

# Toward a New Proof of the Four Coloring Theorem

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## Abstract

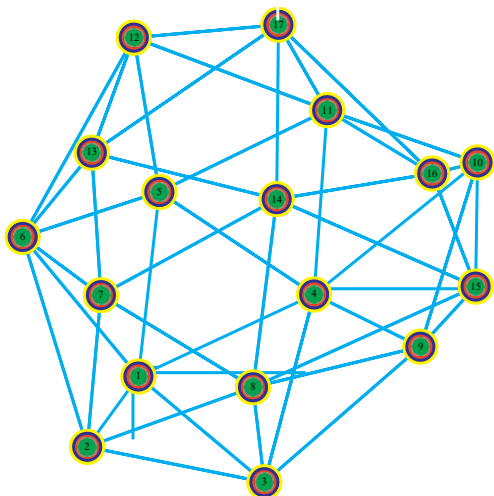
A heuristic algorithm is described for four coloring planar graphs. The algorithm is based on the principle of breaking a problem into components and solving them one at a time. The algorithm uses generalized alternating chains of the most general kind, for instance they can have branches and self-intersections. Alternating chains are found which, after completing each major iteration of the algorithm, a certain property is preserved. This property ensures that a successive alternating chain will be easy to find.

Specifically, the property ensures that the branches of an alternating chain cannot conflict with each other, and a branch cannot conflict with itself. This algorithm solves one set of problems, but the solution has its own set of problems. However, I think these can be easily resolved, leading to a new and simple proof of the Four-Color Theorem.

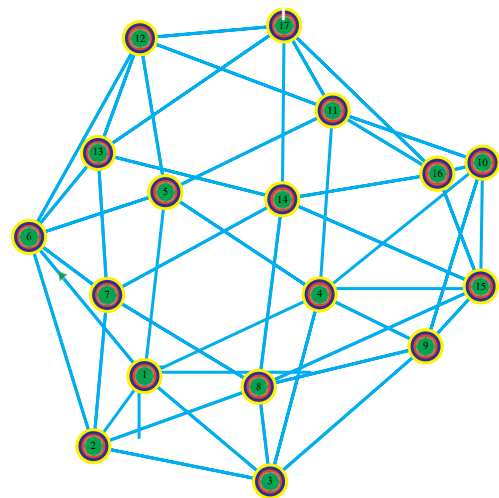
## 1. An Example

In the beginning a checker of each of the four colors is placed on every vertex. Things start off slowly, the first alternating chain of length greater than one occurs at figure 64. Property B, the crux of the algorithm, is defined at figure 4.

(Step through the example page by page so you can see the algorithm in action - don't scroll.)

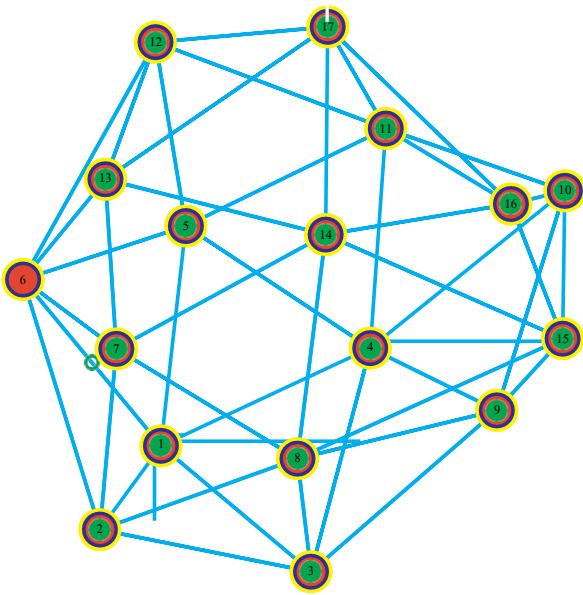


**Figure 1. Instructions:** In the beginning a checker of each of the four colors, Green, Red, Blue, and Yellow, is placed on every vertex.



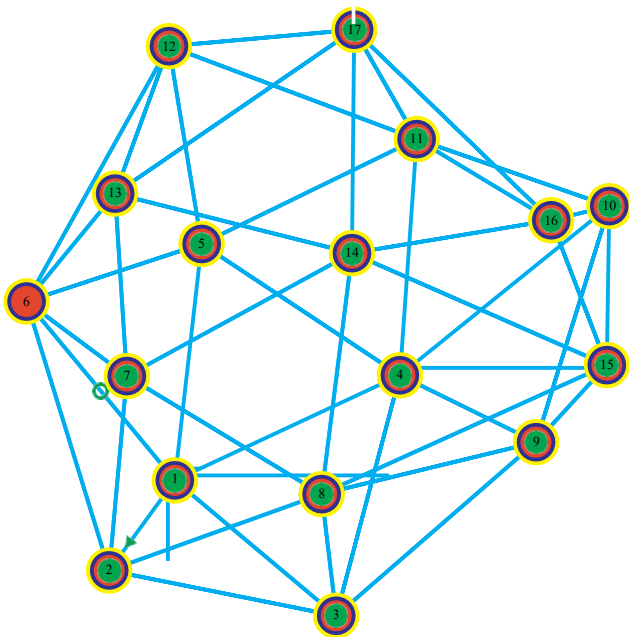
**Figure 2. Instructions:** 1: place edge 1→6 Green Arrow R.

When the above instruction is executed by the computer a triangular green arrowhead is placed on the directed edge 1→6. A triangular green arrowhead is used to indicate the deletion (Removal) of the green checker on the vertex pointed to (in this case vertex 6). Define triangle arrowheads as deletion (Removal) arrows. Later we'll define insertion arrows.



**Figure 3. Instructions:** 4: Color Edge 1–6 Green, 5: Un Color Vertex 6 Green.

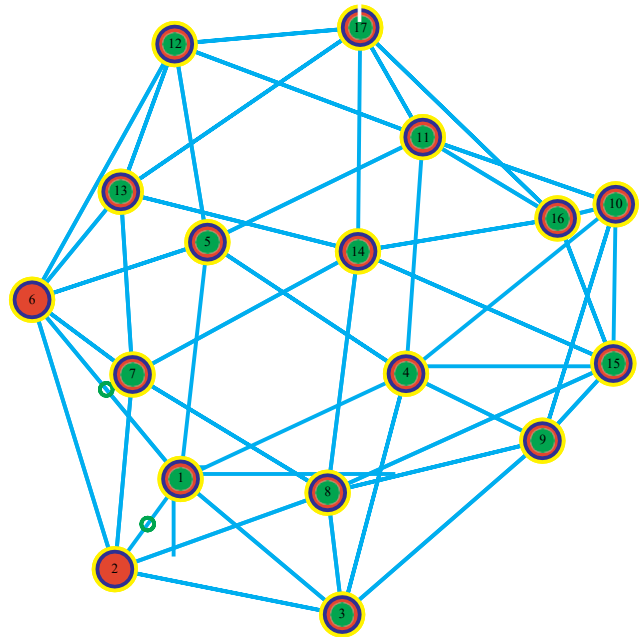
When the above instructions are executed a circle is placed (exactly in the middle) on the undirected edge 1-6 indicating that this edge is green colored. The green checker has been removed from vertex 6. Now the edge is conflict free wtr the color green ie there is only one green checker on vertices of this edge.



**Figure 4. Instructions:** 7: Place Edge 1→2 Green Arrow R. Continuing in this manner we obtain a sequence of graphs with the following properties.

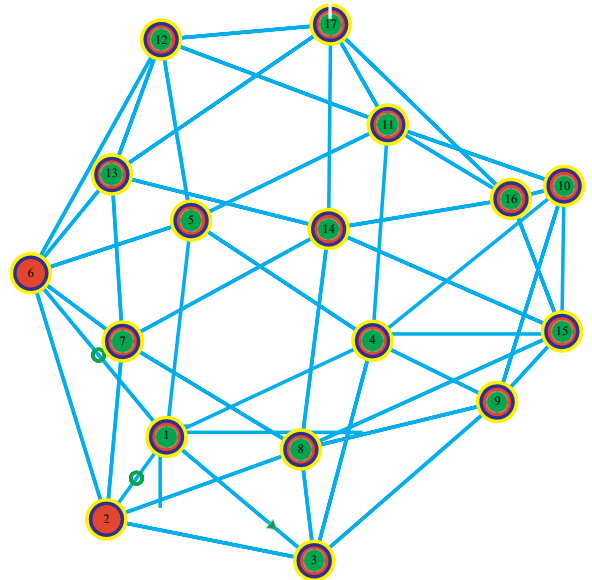
1. If a circle of a given color is on an edge there cannot be two checkers of the same color on vertices of that edge. Let's call this property A.

2. If a circle of a given color is on an edge there must be one and only one checker of that color on vertices of that edge. Let's call this property B.

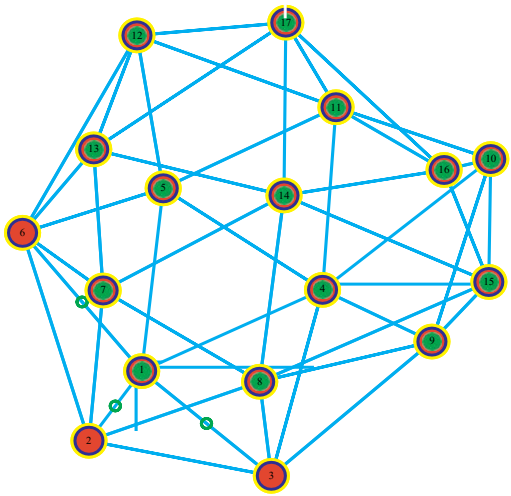


**Figure 5. Instructions:** 10: Color Edge 1–2 Green, 11: Un Color Vertex 2 Green.

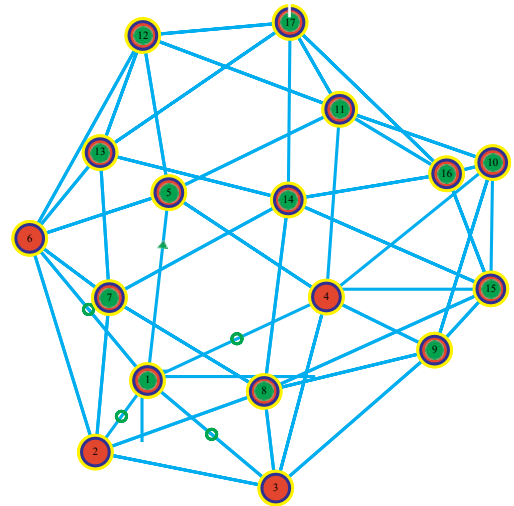
The green checker has been removed from vertex 2 and a green circle has been placed on edge 1-2 and properties A and B are satisfied as they will be after each major iteration of the algorithm



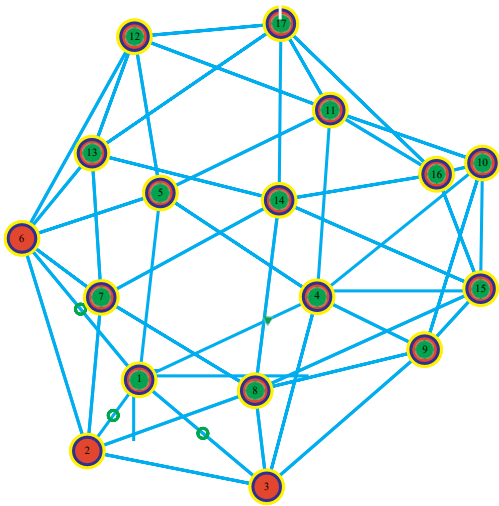
**Figure 6. Instructions:** 13: Place Edge 1→3 Green Arrow R..



