3SAT ≤P Vertex-Cover & Clique ≤P Vertex-Cover

Brief Summary of the Methods:

Creating Graph Data Structure: Initially we must create a graph data structure using array list, Two Separate array lists are used to store all the vertices and edges, then will pass these two lists to graph class which will give connections between vertices and edges. The resultant graph will be used to solve the methods given in the programming assignment.

Method that takes an undirected graph G: (V, E) and an integer $1 \leq k \leq |V|$ as inputs of the method and returns a k-vertex cover, if such k-vertex cover exists in G

Summary: As we all know minimum vertex cover is NP-complete problem. In the initial stage we approached this problem using greedy algorithm. But we noticed that it is giving wrong vertex cover as the graph size increasing. Next, we approached using brute-force algorithm. Brute-force algorithm gives correct answer. But with brute force approach as graph size increasing its showing TLE error because it must check each combination in graph from starting. So, we need to optimize this algorithm in order to overcome time limit exceeded problem.

We know that greedy algorithm gives a value k that is equal to or greater than the minimum vertex in all the cases. So, we use this k as our starting point for our new algorithm.

Example: (100^{th} graph-202 vertices) – we will pass this graph to greedy algorithm; we will get minimum vertex as "k" (k=194). But the minimum vertex cover is 191. So, we are bounding k value to 191 and calling "GreedyCoverExp" algorithm. This will save lot of time because we are not starting from the 202 vertices. So, it will remove the unwanted vertices by recursively calling the function. So, we will get solution as 191 which is the correct solution. In this new algorithm we can include or exclude the max vertex by using recursion.

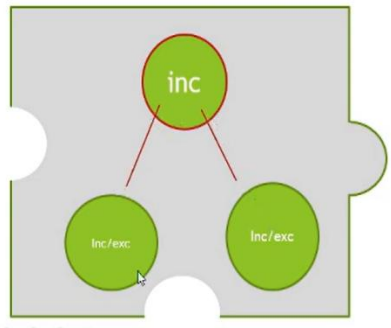
Pseudocode: GreedyCoverExponential (It is a method in our program):

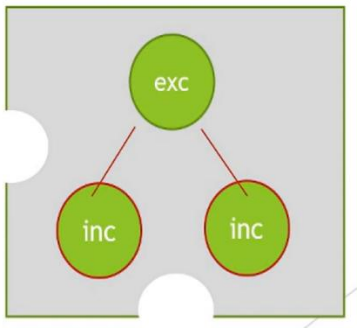
P (x, [INC, EXC])

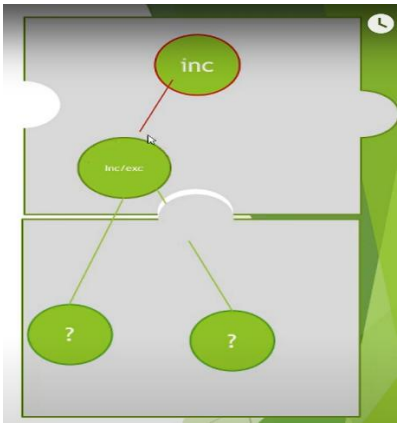
P -> Minimum size of cover

X -> Given node

INC, EXC – Include the node in cover or exclude the node in cover







With is approach we can get minimum vertex cover for all the graphs in less time.

Other Methods used in Method A :

printVetexList - This method will print all the vertices in the list.
removeEdges – This method will remove the edges from the graph.
getMaxDegree – This method will return the max degree vertex.
getVertexEdges – This method will return edges for vertex
getVertexDegree – This method will return degree of a vertex
removeVertex - This will remove vertex from the vertices list.

Output:

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graphs1f428.txt

G1 (4, 4) (size=1 ms=0) {0}

G2 (6, 16) (size=3 ms=0) {0,1,5}

G3 (8, 30) (size=4 ms=0) {0,2,4,6}

G4 (10, 56) (size=7 ms=0) {0,1,3,4,5,6,7}

G5 (12, 76) (size=8 ms=0) {1,2,3,4,5,6,8,11}

G6 (14, 92) (size=9 ms=1) {0,1,3,4,5,6,8,10,12}

G7 (16, 106) (size=11 ms=2) {0,1,2,3,4,5,6,8,12,14,15}

G8 (18, 166) (size=13 ms=2) {0,1,2,3,4,6,8,9,10,11,14,16,17}

G9 (20, 180) (size=14 ms=5) {1,2,3,4,6,7,8,10,11,12,13,15,16,18}

G10 (22, 226) (size=16 ms=3) {1,2,3,4,6,7,10,11,13,14,15,16,17,18,19,21}

G11 (24, 284) (size=19 ms=2) {1,2,3,5,6,8,9,10,11,12,13,15,16,17,18,19,20,21,23}

G12 (26, 334) (size=21 ms=2) {0,1,2,3,4,5,6,8,9,11,13,14,15,16,17,18,19,20,21,23,24}

G13 (28, 386) (size=22 ms=6) {0,2,4,5,6,8,9,11,12,13,14,16,17,18,20,21,22,23,24,25,26,27}

G14 (30, 422) (size=24 ms=6) {0,1,2,3,5,6,7,8,9,10,11,13,14,15,16,17,18,19,20,22,23,26,27,29}

G15 (32, 508) (size=25 ms=10) {3,5,6,7,8,9,11,12,13,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31}

G16 (34, 530) (size=27 ms=15) {0,1,2,3,5,6,8,9,10,11,12,13,15,16,17,20,21,22,23,24,25,26,27,28,30,31,33}

G17 (36, 624) (size=30 ms=8) {0,1,2,3,4,5,6,8,10,11,12,13,14,15,17,18,19,22,24,25,26,27,28,29,30,31,32,33,34,35}

G18 (38, 718) (size=31 ms=9) {0,1,2,3,4,5,6,8,9,10,11,12,13,15,16,17,18,21,22,23,24,25,26,27,28,29,31,32,33,34,37}

G19 (40, 750) (size=33 ms=9) {0,1,2,3,4,5,6,8,9,11,12,13,14,15,16,17,18,21,23,24,25,26,28,29,31,32,33,34,35,36,37,38,39}

G20 (42, 834) (size=34 ms=7) {0,1,2,3,4,5,6,7,8,9,11,12,13,14,15,17,18,19,20,23,24,25,26,27,30,31,32,35,36,37,38,39,40,41}

G21 (44, 998) (size=37 ms=17) {0,2,3,5,6,7,8,10,11,12,13,14,15,17,18,19,20,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,38,40,41,42,43}

G22 (46, 1060) (size=39 ms=16) {0,1,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,26,27,28,29,30,31,32,34,35,36,37,38,39,40,41,44,45}

G23 (48, 1116) (size=40 ms=11) {1,2,5,6,7,8,9,10,12,13,14,15,16,17,18,19,20,21,23,24,25,27,28,29,30,31,32,33,34,35,36,37,38,40,41,42,43,44,45,47}
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C:\Windows\System32\cmd.exe
G24 (50, 1244) (size=43 ms=13) {0,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,21,22,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,41,42,44,45,46,47,49}

G25 (52, 1330) (size=45 ms=28) {0,1,2,3,4,5,6,7,9,10,11,12,13,14,16,18,19,20,21,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,47,49,50}

G26 (54, 1388) (size=46 ms=18) {0,1,3,4,5,6,7,8,9,11,12,13,14,15,17,18,19,20,21,22,23,24,25,26,27,31,32,33,34,35,36,37,38,40,41,42,43,44,45,46,47,48,49,50,51,53}

G27 (56, 1620) (size=48 ms=18) {0,1,2,3,4,5,6,8,11,12,13,14,15,16,17,18,19,20,21,23,24,25,26,27,28,29,31,32,34,35,36,37,38,39,40,41,42,44,45,46,47,48,49,50,51,52,53,55}

G28 (58, 1636) (size=50 ms=32) {0,1,2,4,5,6,7,8,9,10,12,13,14,15,16,17,18,20,21,22,23,24,25,26,27,28,30,31,32,33,35,36,37,39,40,41,42,43,44,45,46,47,49,50,52,53,54,55,56,57}

G29 (60, 1826) (size=53 ms=33) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,22,23,24,26,27,29,30,31,32,33,35,36,37,38,39,40,41,43,44,45,46,47,48,51,52,53,54,55,56,57,58,59}

G30 (62, 1874) (size=53 ms=35) {0,1,2,3,4,5,7,9,10,11,12,13,14,15,16,20,22,23,24,25,26,27,29,30,32,33,34,35,36,37,38,39,40,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61}

G31 (64, 2020) (size=56 ms=40) {0,1,2,3,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22,24,25,26,27,28,29,30,31,32,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,52,54,55,56,58,59,60,61,62,63}

