Hopcroft karp bipartite matching algorithm
   - problems - ANGLES on SPOJ
g. Maximum matching in general graph (blossom shrinking)
h. Suggested reading for Full category
   - Network flow - Algorithms and Applications by Ahuja

Dynamic Programming:

- Bitmask DP (Traveling salesman problem)
- Modular DP (DP with MOD value as a state)

a. Suggested Reading - Dynamic Programming(DP) as a tabulation method
   - Cormen chapter on DP
b. Standard problems (you should really feel comfortable with these types)

c. State space reduction

d. Solving in the reverse - easier characterizations looking from the end
   - http://www.spoj.pl/problems/MUSKET/

e. Counting/optimizing arrangements satisfying some specified properties

f. Strategies and expected values

g. DP on probability spaces

h. DP on trees

i. Symmetric characterization of DP state

j. A good collection of problems
   - http://codeforces.com/blog/entry/325

Greedy:
- Maximum Sum 2D in O(n^3)
- Maximum Rectangle O(n^2)

Number Theory:

a. Chinese remainder theorem
   - Suggested Reading
1. From Cormen

2. 1.6 from Number Theory by SY Yan
   ■ Problems
   1. Project Euler 271

b. Logarithmic Exponentiation
   ■ Suggested Reading -

c. Integer Factorization
   ■ Naive O(sqrt(n)) method
   ■ Pollard Rho factorization
   ■ Suggested Reading
      1. 2.3 from Number Theory SY Yan
      2. 31.9 Cormen

   ■ Problems –

d. Stirling numbers

e. Wilson theorem
   ■ nCr % p in O(p) preprocess and O(log n) query

f. Lucas Theorem
   1. 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
Math (Probability, Counting, Game Theory, Group Theory, Generating functions, Permutation Cycles, Linear Algebra)

a. Probability:

- Special discrete and continuous probability distributions
  1. Bernoulli, Binomial, Poisson, normal distribution
  2. Suggested Problem
- Suggested Readings
  1. Cormen appendix C (very basic)
  2. Topcoder probability tutorial
     http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=probabilities
  5. William Feller, An introduction to probability theory and its applications

b. Counting

- Special numbers
  1. Suggested reading
     - Stirling, eulerian, harmonic, bernoulli, fibonacci numbers
     - Concrete mathematics by Knuth
  2. Suggested problems

- Advanced counting techniques
  - Polya counting, burnside's lemma
  1. Suggested reading
  2. Suggested Problems
c. Game theory
   ■ Basic principles and Nim game
   1. Sprague-Grundy theorem, Grundy numbers
   2. Suggested readings

   3. Suggested problems

   ■ Hackenbush
   1. Suggested readings

   2. Suggested problems

   d. Linear Algebra

   ■ Matrix Operations

   1. Matrix transformations [Transpose, Rotation of Matrix, Representing Linear transformations using matrix]
      a. Suggested reading
         i. Linear Algebra By Kenneth Hoffman Section 3.1, 3.2, 3.4, 3.7
      b. Problems
         ii. JPIX on Spoj

   2. Determinant, Rank and Inverse of Matrix [Gaussean Elimination, Gauss Jordan Elimination]
      a. Suggested Reading
         i. Cormen
         ii. Linear Algebra by Kenneth Chapter 1
      b. Problems
         iv. HIGH on Spoj
4. Solving system of linear equations
   a. Suggested Reading
   i. Cormen
   ii. Linear Algebra by Kenneth Chapter 1

   b. Problems

5. Using matrix exponentiation to solve recurrences
   a. Suggested Reading

   b. Problems
   i. REC, RABBIT1, PLHOP on spoj

6. Eigen values and Eigen vectors
   a. Problems

   e. Permutation cycles
      ■ Suggested Reading
      1. Art of Computer Programming by Knuth Vol. 3

      ■ Problems
      1. ShuffleMethod, Permutation and WordGame on topcoder.

   f. Group Theory
      ■ BURNSIDE LEMMA, POLIA'S THEOREM
      1. Suggested Reading
         a. Hernstein's topics in algebra
      2. Problems
         a. TRANSP on spoj

   g. Generating functions
      ■ Suggested Reading
      1. Herbert Wilf's generating functionology
      2. Robert Sedgewick and Flajolet's Combinatorial analysis
Data Structures.

i. Basic

a. Hash Tables:
   ■ Problems
   1. https://www.spoj.pl/problems/HASHIT/
   ■ Reading: CLRS: Chapter 11, Mark Allen Weies Chapter 5

ii. Advanced

a. Interval trees / Segment Trees
   ■ Problems
   ■ Reading
b. Fenwick (Binary Indexed) trees
   ■ Problems
   ■ Reading: http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=binaryIndexedTrees

c. Disjoint data structures
   ■ Problems
   ■ Reading:
   2. Mark Allen Weies Chapter 8

d. Range minimum Query (RMQ)
   ■ Problems
   ■ Reading: http://www.topcoder.com/tc?module=Static&d1=tutorials&d2=lowestCommonAncestor

e. Customized interval / segment trees (Augmented DS)
   ■ Problems
   ■ Reading: CLRS: Chapter 14 (augmented DS)

f. AVL Trees
   ■ Problems

g. BST & Variation

h. Least Common Ancestor
iii. Miscellaneous [if possible]
   a. Splay Trees
   b. B/B+ Trees
   c. k-d Trees
   d. Red-black Trees
   e. Skip List
   f. Binomial/ Fibonacci heaps

iv. Exercises

Search Techniques/Bruteforce writing techniques/Randomized algorithms:

a. Backtracking - [Beginner].
   ■problems-
   1. Sudoku Problem
   2. Tiling Problem.
   3. 15 puzzle.

b. Dancing Links and Algorithm X given by Knuth - [Advanced]
   ■problems - PRLGAME, SUDOKU, NQUEEN on SPOJ
   ■ Suggested reading –

c. Hill Climbing [Advanced].

d. 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.

e. Min-max algorithm