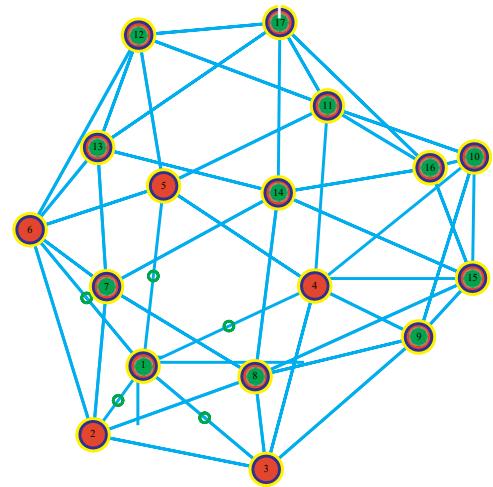
**Figure 7. Instructions:** 16: Color Edge 1-3 Green, 17: Un Color Vertex 3 Green.



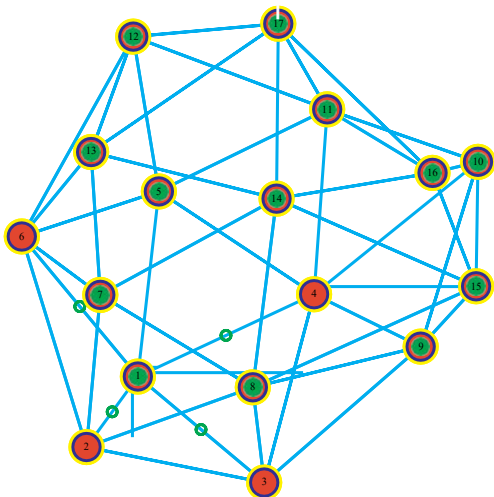
**Figure 10. Instructions:** 25: Place Edge 1-5 Green Arrow R.



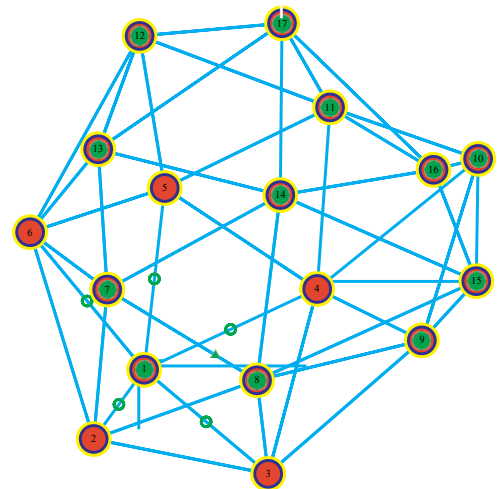
**Figure 8. Instructions:** 19: Place Edge 1-4 Green Arrow R.



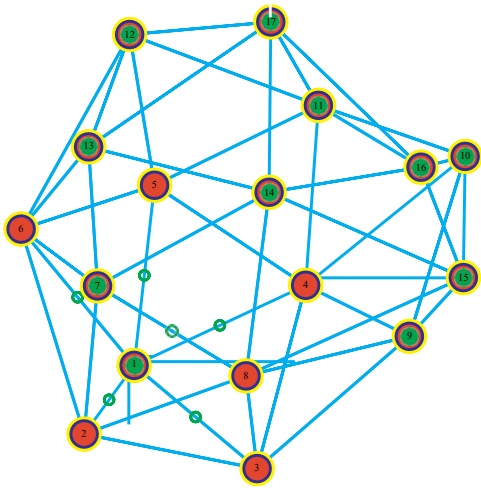
**Figure 11. Instructions:** 28: Color Edge 1-5 Green, 29: Un Color Vertex 5 Green.



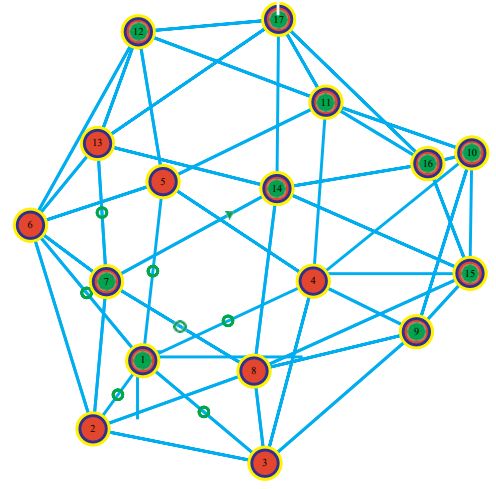
**Figure 9. Instructions:** 22: Color Edge 1-4 Green, 23: Un Color Vertex 4 Green.



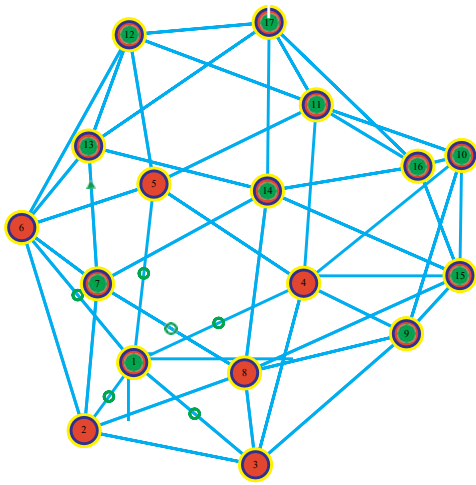
**Figure 12. Instructions:** 31: Place Edge 7-8 Green Arrow R.



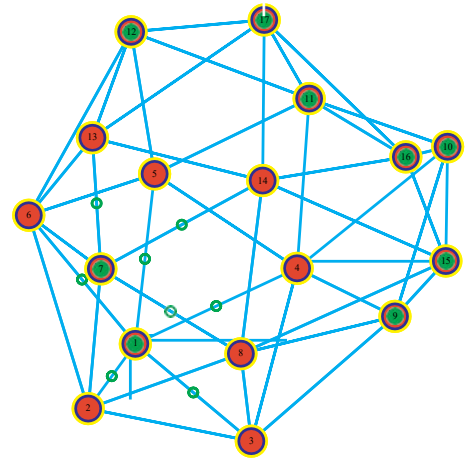
**Figure 13. Instructions:** 34: Color Edge 7-8 Green, 35: Un Color Vertex 8 Green.



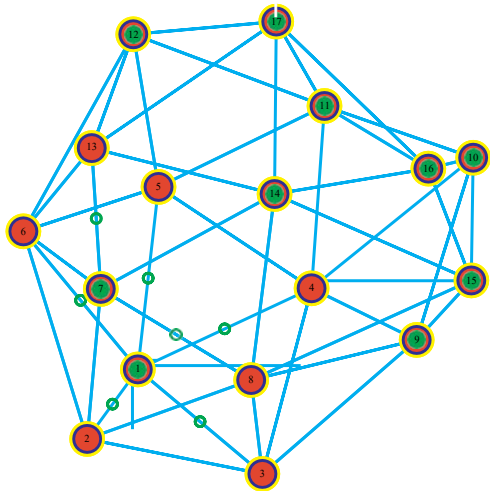
**Figure 16. Instructions:** 43: Place Edge 7-14 Green Arrow R.



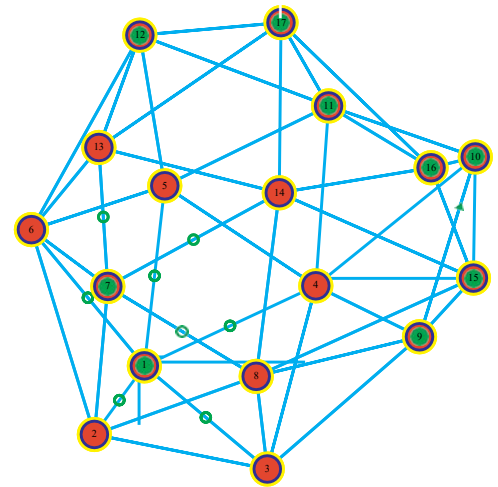
**Figure 14. Instructions:** 37: Place Edge 7-13 Green Arrow R.



**Figure 17. Instructions:** 46: color edge 7-14 Green, 47: Un Color Vertex 14 Green.



**Figure 15. Instructions:** 40: Color Edge 7-13 Green, 41: Un Color Vertex 13 Green.



**Figure 18. Instructions:** 49: Place Edge 9-10 Green Arrow R.

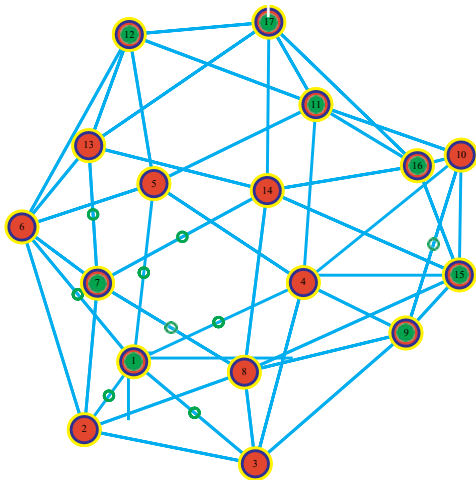


Figure 19. Instructions: 52: Color Edge 9–10 Green, 53: Un Color Vertex 10 Green.