G32 (66, 2132) (size=58 ms=43) {0,1,2,3,4,5,7,8,9,10,11,12,13,14,16,17,18,20,21,22,23,24,25,26,28,29,30,31,32,33,34,35,36,37,38,39,40,41,43,44,45,47,48,49,50,51,52,54,55,56,57,58,59,60,61,62,63,65}

G33 (68, 2284) (size=60 ms=43) {0,1,3,5,6,7,8,9,10,11,12,13,14,15,17,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,50,51,52,53,54,55,57,58,59,60,61,62,63,65,66,67}

G34 (70, 2438) (size=61 ms=42) {0,1,2,3,4,5,6,7,8,9,11,13,14,15,16,17,18,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,38,40,41,42,43,44,45,46,47,49,51,52,53,54,55,56,57,59,60,61,63,64,65,66,67,68,69}

G35 (72, 2528) (size=63 ms=70) {0,1,2,4,5,6,7,9,10,11,13,14,15,16,17,18,20,21,23,24,25,26,27,28,29,30,31,32,33,34,35,36,38,39,40,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,58,59,60,61,63,64,65,66,67,68,69,70,7
1}

G36 (74, 2760) (size=66 ms=78) {0,1,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,32,33,34,35,36,38,39,40,41,43,44,45,46,47,48,49,51,52,53,54,55,56,57,58,59,60,61,63,64,65,66,67,68,69,7
0,71,72,73}

G37 (76, 2924) (size=68 ms=82) {0,1,2,3,5,7,8,9,10,11,12,14,15,17,18,19,20,21,22,23,24,25,26,27,28,29,30,32,33,34,35,36,37,38,39,40,41,42,43,44,45,47,49,50,51,52,53,54,55,56,57,58,59,60,61,62,64,65,66,67,68,69,7
0,71,72,73,74,75}

G38 (78, 3004) (size=69 ms=87) {0,1,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,36,37,38,39,40,41,43,45,48,49,50,51,52,53,54,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70
,71,72,73,74,76,77}

G39 (80, 3064) (size=71 ms=100) {0,1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17,18,20,21,22,23,24,25,26,27,28,29,30,33,34,35,36,37,38,39,40,41,42,43,45,46,47,48,49,50,51,53,54,55,57,58,60,61,62,63,64,65,67,68,69,70,7
1,72,73,74,75,76,77,78,79}

G40 (82, 3192) (size=73 ms=149) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,23,24,25,26,28,29,30,31,33,34,35,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,59,60,61,62,63,64,65,66,67,68
,69,70,71,72,75,76,77,78,79,81}

G41 (84, 3368) (size=75 ms=161) {0,1,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,22,23,24,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,43,45,46,47,48,49,50,51,52,53,54,55,58,59,60,61,62,63,64,65,66,67,68,6
9,70,71,72,73,74,76,77,78,79,80,81,82}

G42 (86, 3682) (size=77 ms=120) {0,1,2,3,5,6,7,8,9,10,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,30,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,58,59,60,61,62,63,64,65,66,67,6
8,69,70,71,72,73,74,75,76,77,78,80,81,83,84}

G43 (88, 3792) (size=79 ms=175) {1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,21,22,23,24,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,51,52,53,54,56,57,59,60,61,63,64,66,67,68,69,7
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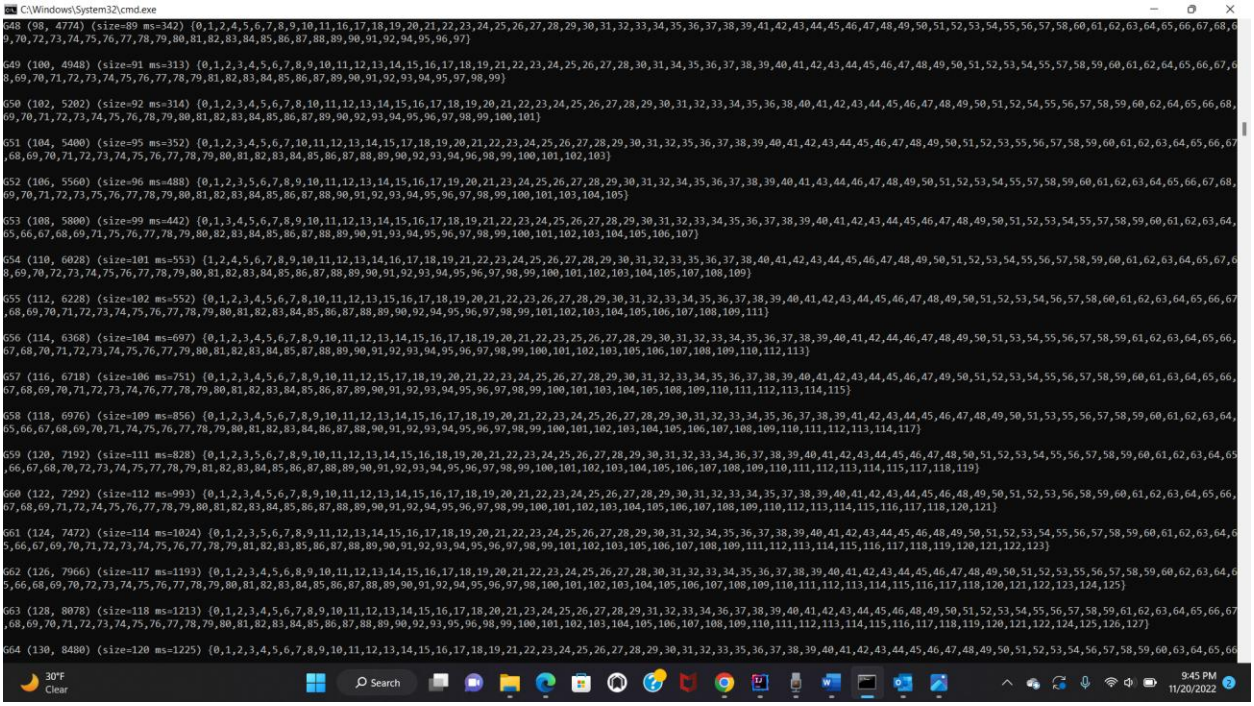
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648 (98, 4774) (size=89 ms=342) {0,1,2,4,5,6,7,8,9,10,11,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,60,61,62,63,64,65,66,67,68,6
9,70,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,94,95,96,97}
649 (100, 4948) (size=91 ms=313) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,30,31,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,57,58,59,60,61,62,64,65,66,67,6
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650 (102, 5202) (size=92 ms=314) {0,1,2,3,4,5,6,7,8,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,38,40,41,42,43,44,45,46,47,48,49,50,51,52,54,55,56,57,58,59,60,62,64,65,66,68,
69,70,71,72,73,74,75,76,78,79,80,81,82,83,84,85,86,87,89,90,92,93,94,95,96,97,98,99,100,101}
651 (104, 5400) (size=95 ms=352) {0,1,2,3,4,5,6,7,10,11,12,13,14,15,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,55,56,57,58,59,60,61,62,63,64,65,66,67
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652 (106, 5560) (size=96 ms=488) {0,1,2,3,5,6,7,8,9,10,11,12,13,14,15,16,17,19,20,21,23,24,25,26,27,28,29,30,31,32,34,35,36,37,38,39,40,41,43,44,46,47,48,49,50,51,52,53,54,55,57,58,59,60,61,62,63,64,65,66,67,68,
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653 (108, 5800) (size=99 ms=442) {0,1,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,57,58,59,60,61,62,63,64,
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654 (110, 6028) (size=101 ms=553) {1,2,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,35,36,37,38,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,67,6
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655 (112, 6228) (size=102 ms=552) {0,1,2,3,4,5,6,7,8,10,11,12,13,15,16,17,18,19,20,21,22,23,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,56,57,58,60,61,62,63,64,65,66,67
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656 (114, 6368) (size=104 ms=697) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,44,46,47,48,49,50,51,53,54,55,56,57,58,59,61,62,63,64,65,66,
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657 (116, 6718) (size=106 ms=751) {0,1,2,3,4,5,6,7,8,9,10,11,12,15,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,49,50,51,52,53,54,55,56,57,58,59,60,61,63,64,65,66,
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658 (118, 6976) (size=109 ms=856) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,41,42,43,44,45,46,47,48,49,50,51,53,55,56,57,58,59,60,61,62,63,64,
65,66,67,68,69,70,71,74,75,76,77,78,79,80,81,82,83,84,86,87,88,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,117}
659 (120, 7192) (size=111 ms=828) {0,1,2,3,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,36,37,38,39,40,41,42,43,44,45,46,47,48,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65
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660 (122, 7292) (size=112 ms=993) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,37,38,39,40,41,42,43,44,45,46,48,49,50,51,52,53,56,58,59,60,61,62,63,64,65,66,
67,68,69,71,72,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,112,113,114,115,116,117,118,120,121}
661 (124, 7472) (size=114 ms=1024) {0,1,2,3,5,6,7,8,9,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,34,35,36,37,38,39,40,41,42,43,44,45,46,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,6
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662 (126, 7966) (size=117 ms=1193) {0,1,2,3,4,5,6,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,55,56,57,58,59,60,62,63,64,6
5,66,68,69,70,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,94,95,96,97,98,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,120,121,122,123,124,125}
663 (128, 8078) (size=118 ms=1213) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,21,23,24,25,26,27,28,29,31,32,33,34,36,37,38,39,40,41,42,43,44,45,46,48,49,50,51,52,53,54,55,56,57,58,59,61,62,63,64,65,66,67
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664 (130, 8480) (size=120 ms=1225) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,21,22,23,24,25,26,27,28,29,30,31,32,33,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,56,57,58,59,60,63,64,65,66
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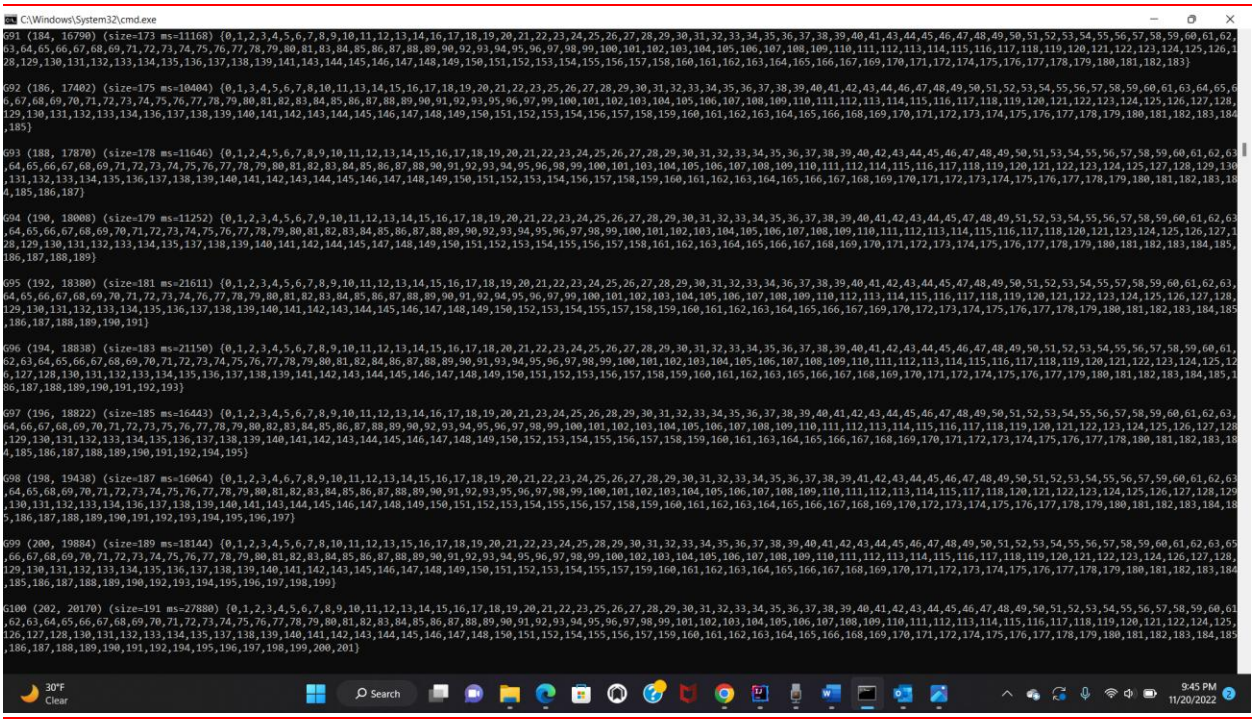
C:\Windows\System32\cmd.exe
691 (184, 16790) (size=173 ms=11168) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,
63,64,65,66,67,68,69,71,72,73,74,75,76,77,78,79,80,81,83,84,85,86,87,88,89,90,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,1
28,129,130,131,132,133,134,135,136,137,138,139,141,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,160,161,162,163,164,165,166,167,169,170,171,172,174,175,176,177,178,179,180,181,182,183}
692 (186, 17402) (size=175 ms=10404) {0,1,3,4,5,6,7,8,10,11,13,14,15,16,17,18,19,20,21,22,23,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,63,64,65,6
6,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,95,96,97,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,
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,185}
693 (188, 17870) (size=178 ms=11646) {0,1,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,42,43,44,45,46,47,48,49,50,51,53,54,55,56,57,58,59,60,61,62,63
,64,65,66,67,68,69,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,90,91,92,93,94,95,96,98,99,100,101,103,104,105,106,107,108,109,110,111,112,114,115,116,117,118,119,120,121,122,123,124,125,127,128,129,130
,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,18
4,185,186,187}
694 (190, 18008) (size=179 ms=11252) {0,1,2,3,4,5,6,7,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,47,48,49,51,52,53,54,55,56,57,58,59,60,61,62,63
,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,120,121,123,124,125,126,127,1
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186,187,188,189}
695 (192, 18380) (size=181 ms=21611) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,36,37,38,39,40,41,42,43,44,45,47,48,49,50,51,52,53,54,55,57,58,59,60,61,62,63,
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,186,187,188,189,190,191}
696 (194, 18838) (size=183 ms=21150) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,
62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,84,86,87,88,89,90,91,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,12
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86,187,188,189,190,191,192,193}
697 (196, 18822) (size=185 ms=16443) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,23,24,25,26,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,
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4,185,186,187,188,189,190,191,192,194,195}
698 (198, 19438) (size=187 ms=16064) {0,1,2,3,4,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,59,60,61,62,63
,64,65,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,117,118,120,121,122,123,124,125,126,127,128,129
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5,186,187,188,189,190,191,192,193,194,195,196,197}
699 (200, 19884) (size=189 ms=18144) {0,1,2,3,4,5,6,7,8,10,11,12,13,15,16,17,18,19,20,21,22,23,24,25,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,65
,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,126,127,128,
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,185,186,187,188,189,190,192,193,194,195,196,197,198,199}
6100 (202, 20170) (size=191 ms=27880) {0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61
,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,124,125,
126,127,128,130,131,132,133,134,135,137,138,139,140,141,142,143,144,145,146,147,148,150,151,152,154,155,156,157,159,160,161,162,163,164,165,166,168,169,170,171,172,174,175,176,177,178,179,180,181,182,183,184,185
,186,187,188,189,190,191,192,194,195,196,197,198,199,200,201}
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Cook-reduction that reduces 3SAT to Vertex Cover

Summary: In this method we need to reduce the 3CNF to k-vertex problem. So, we need to convert the given 3CNF from the input file to a matrix form of a graph and we obtain k value (v+2*c where v = variables, c = clauses) by using cook-reduction and then pass to the first method (k-vertex cover problem). So, the Method A will return the solution. With this solution we answer method B(3CNF).

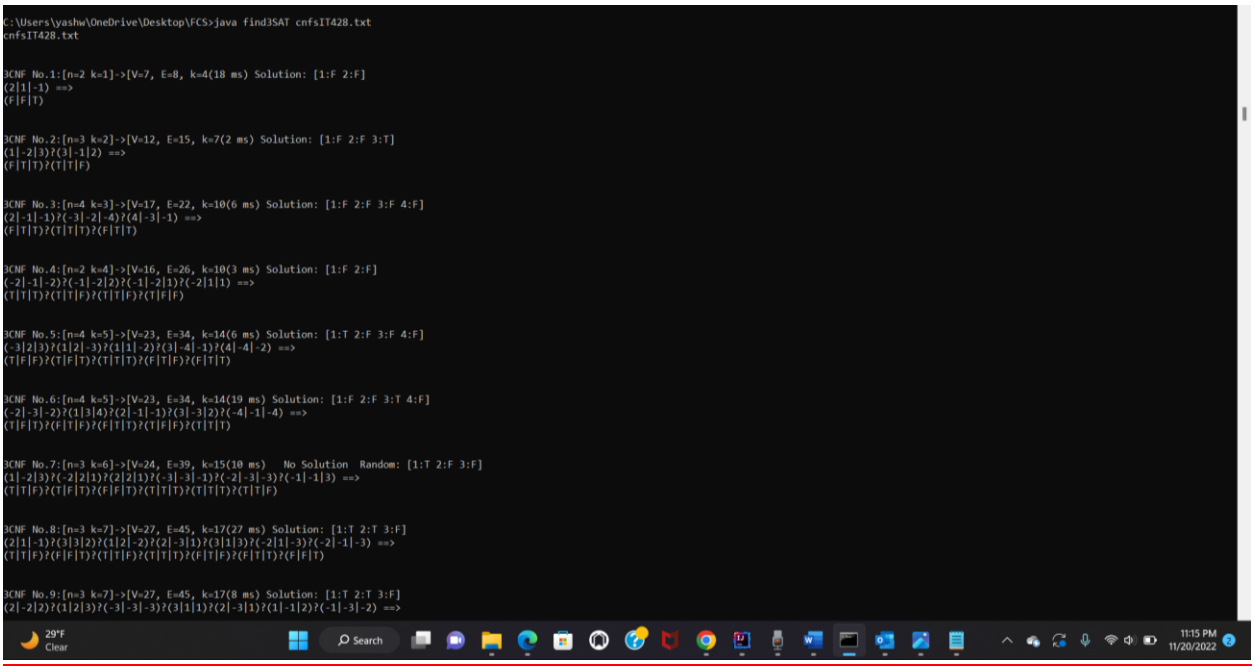
Algorithm:

step 1 : The program will get total number of vertices of a given 3CNF by v = 2*n + 3*k.
step 2 : Algorithm will give connection between the bars and the clauses.
step 3 : Program will pass this graph and k value (v+2*c where v = variables, c = clauses) to the findVCover program.
step 4 : If it returns a k-vertex cover(minimum vertex) then there is a solution, and algorithm will give a assignment based on it.
step 5 : If the return value is more than the K value(Minimum vertex) then algorithm will print no solution and give a random assignment to it.