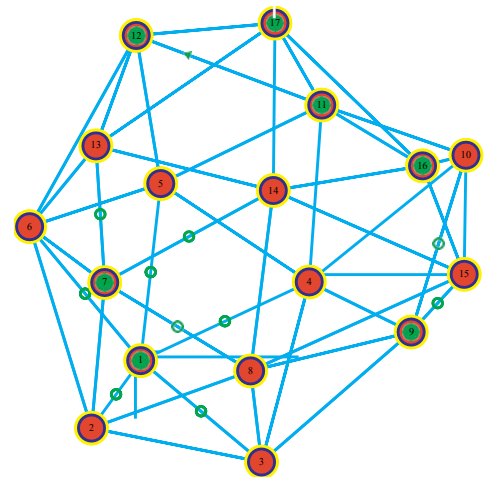


Figure 22. Instructions: 61: Place Edge 11→12 Green Arrow R.

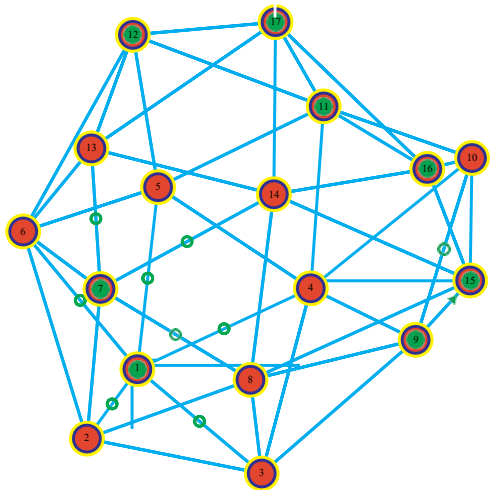


Figure 20. Instructions: 55: Place Edge 9→15 Green Arrow R.

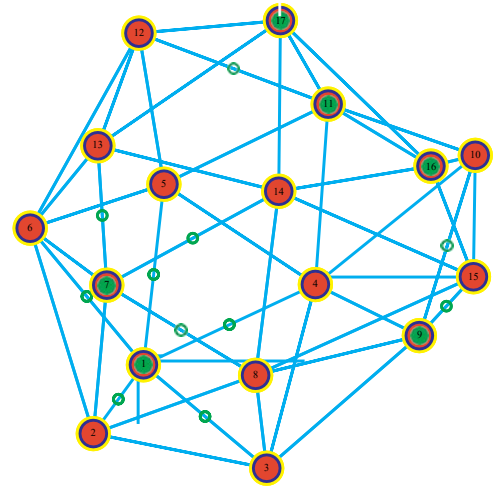


Figure 23. Instructions: 64: Color Edge 11–12 Green, 65: Un Color Vertex 12 Green.

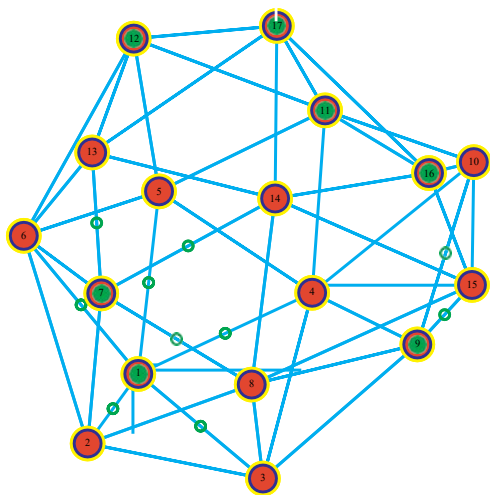


Figure 21. Instructions: 58: Color Edge 9–15 Green, 59: Un Color Vertex 15 Green.

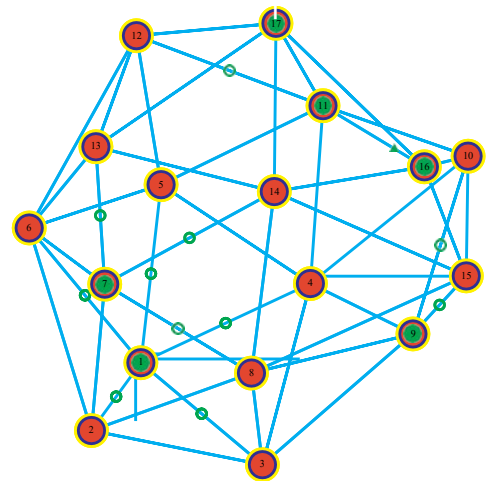
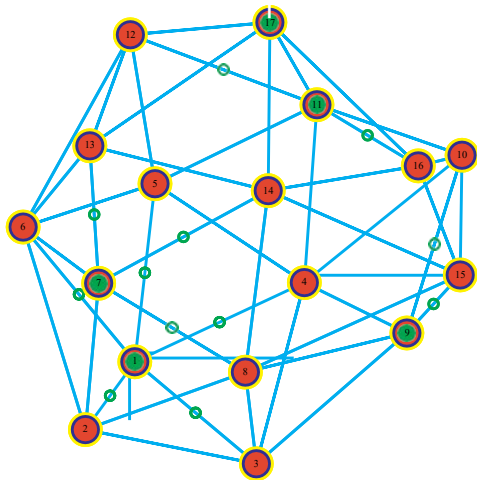
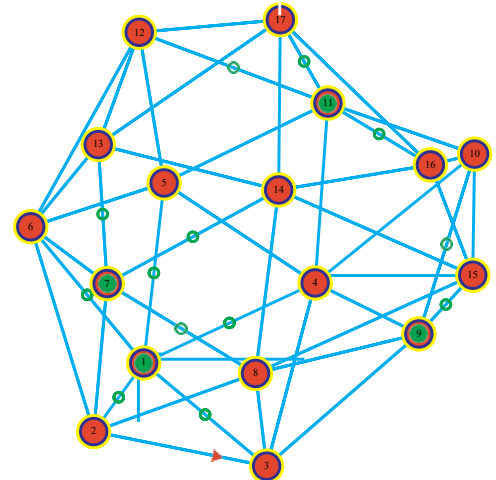


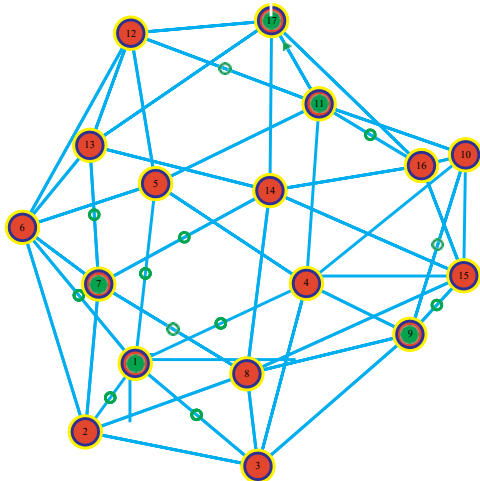
Figure 24. Instructions: 67: Place Edge 11→16 Green Arrow R.



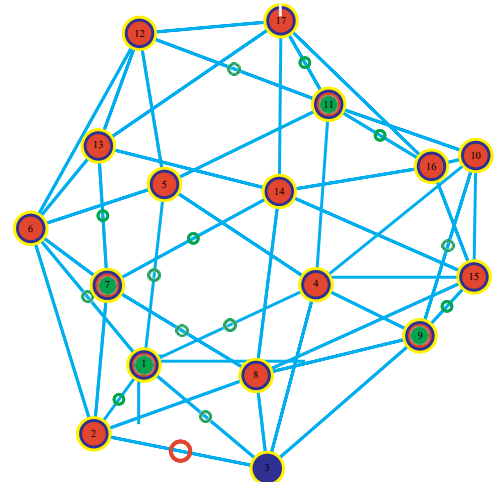
**Figure 25. Instructions:** 70: Color Edge 11–16 Green, 71: Un Color Vertex 16 Green.



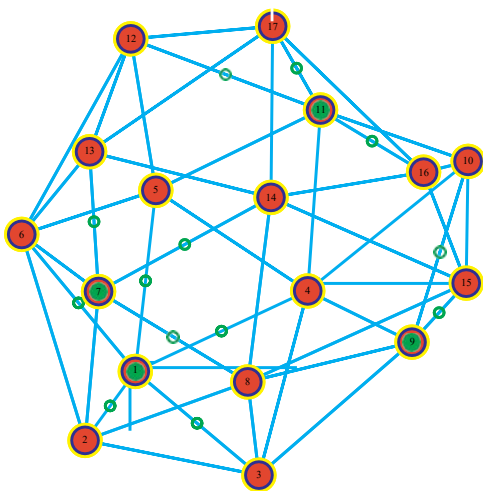
**Figure 28. Instructions:** 79: Place Edge 2→3 Red Arrow R.



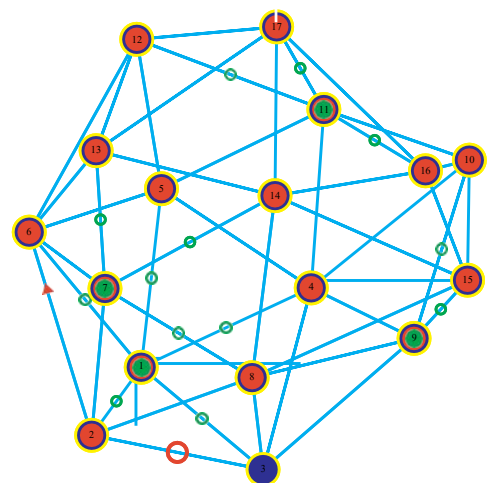
**Figure 26. Instructions:** 73: Place Edge 11→17 Green Arrow R.



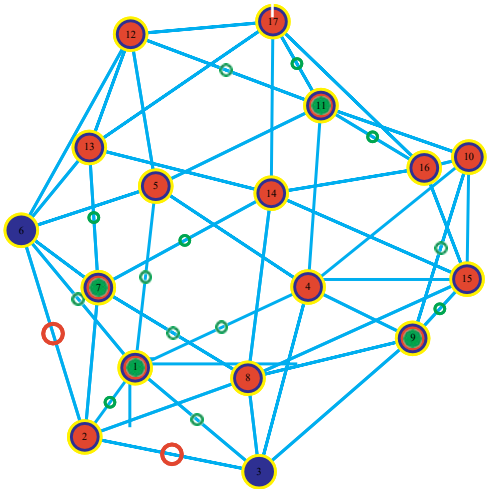
**Figure 29. Instructions:** 82: Color Edge 2–3 Red, 83: Un Color Vertex 3 Red.