Other Methods used in Method B :

greedyCover - Returns a minimum vertex which will be used by greedyCoverExp method.
greedyCoverExp – Returns vertex cover if there exist a k vertex cover
printVetexList - This method will print all the vertices in the list.
removeEdges – This method will remove the edges from the graph.
getMaxDegree – This method will return the max degree vertex.
getVertexEdges – This method will return edges for vertex
getVertexDegree – This method will return degree of a vertex
removeVertex - This will remove vertex from the vertices list.

Output:


C:\Users\yashw\OneDrive\Desktop\FCS>java find3SAT cnfsIT428.txt
cnfsIT428.txt
3CNF No.1:[n=2 k=1]->[V=7, E=8, k=4(18 ms) Solution: [1:F 2:F]
(2|1|-1) ==>
(F|F|T)
3CNF No.2:[n=3 k=2]->[V=12, E=15, k=7(2 ms) Solution: [1:F 2:F 3:T]
(1|-2|3)?(3|-1|2) ==>
(F|T|T)?(T|T|F)
3CNF No.3:[n=4 k=3]->[V=17, E=22, k=10(6 ms) Solution: [1:F 2:F 3:F 4:F]
(2|-1|-1)?(-3|-2|-4)?(4|-3|-1) ==>
(F|T|T)?(T|T|T)?(F|T|T)
3CNF No.4:[n=2 k=4]->[V=16, E=26, k=10(3 ms) Solution: [1:F 2:F]
(-2|-1|-2)?(-1|-2|2)?(-1|-2|1)?(-2|1|1) ==>
(T|T|T)?(T|T|F)?(T|T|F)?(T|F|F)
3CNF No.5:[n=4 k=5]->[V=23, E=34, k=14(6 ms) Solution: [1:T 2:F 3:F 4:F]
(-3|2|3)?(1|2|-3)?(1|1|-2)?(3|-4|-1)?(4|-4|-2) ==>
(T|F|F)?(T|F|T)?(T|T|T)?(F|T|F)?(F|T|T)
3CNF No.6:[n=4 k=5]->[V=23, E=34, k=14(19 ms) Solution: [1:F 2:F 3:T 4:F]
(-2|-3|-2)?(1|3|4)?(2|-1|-1)?(3|-3|2)?(-4|-1|-4) ==>
(T|F|T)?(F|T|F)?(F|T|T)?(T|F|F)?(T|T|T)
3CNF No.7:[n=3 k=6]->[V=24, E=39, k=15(10 ms) No Solution Random: [1:T 2:F 3:F]
(1|-2|3)?(-2|2|1)?(2|2|1)?(-3|-3|-1)?(-2|-3|-3)?(-1|-1|3) ==>
(T|T|F)?(T|F|T)?(F|F|T)?(T|T|T)?(T|T|T)?(T|T|F)
3CNF No.8:[n=3 k=7]->[V=27, E=45, k=17(27 ms) Solution: [1:T 2:T 3:F]
(2|1|-1)?(3|3|2)?(1|2|-2)?(2|-3|1)?(3|1|3)?(-2|1|-3)?(-2|-1|-3) ==>
(T|T|F)?(F|F|T)?(T|T|F)?(T|T|T)?(F|T|F)?(F|T|T)?(F|F|T)
3CNF No.9:[n=3 k=7]->[V=27, E=45, k=17(8 ms) Solution: [1:T 2:T 3:F]
(2|-2|2)?(1|2|3)?(-3|-3|-3)?(3|1|1)?(2|-3|1)?(1|-1|2)?(-1|-3|-2) ==>
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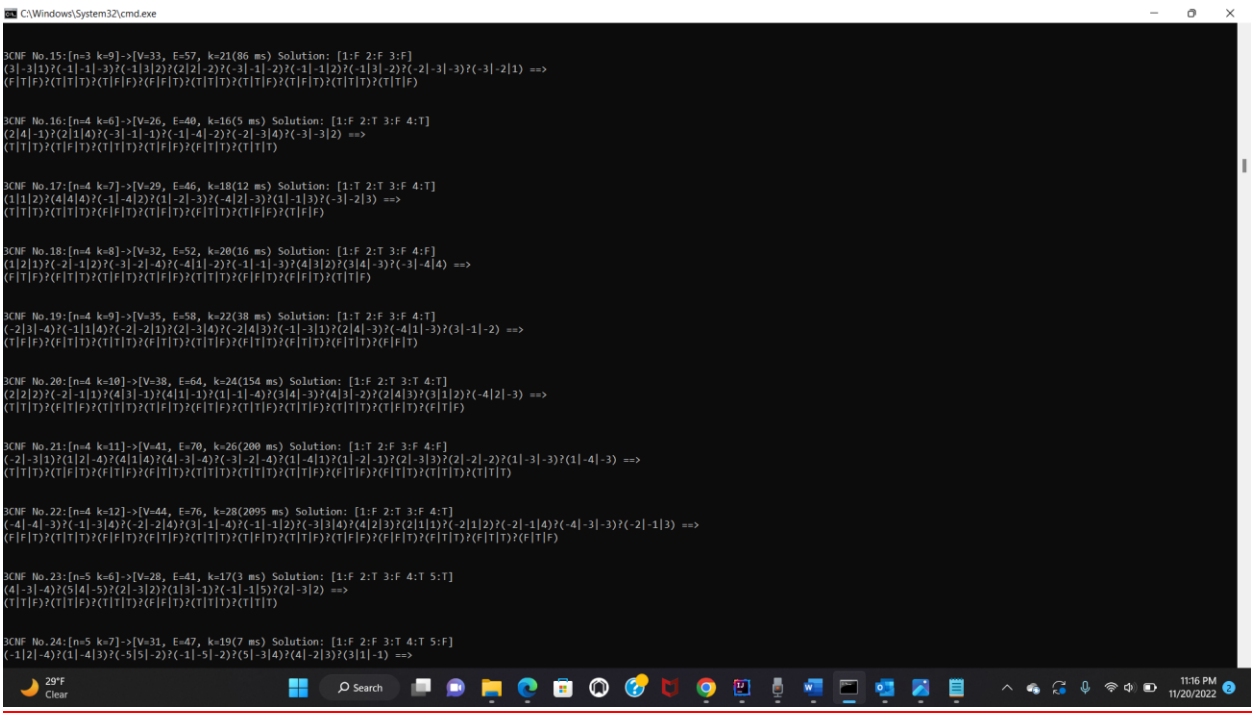
C:\Windows\System32\cmd.exe
3CNF No.15:[n=3 k=9]->[V=33, E=57, k=21(86 ms) Solution: [1:F 2:F 3:F]
(3|-3|1)?(-1|-1|-3)?(-1|3|2)?(2|2|-2)?(-3|-1|-2)?(-1|-1|2)?(-1|3|-2)?(-2|-3|-3)?(-3|-2|1) ==>
(F|T|F)?(T|T|T)?(T|F|F)?(F|F|T)?(T|T|T)?(T|T|F)?(T|F|T)?(T|T|T)?(T|T|F)
3CNF No.16:[n=4 k=6]->[V=26, E=40, k=16(5 ms) Solution: [1:F 2:T 3:F 4:T]
(2|4|-1)?(2|1|4)?(-3|-1|-1)?(-1|-4|-2)?(-2|-3|4)?(-3|-3|2) ==>
(T|T|T)?(T|F|T)?(T|T|T)?(T|F|F)?(F|T|T)?(T|T|T)
3CNF No.17:[n=4 k=7]->[V=29, E=46, k=18(12 ms) Solution: [1:T 2:T 3:F 4:T]
(1|1|2)?(4|4|4)?(-1|-4|2)?(1|-2|-3)?(-4|2|-3)?(1|-1|3)?(-3|-2|3) ==>
(T|T|T)?(T|T|T)?(F|F|T)?(T|F|T)?(F|T|T)?(T|F|F)?(T|F|F)
3CNF No.18:[n=4 k=8]->[V=32, E=52, k=20(16 ms) Solution: [1:F 2:T 3:F 4:F]
(1|2|1)?(-2|-1|2)?(-3|-2|-4)?(-4|1|-2)?(-1|-1|-3)?(4|3|2)?(3|4|-3)?(-3|-4|4) ==>
(F|T|F)?(F|T|T)?(T|F|T)?(T|F|F)?(T|T|T)?(F|F|T)?(F|F|T)?(T|T|F)
3CNF No.19:[n=4 k=9]->[V=35, E=58, k=22(38 ms) Solution: [1:T 2:F 3:F 4:T]
(-2|3|-4)?(-1|1|4)?(-2|-2|1)?(2|-3|4)?(-2|4|3)?(-1|-3|1)?(2|4|-3)?(-4|1|-3)?(3|-1|-2) ==>
(T|F|F)?(F|T|T)?(T|T|T)?(F|T|T)?(T|T|F)?(F|T|T)?(F|T|T)?(F|T|T)?(F|F|T)
3CNF No.20:[n=4 k=10]->[V=38, E=64, k=24(154 ms) Solution: [1:F 2:T 3:T 4:T]
(2|2|2)?(-2|-1|1)?(4|3|-1)?(4|1|-1)?(1|-1|-4)?(3|4|-3)?(4|3|-2)?(2|4|3)?(3|1|2)?(-4|2|-3) ==>
(T|T|T)?(F|T|F)?(T|T|T)?(T|F|T)?(F|T|F)?(T|T|F)?(T|F|F)?(T|T|T)?(T|F|T)?(F|T|F)
3CNF No.21:[n=4 k=11]->[V=41, E=70, k=26(200 ms) Solution: [1:T 2:F 3:F 4:F]
(-2|-3|1)?(1|2|-4)?(4|1|4)?(4|-3|-4)?(-3|-2|-4)?(1|-4|1)?(1|-2|-1)?(2|-3|3)?(2|-2|-2)?(1|-3|-3)?(1|-4|-3) ==>
(T|T|T)?(T|F|T)?(F|T|F)?(F|T|T)?(T|T|T)?(T|T|T)?(T|T|F)?(F|T|F)?(F|T|T)?(T|T|T)?(T|T|T)
3CNF No.22:[n=4 k=12]->[V=44, E=76, k=28(2095 ms) Solution: [1:F 2:T 3:F 4:T]
(-4|-4|-3)?(-1|-3|4)?(-2|-2|4)?(3|-1|-4)?(-1|-1|2)?(-3|3|4)?(4|2|3)?(2|1|1)?(-2|1|2)?(-2|-1|4)?(-4|-3|-3)?(-2|-1|3) ==>
(F|F|T)?(T|T|T)?(F|F|T)?(F|T|F)?(T|T|T)?(T|F|T)?(T|T|F)?(T|F|F)?(F|F|T)?(F|T|T)?(F|T|F)
3CNF No.23:[n=5 k=6]->[V=28, E=41, k=17(3 ms) Solution: [1:F 2:T 3:F 4:T 5:T]
(4|-3|-4)?(5|4|-5)?(2|-3|2)?(1|3|-1)?(-1|-1|5)?(2|-3|2) ==>
(T|T|F)?(T|T|F)?(T|T|T)?(F|F|T)?(T|T|T)?(T|T|T)
3CNF No.24:[n=5 k=7]->[V=31, E=47, k=19(7 ms) Solution: [1:F 2:F 3:T 4:T 5:F]
(-1|2|-4)?(1|-4|3)?(-5|5|-2)?(-1|-5|-2)?(5|-3|4)?(4|-2|3)?(3|1|-1) ==>
29°F
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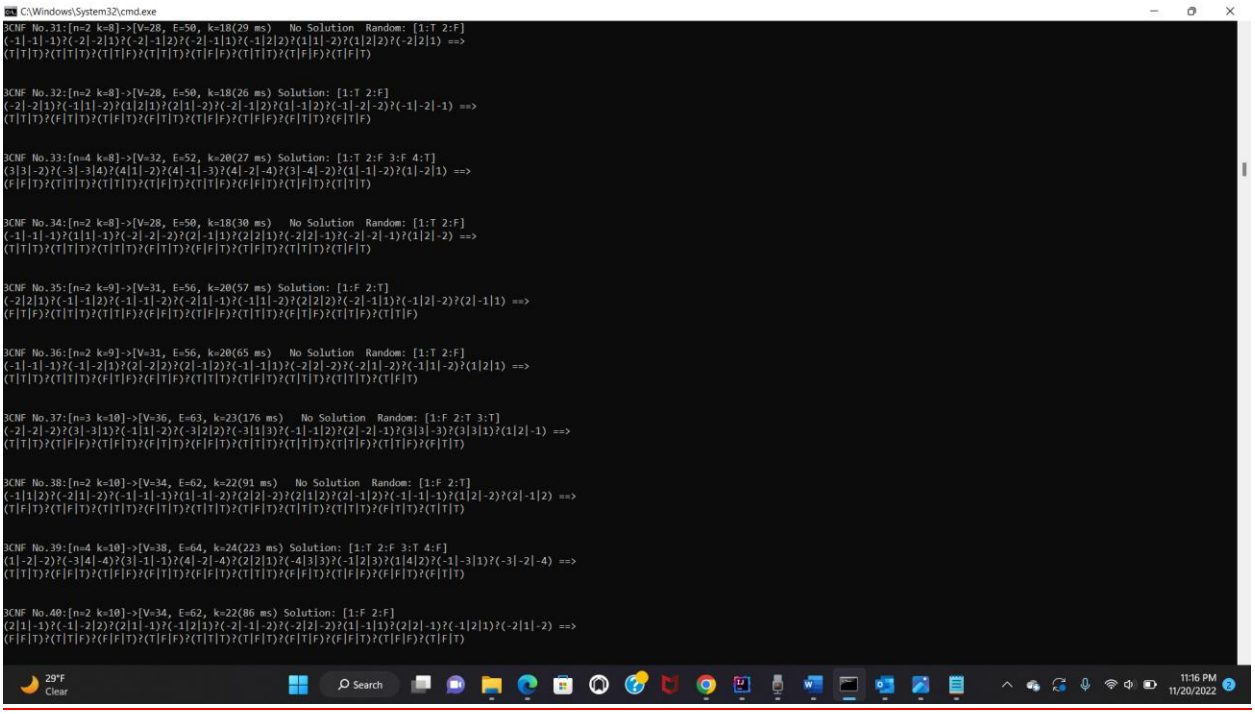
11:16 PM
11/20/2022



Cook-reduction that reduces Clique to Vertex-Cover

Summary: Here we need to find minimum vertex cover of the given graph using first method (findVCover). After getting minimum vertex we will remove this vertex from actual graph vertices. The remaining vertices will become a clique for that graph.

Algorithm:

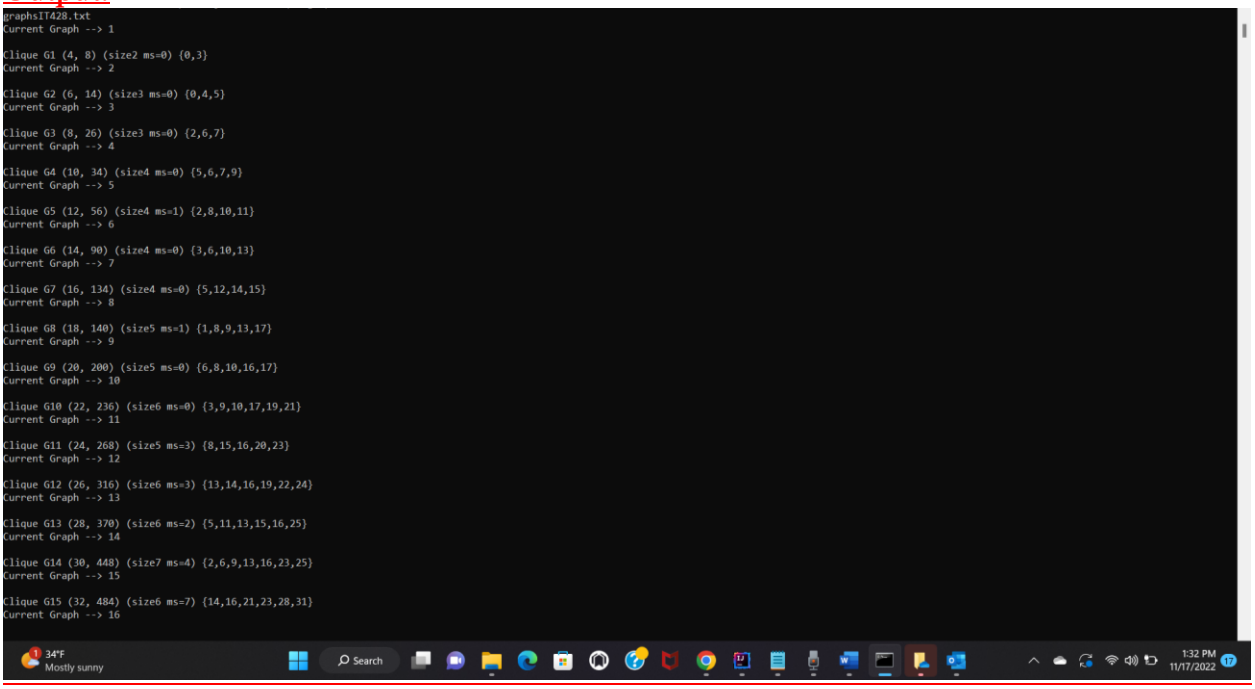
step1 – Program will send the given graph to method findVCover method which will return minimum vertex cover.
step 2 – After getting minimum vertex cover, algorithm will exclude this from the given graph
step 3 – Algorithm will print the remaining vertices which are clique for a given graph.