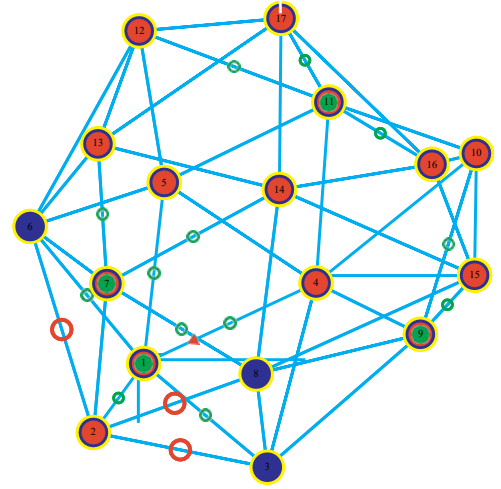
**Figure 27. Instructions:** 76: Color Edge 11–17 Green, 77: Un Color Vertex 17 Green.



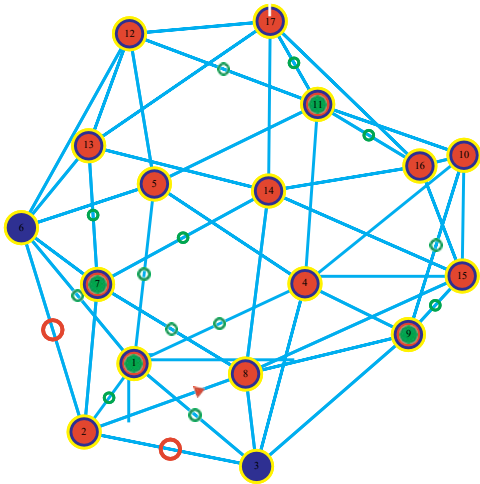
**Figure 30. Instructions:** 85: Place Edge 2→6 Red Arrow R.



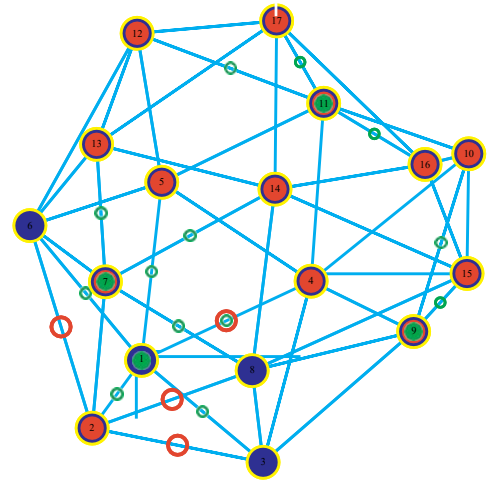
**Figure 31. Instructions:** 88: Color Edge 2-6 Red, 89: Un Color Vertex 6 Red.



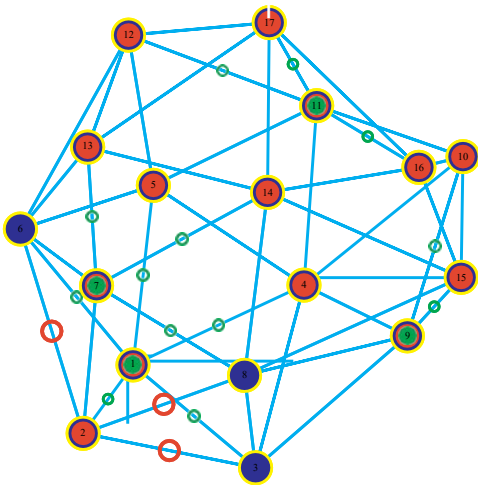
**Figure 34. Instructions:** 97: Place Edge 4→1 Red Arrow R.



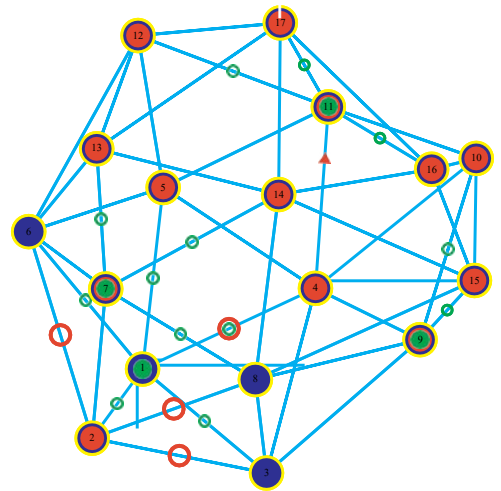
**Figure 32. Instructions:** 91: Place Edge 2→8 Red Arrow R.



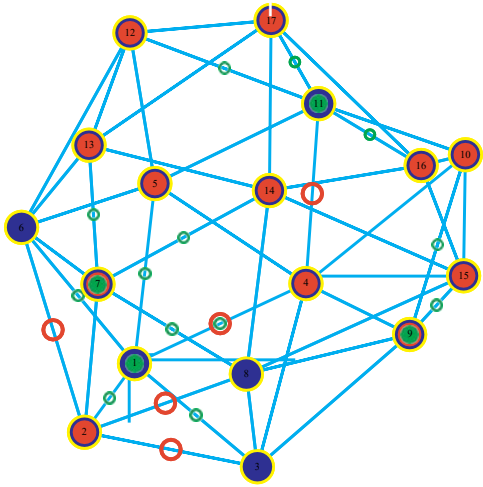
**Figure 35. Instructions:** 100: Color Edge 4-1 Red, 101: Un Color Vertex 1 Red.



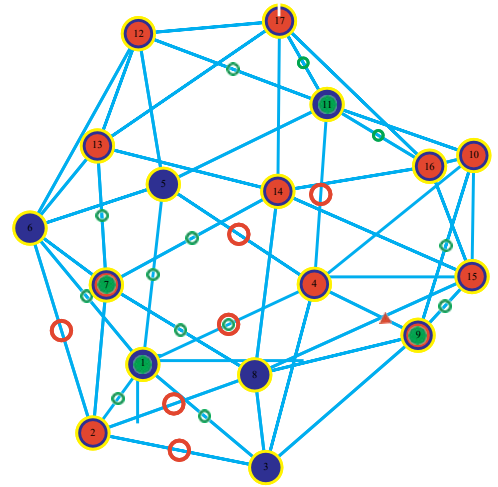
**Figure 33. Instructions:** 94: Color Edge 2-8 Red, 95: Un Color Vertex 8 Red.



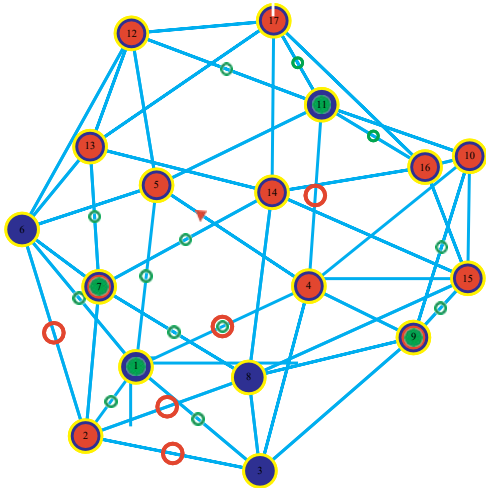
**Figure 36. Instructions:** 103: Place Edge 4→11 Red Arrow R.



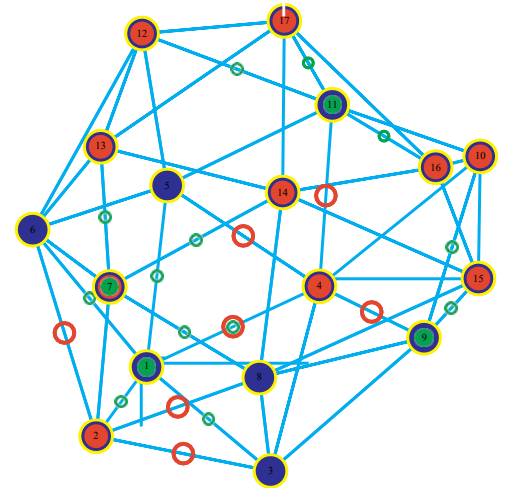
**Figure 37. Instructions:** 106: Color Edge 4-11 Red, 107: Un Color Vertex 11 Red.



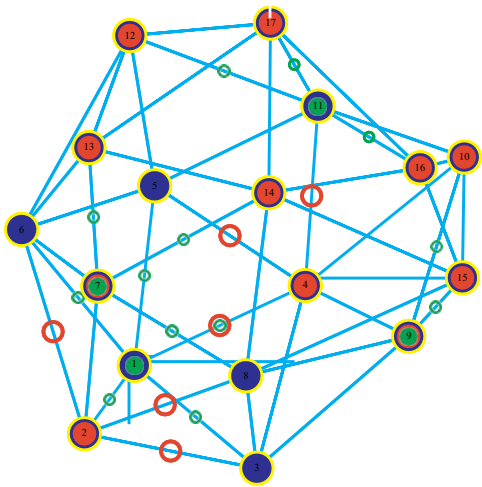
**Figure 40. Instructions:** 115: Place Edge 4-9 Red Arrow R.



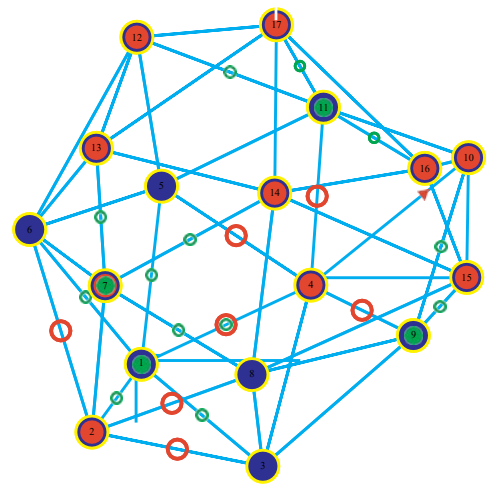
**Figure 38. Instructions:** 109: Place Edge 4-5 Red Arrow R.



**Figure 41. Instructions:** 118: Color Edge 4-9 Red, 119: Un Color Vertex 9 Red.

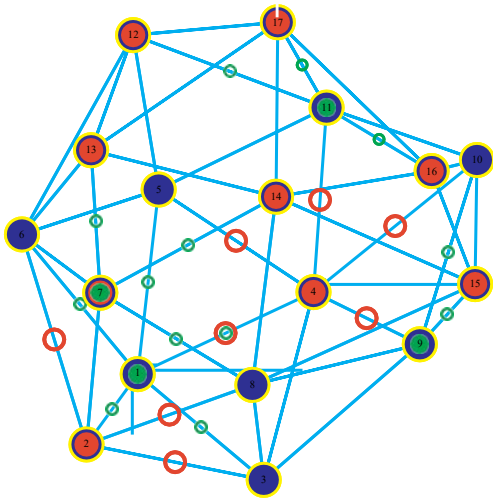


**Figure 39. Instructions:** 112: Color Edge 4-5 Red, 113: Un Color

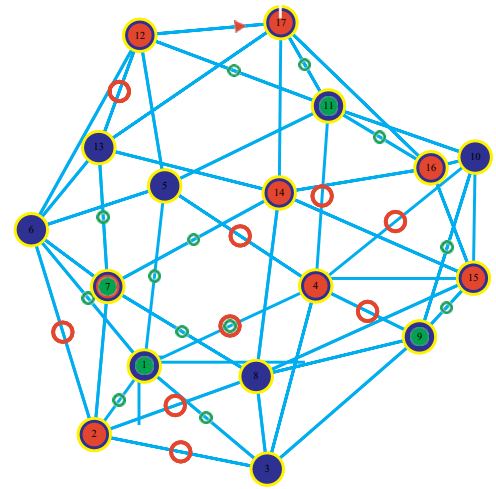


**Figure 42. Instructions:** 121: Place Edge 4-10 Red Arrow R.

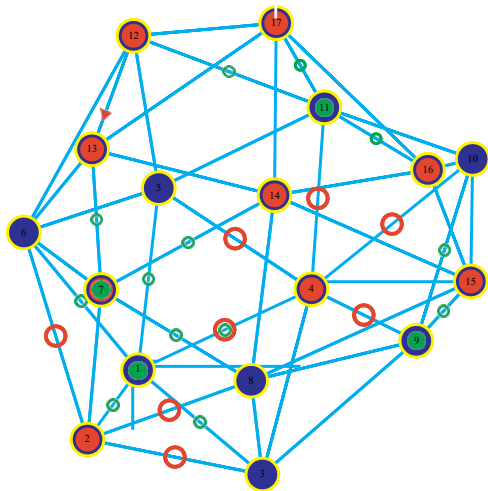




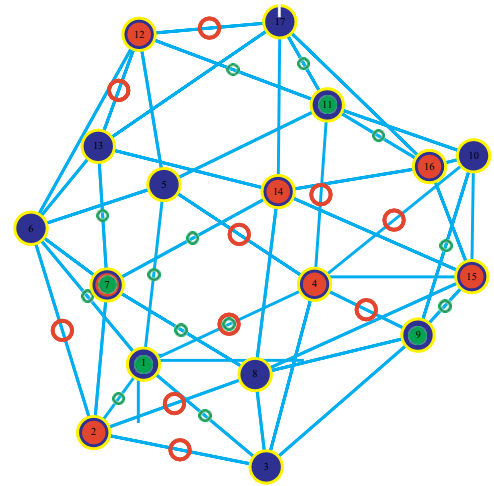
**Figure 43. Instructions:** 124: Color Edge 4–10 Red, 125: Un Color Vertex 10 Red.



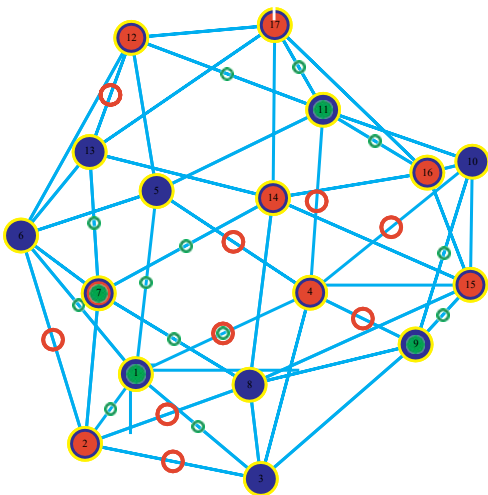
**Figure 46. Instructions:** 133: Place Edge 12→17 Red Arrow R.



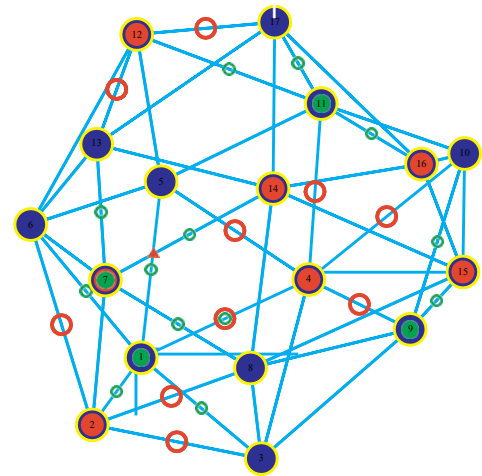
**Figure 44. Instructions:** 127: Place Edge 12→13 Red Arrow R.



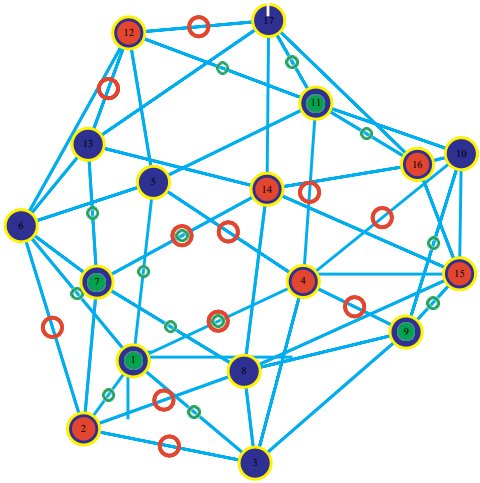
**Figure 47. Instructions:** 136: Color Edge 12–17 Red, 137: Un Color Vertex 17 Red.



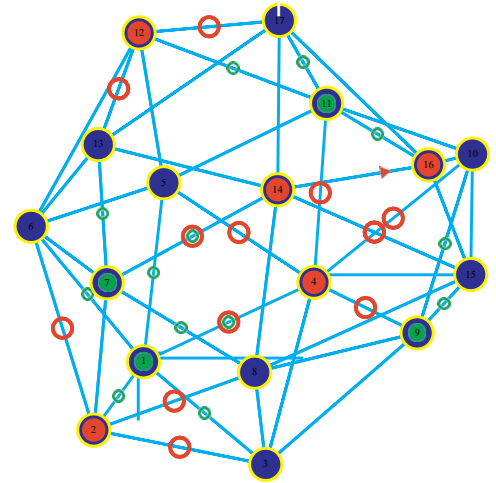
**Figure 45. Instructions:** 130: Color Edge 12–13 Red, 131: Un Color Vertex 13 Red.



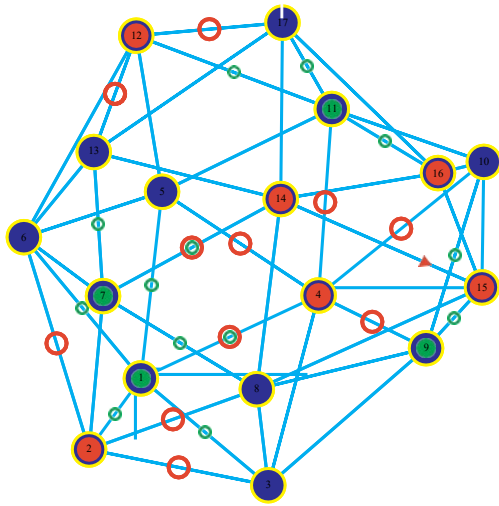
**Figure 48. Instructions:** 139: Place Edge 14→7 Red Arrow R.



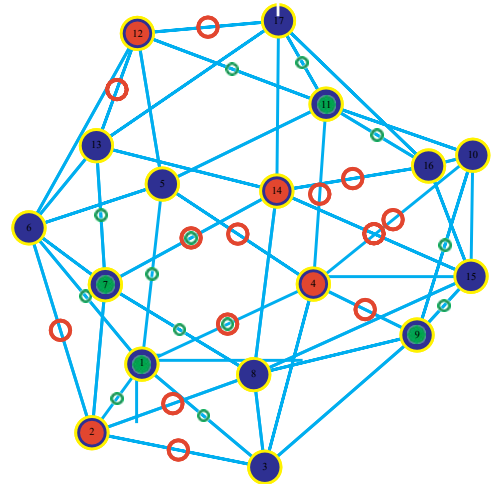
**Figure 49. Instructions:** 142: Color Edge 14-7 Red, 143: Un Color Vertex 7 Red.



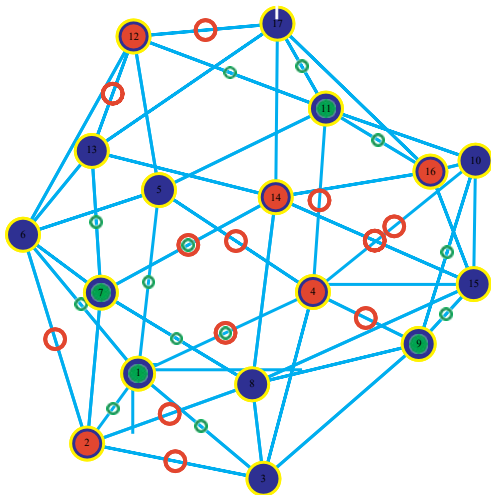
**Figure 52. Instructions:** 151: Place Edge 14→16 Red Arrow R.



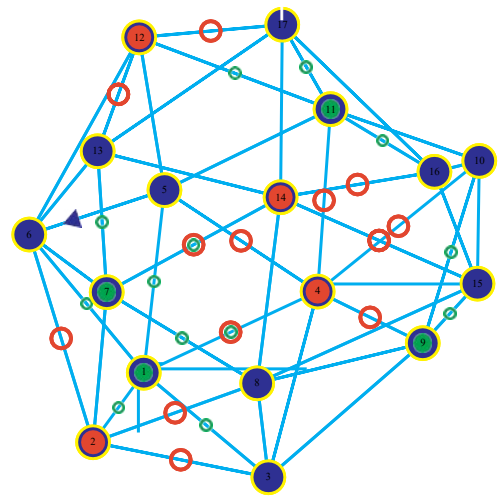
**Figure 50. Instructions:** 145: Place Edge 14→15 Red Arrow R.