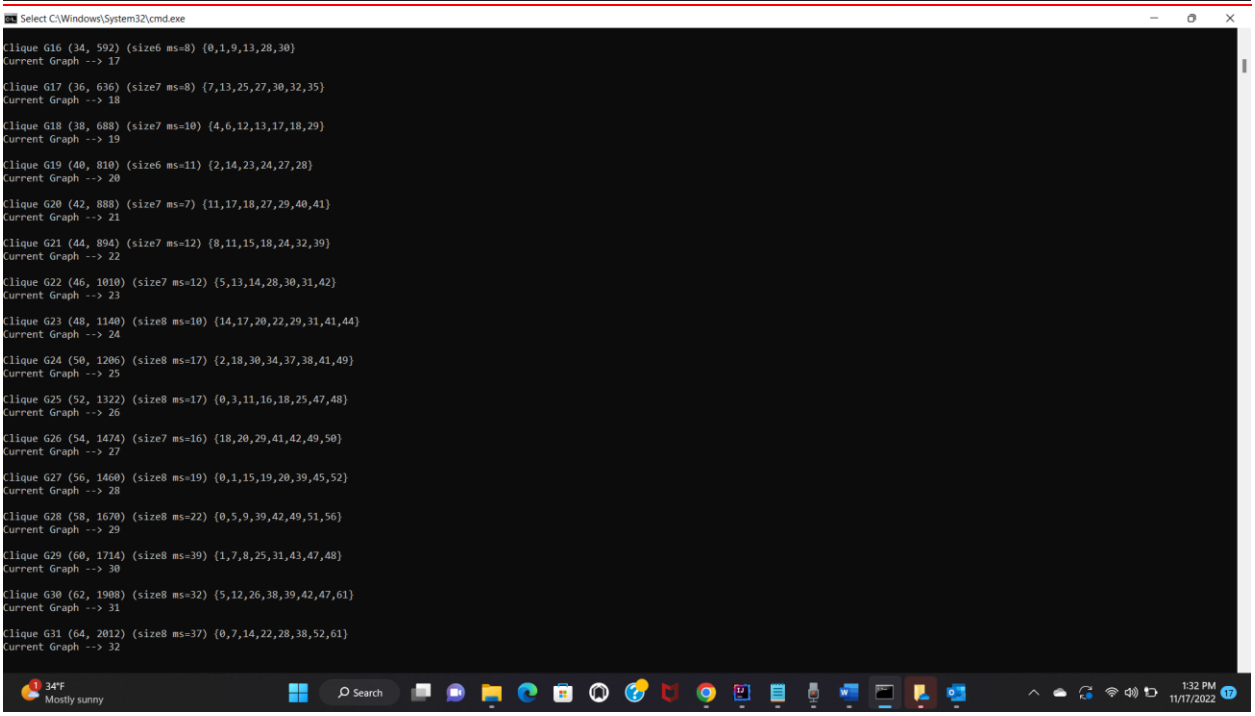
Other Methods used in Method c :

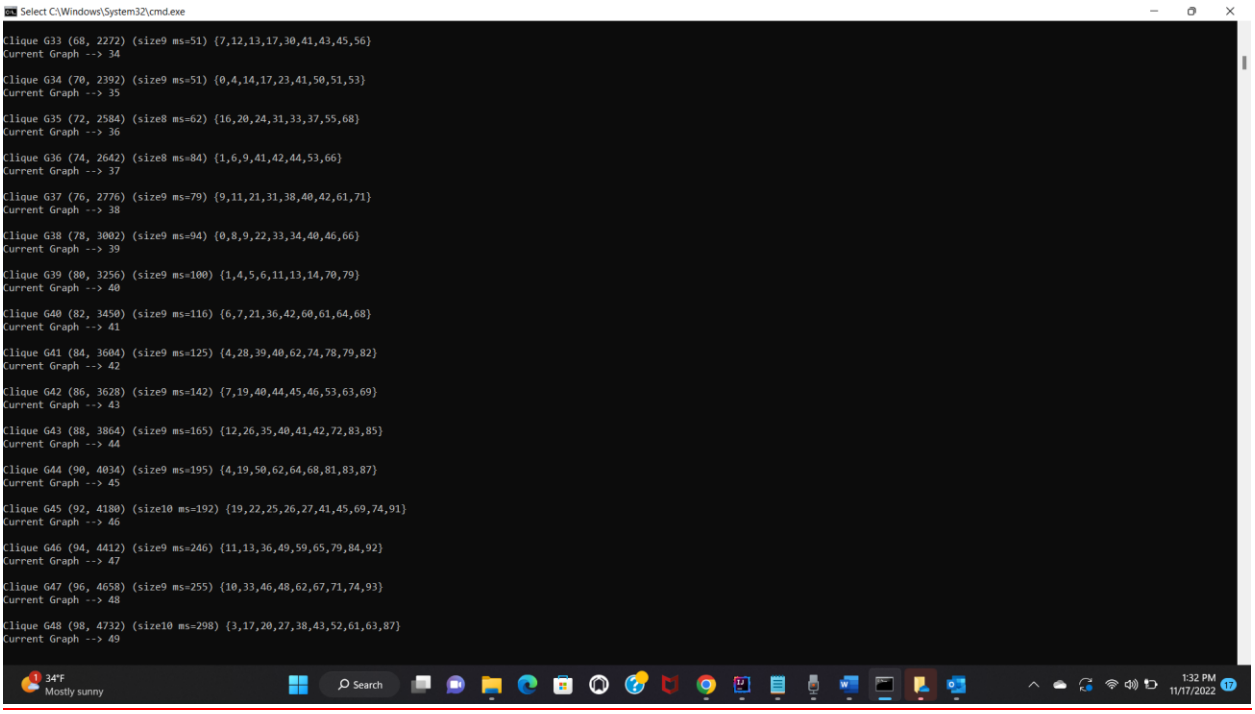
greedyCover - Returns a minimum vertex which will be used by greedyCoverExp method.
greedyCoverExp – Returns vertex cover if there exist a k vertex cover.
printVetexList - This method will print all the vertices in the list.
removeEdges – This method will remove the edges from the graph.
getMaxDegree – This method will return the max degree vertex.

getVertexEdges – This method will return edges for vertex
getVertexDegree – This method will return degree of a vertex
removeVertex - This will remove vertex from the vertices list.