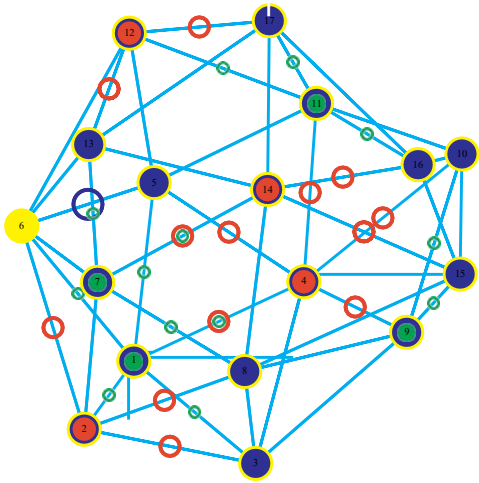
**Figure 53. Instructions:** 154: Color Edge 14-16 Red, 155: Un Color Vertex 16 Red.



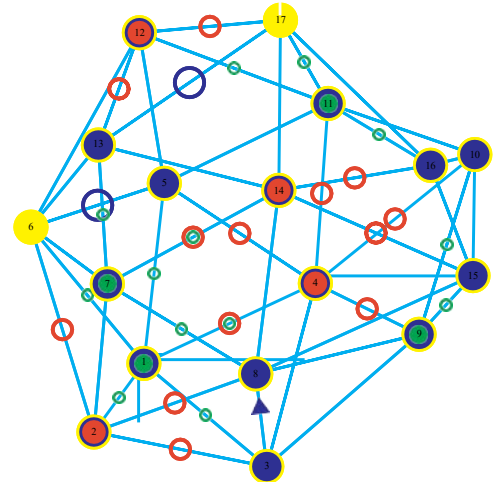
**Figure 51. Instructions:** 148: Color Edge 14-15 Red, 149: Un Color Vertex 15 Red.



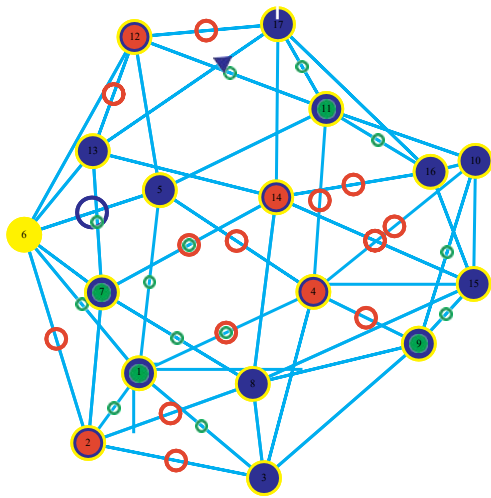
**Figure 54. Instructions:** 157: Place Edge 5→6 Blue Arrow R.



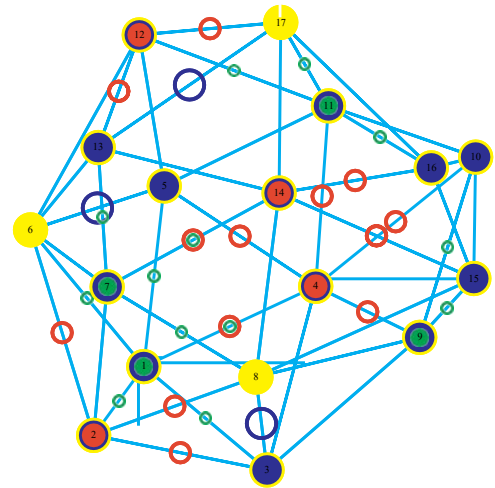
**Figure 55. Instructions:** 160: Color Edge 5-6 Blue, 161: Un Color Vertex 6 Blue.



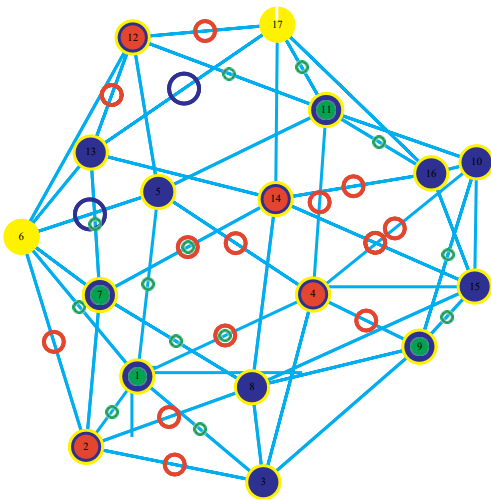
**Figure 58. Instructions:** 169: Place Edge 3→8 Blue Arrow R. Color Vertex 8 Blue.



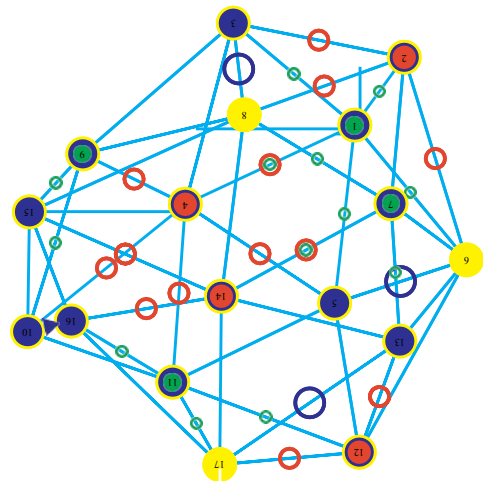
**Figure 56. Instructions:** 163: Place Edge 13→17 Blue Arrow R. Color Vertex 17 Blue.



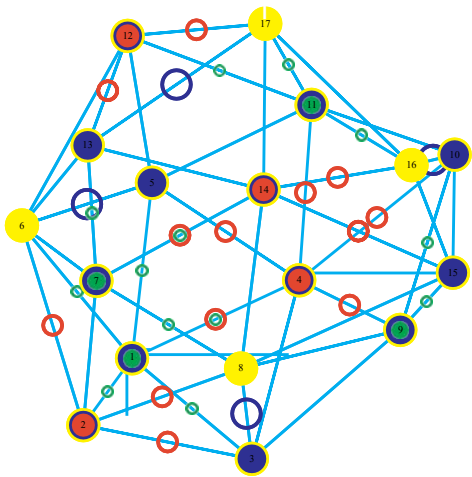
**Figure 59. Instructions:** 172: Color Edge 3-8 Blue, 173: Un Color Vertex 8 Blue.



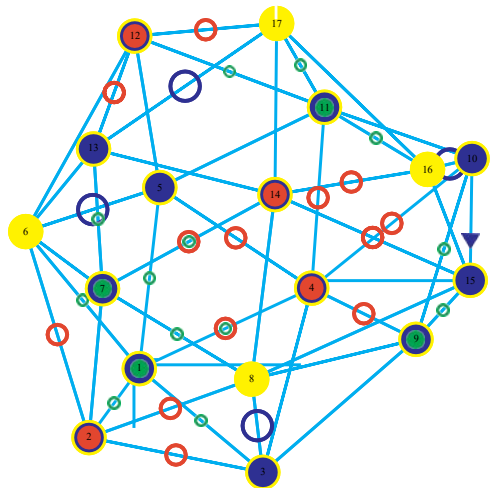
**Figure 57. Instructions:** 166: Color Edge 13-17 Blue, 167: Un Color Vertex 17 Blue.



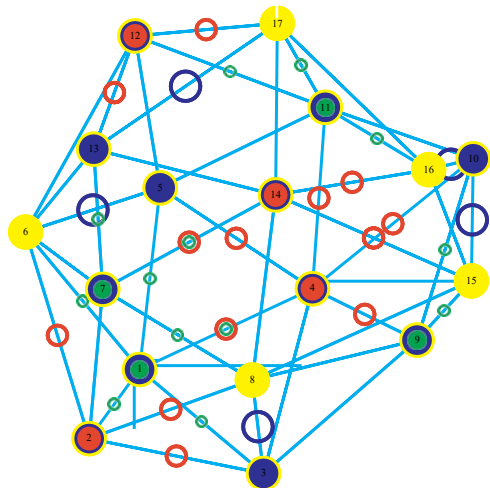
**Figure 60. Instructions:** 175: Place Edge 10→16 Blue Arrow R. Color Vertex 16 Blue.



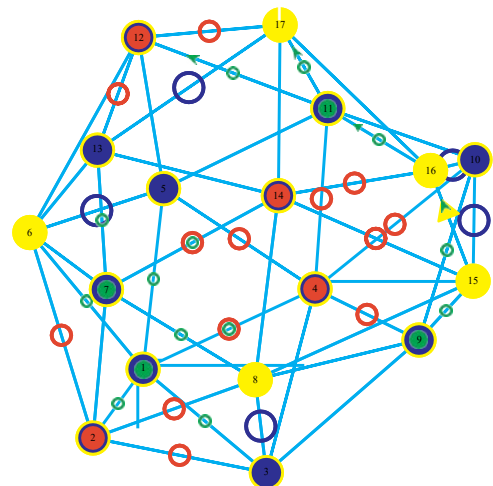
**Figure 61. Instructions:** 178: Color Edge 10–16 Blue, 179: Un Color Vertex 16 Blue.



**Figure 62. Instructions:** 181: Place Edge 10→15 Blue Arrow R.

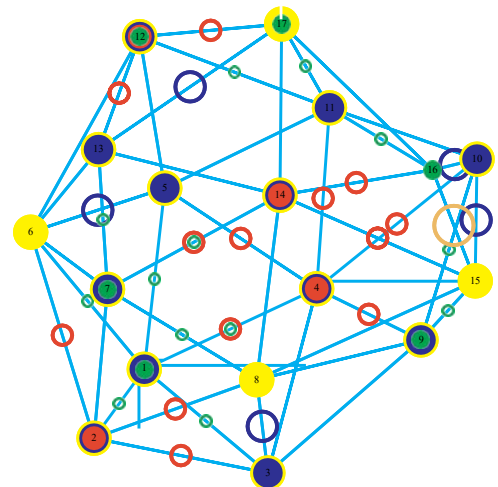


**Figure 63. Instructions:** 184: Color Edge 10–15 Blue, 185: Un Color Vertex 15 Blue.



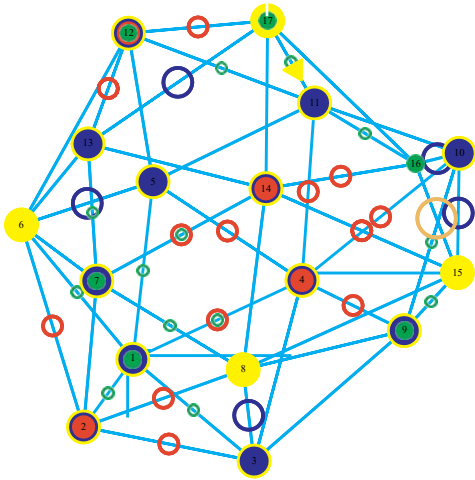
**Figure 64. Instructions:** 187: Place Edge 15→16 Yellow Arrow R, 188: Place Edge 15→16 Green Arrow I, 189: Place Edge 16→11 Green Arrow R, 190: Place Edge 11→17 Green Arrow I, 191: Place Edge 11→12 Green Arrow I.

Figure 64. Instructions: 187: Place Edge 15→16 Yellow Arrow R, 188: Place Edge 15→16 Green Arrow I, 189: Place Edge 16→11 Green Arrow R, 190: Place Edge 11→17 Green Arrow I, 191: Place Edge 11→12 Green Arrow I.

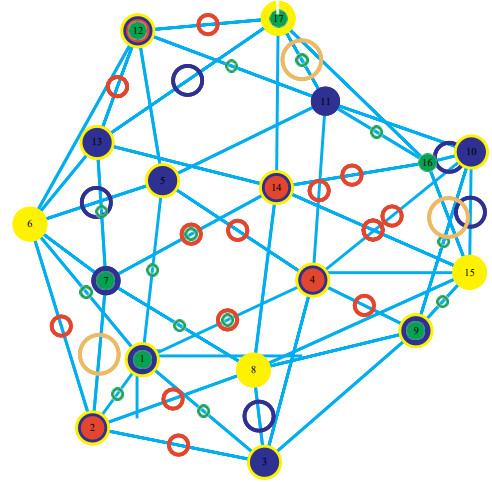


**Figure 65. Instructions:** 198: Color Edge 15–16 Yellow, 199: Un Color Vertex 16 Yellow, 200: Color Vertex 16 Green, 201: Un Color Vertex 11 Green, 202: Color Vertex 17 Green, 203: Color Vertex 12 Green.

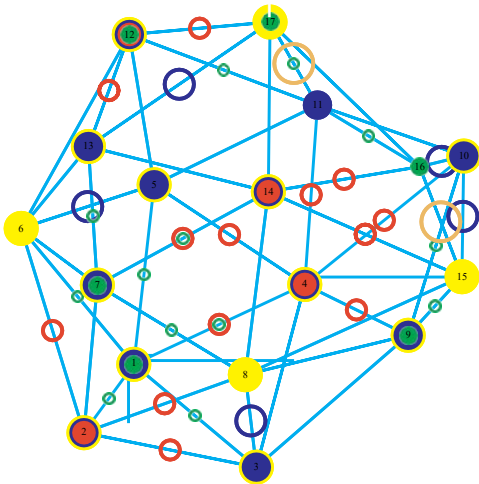
The checkers have been moved according to the arrows and a new Yellow circle has been placed on edge 15-16 indicating that there is no conflict on this edge wrt Yellow. Also, Properties A and B obtain.



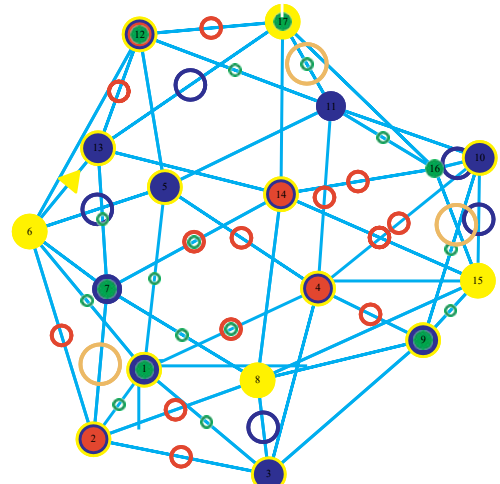
**Figure 66. Instructions:** 205: Place Edge 17→11 Yellow Arrow R.



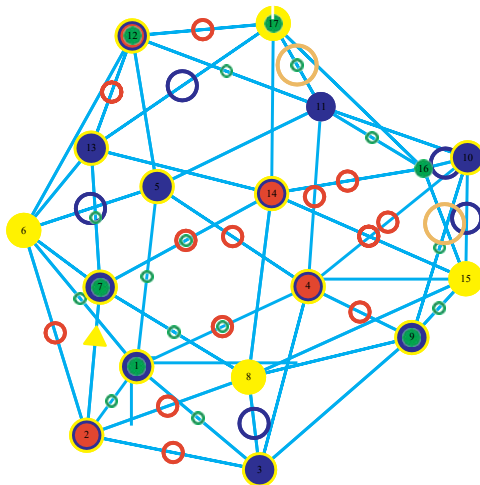
**Figure 69. Instructions:** 214: Color Edge 2-7 Yellow, 215: Un Color Vertex 7 Yellow.



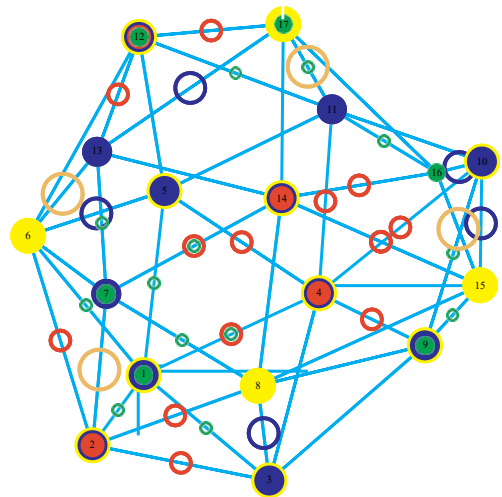
**Figure 67. Instructions:** 208: Color Edge 11-17 Yellow, 209: Un Color Vertex 11 Yellow.



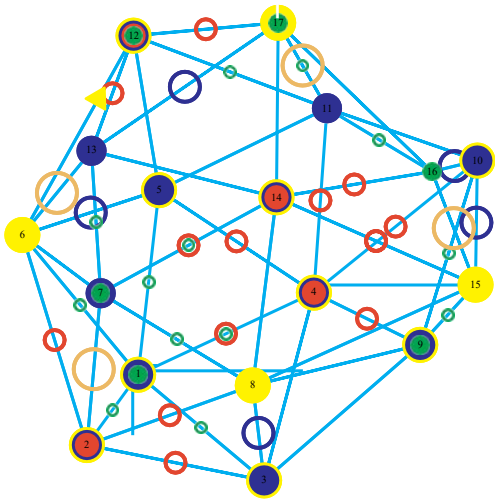
**Figure 70. Instructions:** 217: Place Edge 6→13 Yellow Arrow R.



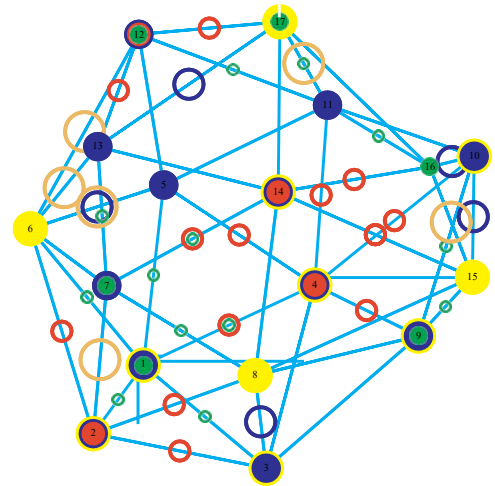
**Figure 68. Instructions:** 211: Place Edge 2→7 Yellow Arrow R.



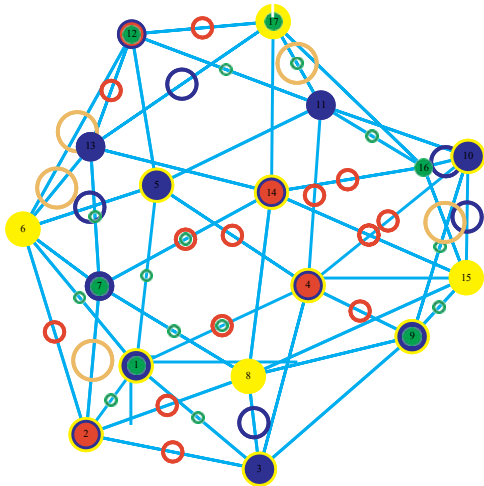
**Figure 71. Instructions:** 220: Color Edge 6-13 Yellow, 221: Un Color Vertex 13 Yellow.



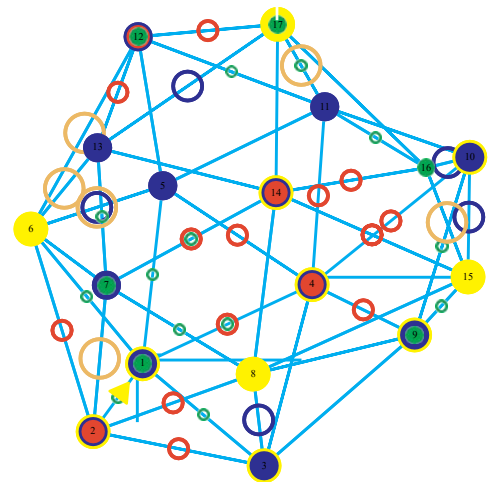
**Figure 72. Instructions:** 223: Place Edge 6→12 Yellow Arrow R.



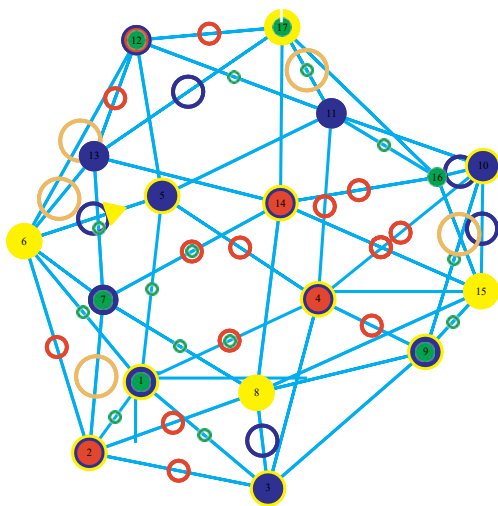
**Figure 75. Instructions:** 232: Color Edge 6-5 Yellow, 233: Un Color Vertex 5 Yellow.