Output:






Select C:\Windows\System32\cmd.exe
Clique G33 (68, 2272) (size9 ms=51) {7,12,13,17,30,41,43,45,56}
Current Graph --> 34
Clique G34 (70, 2392) (size9 ms=51) {0,4,14,17,23,41,50,51,53}
Current Graph --> 35
Clique G35 (72, 2584) (size8 ms=62) {16,20,24,31,33,37,55,68}
Current Graph --> 36
Clique G36 (74, 2642) (size8 ms=84) {1,6,9,41,42,44,53,66}
Current Graph --> 37
Clique G37 (76, 2776) (size9 ms=79) {9,11,21,31,38,40,42,61,71}
Current Graph --> 38
Clique G38 (78, 3002) (size9 ms=94) {0,8,9,22,33,34,40,46,66}
Current Graph --> 39
Clique G39 (80, 3256) (size9 ms=100) {1,4,5,6,11,13,14,70,79}
Current Graph --> 40
Clique G40 (82, 3450) (size9 ms=116) {6,7,21,36,42,60,61,64,68}
Current Graph --> 41
Clique G41 (84, 3604) (size9 ms=125) {4,28,39,40,62,74,78,79,82}
Current Graph --> 42
Clique G42 (86, 3628) (size9 ms=142) {7,19,40,44,45,46,53,63,69}
Current Graph --> 43
Clique G43 (88, 3864) (size9 ms=165) {12,26,35,40,41,42,72,83,85}
Current Graph --> 44
Clique G44 (90, 4034) (size9 ms=195) {4,19,50,62,64,68,81,83,87}
Current Graph --> 45
Clique G45 (92, 4180) (size10 ms=192) {19,22,25,26,27,41,45,69,74,91}
Current Graph --> 46
Clique G46 (94, 4412) (size9 ms=246) {11,13,36,49,59,65,79,84,92}
Current Graph --> 47
Clique G47 (96, 4658) (size9 ms=255) {10,33,46,48,62,67,71,74,93}
Current Graph --> 48
Clique G48 (98, 4732) (size10 ms=298) {3,17,20,27,38,43,52,61,63,87}
Current Graph --> 49
34°F
Mostly sunny
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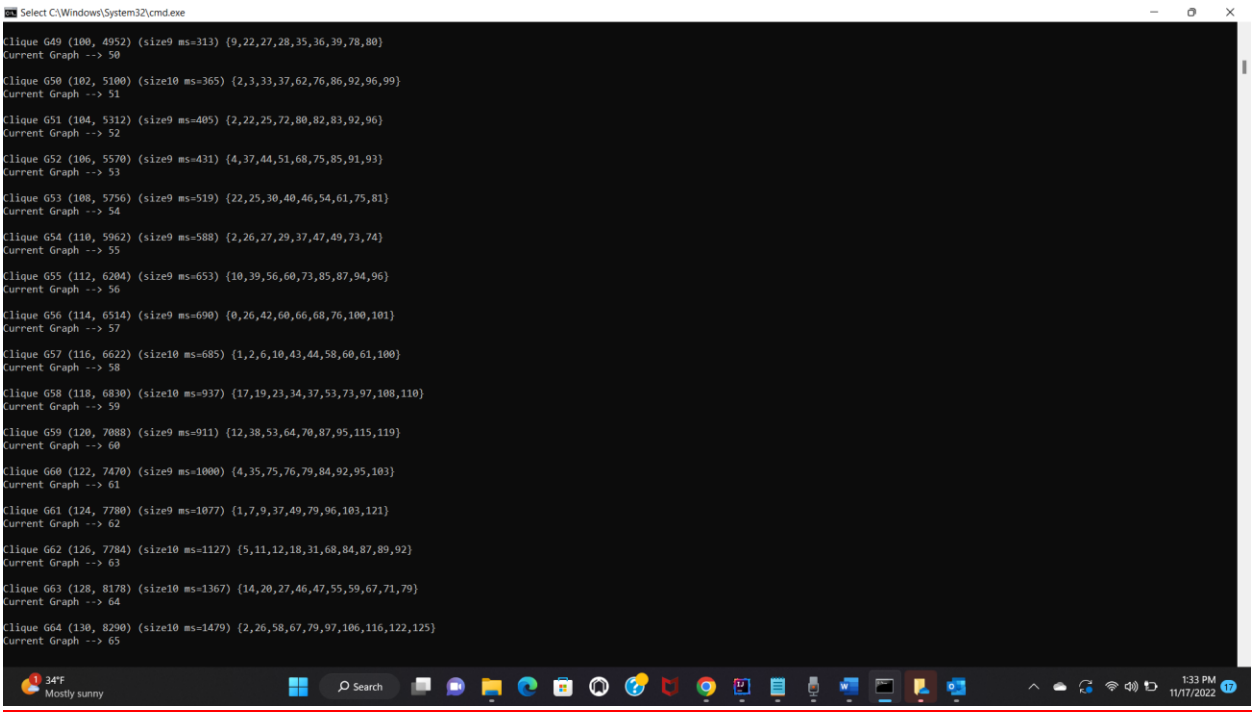
1:32 PM
11/17/2022


Select C:\Windows\System32\cmd.exe
Clique G49 (100, 4952) (size9 ms=313) {9,22,27,28,35,36,39,78,80}
Current Graph --> 50
Clique G50 (102, 5100) (size10 ms=365) {2,3,33,37,62,76,86,92,96,99}
Current Graph --> 51
Clique G51 (104, 5312) (size9 ms=405) {2,22,25,72,80,82,83,92,96}
Current Graph --> 52
Clique G52 (106, 5570) (size9 ms=431) {4,37,44,51,68,75,85,91,93}
Current Graph --> 53
Clique G53 (108, 5756) (size9 ms=519) {22,25,30,40,46,54,61,75,81}
Current Graph --> 54
Clique G54 (110, 5962) (size9 ms=588) {2,26,27,29,37,47,49,73,74}
Current Graph --> 55
Clique G55 (112, 6204) (size9 ms=653) {10,39,56,60,73,85,87,94,96}
Current Graph --> 56
Clique G56 (114, 6514) (size9 ms=690) {0,26,42,60,66,68,76,100,101}
Current Graph --> 57
Clique G57 (116, 6622) (size10 ms=685) {1,2,6,10,43,44,58,60,61,100}
Current Graph --> 58
Clique G58 (118, 6830) (size10 ms=937) {17,19,23,34,37,53,73,97,108,110}
Current Graph --> 59
Clique G59 (120, 7088) (size9 ms=911) {12,38,53,64,70,87,95,115,119}
Current Graph --> 60
Clique G60 (122, 7470) (size9 ms=1000) {4,35,75,76,79,84,92,95,103}
Current Graph --> 61
Clique G61 (124, 7780) (size9 ms=1077) {1,7,9,37,49,79,96,103,121}
Current Graph --> 62
Clique G62 (126, 7784) (size10 ms=1127) {5,11,12,18,31,68,84,87,89,92}
Current Graph --> 63
Clique G63 (128, 8178) (size10 ms=1367) {14,20,27,46,47,55,59,67,71,79}
Current Graph --> 64
Clique G64 (130, 8290) (size10 ms=1479) {2,26,58,67,79,97,106,116,122,125}
Current Graph --> 65
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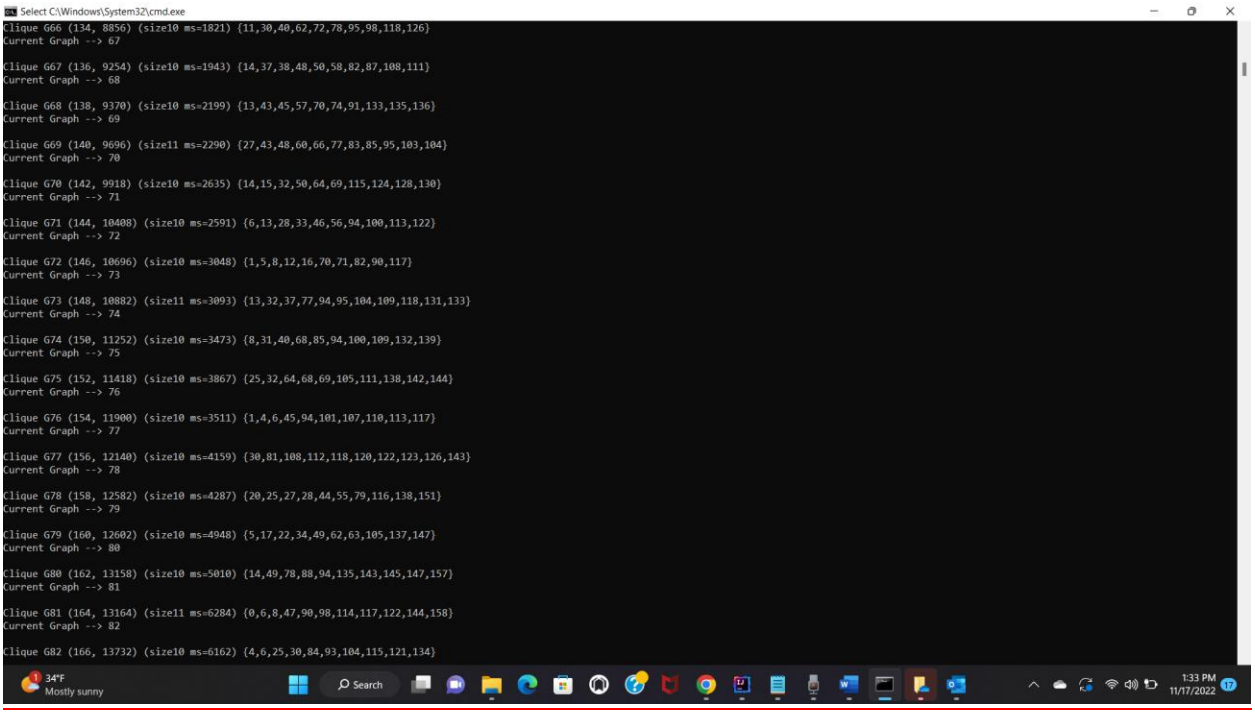
11/17/2022


Select C:\Windows\System32\cmd.exe
Clique G66 (134, 8856) (size10 ms=1821) {11,30,40,62,72,78,95,98,118,126}
Current Graph --> 67
Clique G67 (136, 9254) (size10 ms=1943) {14,37,38,48,50,58,82,87,108,111}
Current Graph --> 68
Clique G68 (138, 9370) (size10 ms=2199) {13,43,45,57,70,74,91,133,135,136}
Current Graph --> 69
Clique G69 (140, 9696) (size11 ms=2290) {27,43,48,60,66,77,83,85,95,103,104}
Current Graph --> 70
Clique G70 (142, 9918) (size10 ms=2635) {14,15,32,50,64,69,115,124,128,130}
Current Graph --> 71
Clique G71 (144, 10408) (size10 ms=2591) {6,13,28,33,46,56,94,100,113,122}
Current Graph --> 72
Clique G72 (146, 10696) (size10 ms=3048) {1,5,8,12,16,70,71,82,90,117}
Current Graph --> 73
Clique G73 (148, 10882) (size11 ms=3093) {13,32,37,77,94,95,104,109,118,131,133}
Current Graph --> 74
Clique G74 (150, 11252) (size10 ms=3473) {8,31,40,68,85,94,100,109,132,139}
Current Graph --> 75
Clique G75 (152, 11418) (size10 ms=3867) {25,32,64,68,69,105,111,138,142,144}
Current Graph --> 76
Clique G76 (154, 11900) (size10 ms=3511) {1,4,6,45,94,101,107,110,113,117}
Current Graph --> 77
Clique G77 (156, 12140) (size10 ms=4159) {30,81,108,112,118,120,122,123,126,143}
Current Graph --> 78
Clique G78 (158, 12582) (size10 ms=4287) {20,25,27,28,44,55,79,116,138,151}
Current Graph --> 79
Clique G79 (160, 12602) (size10 ms=4948) {5,17,22,34,49,62,63,105,137,147}
Current Graph --> 80
Clique G80 (162, 13158) (size10 ms=5010) {14,49,78,88,94,135,143,145,147,157}
Current Graph --> 81
Clique G81 (164, 13164) (size11 ms=6284) {0,6,8,47,90,98,114,117,122,144,158}
Current Graph --> 82
Clique G82 (166, 13732) (size10 ms=6162) {4,6,25,30,84,93,104,115,121,134}
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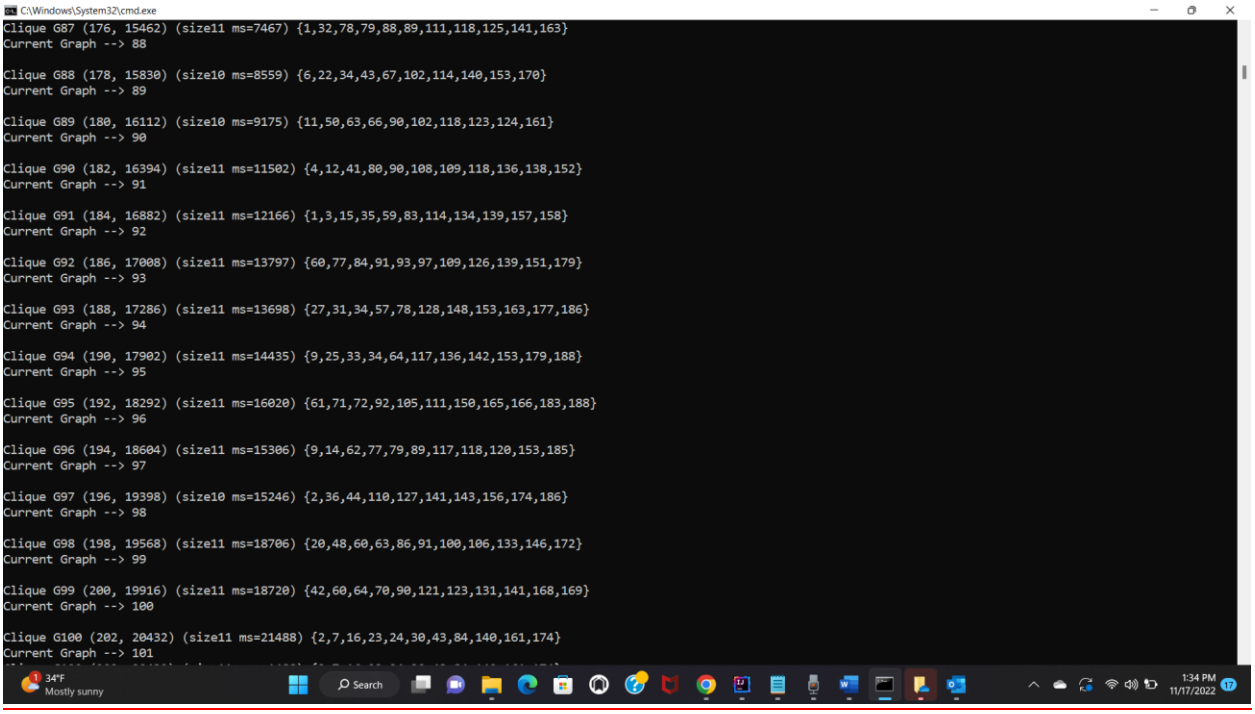
C:\Windows\System32\cmd.exe
Clique G87 (176, 15462) (size11 ms=7467) {1,32,78,79,88,89,111,118,125,141,163}
Current Graph --> 88
Clique G88 (178, 15830) (size10 ms=8559) {6,22,34,43,67,102,114,140,153,170}
Current Graph --> 89
Clique G89 (180, 16112) (size10 ms=9175) {11,50,63,66,90,102,118,123,124,161}
Current Graph --> 90
Clique G90 (182, 16394) (size11 ms=11502) {4,12,41,80,90,108,109,118,136,138,152}
Current Graph --> 91
Clique G91 (184, 16882) (size11 ms=12166) {1,3,15,35,59,83,114,134,139,157,158}
Current Graph --> 92
Clique G92 (186, 17008) (size11 ms=13797) {60,77,84,91,93,97,109,126,139,151,179}
Current Graph --> 93
Clique G93 (188, 17286) (size11 ms=13698) {27,31,34,57,78,128,148,153,163,177,186}
Current Graph --> 94
Clique G94 (190, 17902) (size11 ms=14435) {9,25,33,34,64,117,136,142,153,179,188}
Current Graph --> 95
Clique G95 (192, 18292) (size11 ms=16020) {61,71,72,92,105,111,150,165,166,183,188}
Current Graph --> 96
Clique G96 (194, 18604) (size11 ms=15306) {9,14,62,77,79,89,117,118,120,153,185}
Current Graph --> 97
Clique G97 (196, 19398) (size10 ms=15246) {2,36,44,110,127,141,143,156,174,186}
Current Graph --> 98
Clique G98 (198, 19568) (size11 ms=18706) {20,48,60,63,86,91,100,106,133,146,172}
Current Graph --> 99
Clique G99 (200, 19916) (size11 ms=18720) {42,60,64,70,90,121,123,131,141,168,169}
Current Graph --> 100
Clique G100 (202, 20432) (size11 ms=21488) {2,7,16,23,24,30,43,84,140,161,174}
Current Graph --> 101
34°F
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Challenges:

Reducing Time Complexity:

- **Difficulty:** As we all know minimum vertex cover is NP-complete problem. In the initial stage we approached this problem using greedy algorithm. But we noticed that it is giving wrong vertex cover as the graph size increasing. Next, we approached using brute-force algorithm. Brute-force algorithm gives correct answer. But with brute force approach as graph size increasing its showing TLE error because it must check every combination in graph.
- **Our Approach:** we need to optimize this algorithm in order to overcome time limit exceeded problem. Extending greedy algorithm using recursive calls. By this we can eliminate time limit exceeded problem. In this new algorithm we can include or exclude the max vertex. The algorithm will not include maximum degree vertex then it will include large number of vertices which will converge the graph faster. By this we can overcome the time limit exceeded problem.

After spending a lot of time on this problem we believe that there will be no polynomial solution for NP-complete problem in future. We believe NP class never convert into P class.

References:

https://youtu.be/iZPzBHGDsWI **Instructor: Michael Sipser**

https://www.tutorialspoint.com/prove-that-the-polynomial-time-reduction-is-from-the-clique-problem-to-the-vertex-cover-problem

https://youtu.be/eqE5ZSJVnn4 **Minimum vertex cover for a tree using dynamic programming**