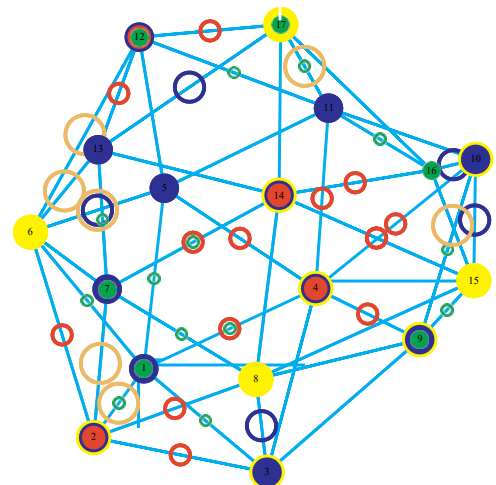
**Figure 73. Instructions:** 226: Color Edge 6-12 Yellow, 227: Un Color Vertex 12 Yellow.



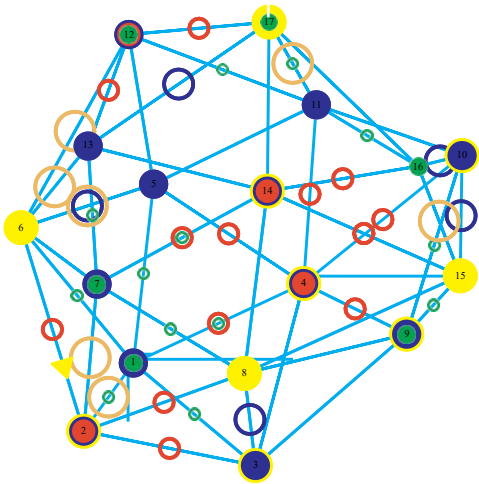
**Figure 76. Instructions:** 235: Place Edge 2→1 Yellow Arrow R.



**Figure 74. Instructions:** 229: Place Edge 6→5 Yellow Arrow R.

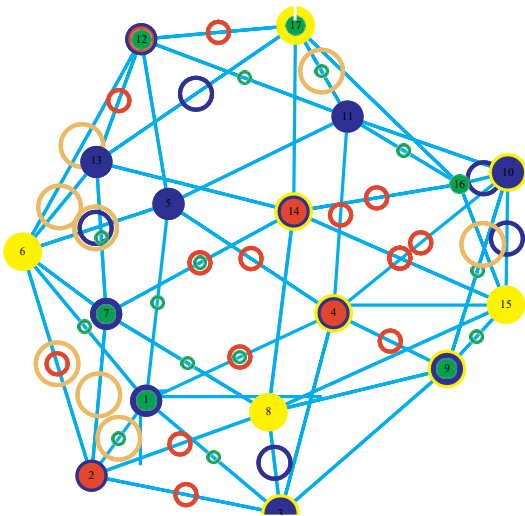


**Figure 77. Instructions:** 238: Color Edge 2-1 Yellow, 239: Un Color Vertex 1 Yellow.



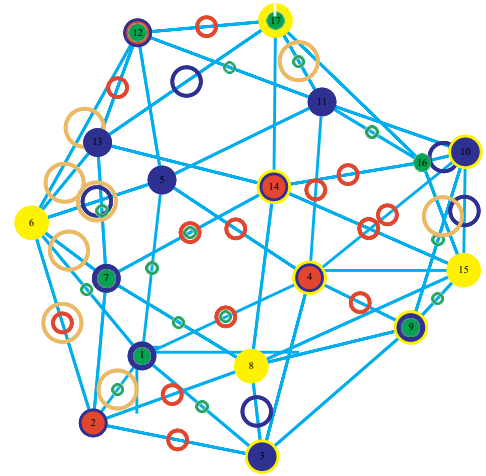
**Figure 78. Instructions:** 241: Place Edge 6→2 Yellow Arrow R.

A yellow arrow has been placed on edge 6→2 indicating removal of the yellow checker from vertex 2. This will create a new problem.



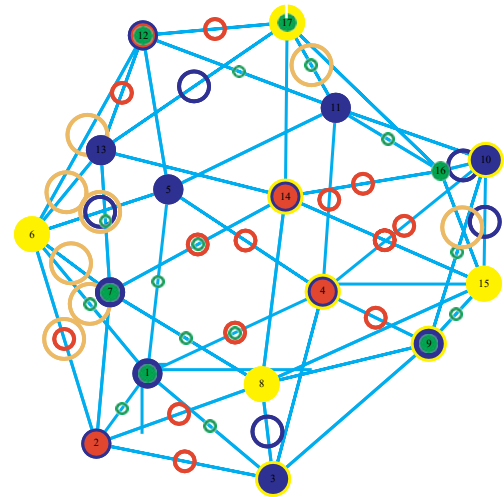
**Figure 79. Instructions:** 244: color edge 6-2 Yellow, 245: un color vertex 2 Yellow.

The yellow checker has been removed from vertex 2 and a yellow circle has been placed on edge 2-6. Now property A obtains but property B does not for there are yellow circles on edges 1-2 and 2-7 but no yellow checkers on vertices 1, 2 or 7. However the situation is easily remedied as follows.



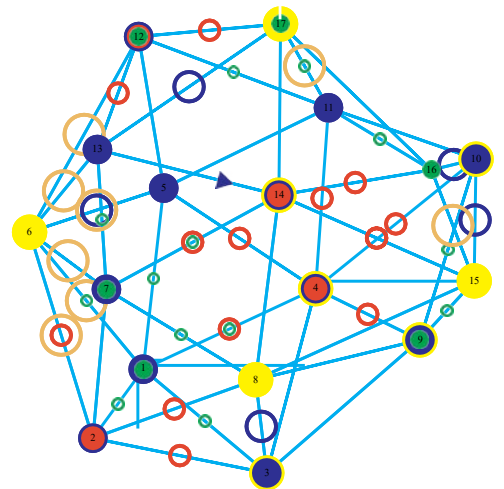
**Figure 80. Instructions:** 249: Color Edge 6-7 Yellow.

The yellow circle on edge 2-7 has been flipped to edge 6-7.

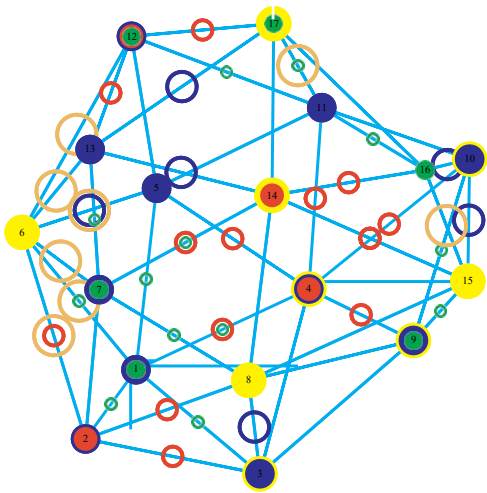


**Figure 81. Instructions:** 253: Color Edge 6-1 Yellow.

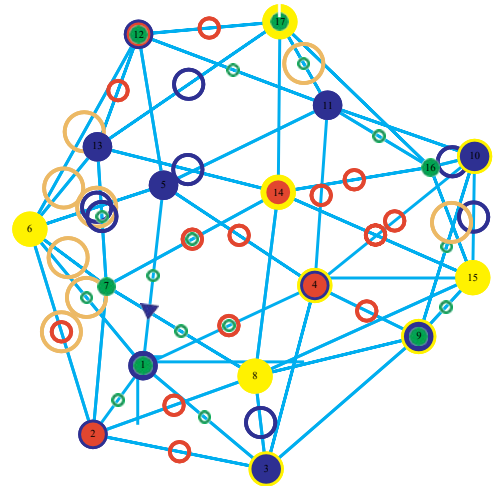
The yellow circle on edge 1-2 has been flipped to edge 2-6 and property B is restored.



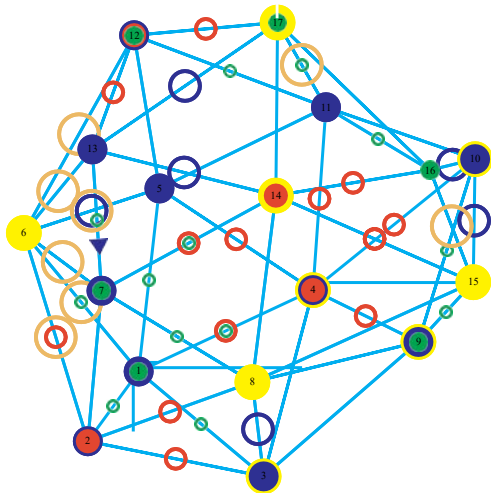
**Figure 82. Instructions:** 255: Place Edge 13→14 Blue Arrow R.



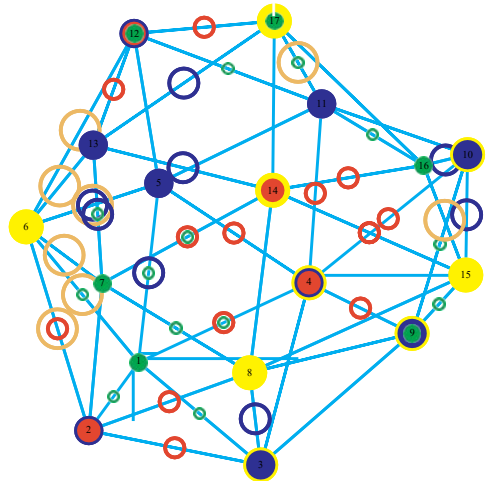
**Figure 83. Instructions:** 258: Color Edge 13–14 Blue, 259: Un Color Vertex 14 Blue.



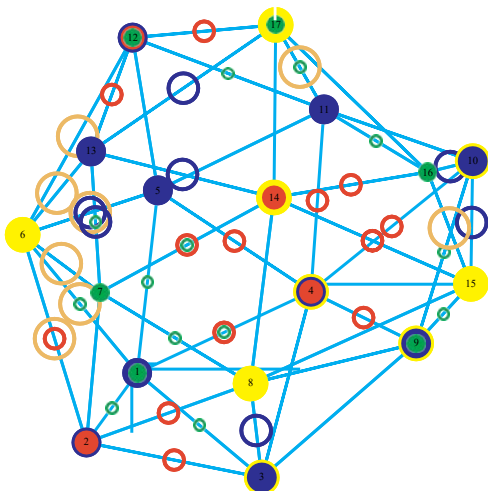
**Figure 86. Instructions:** 267: Place Edge 5→1 Blue Arrow R.



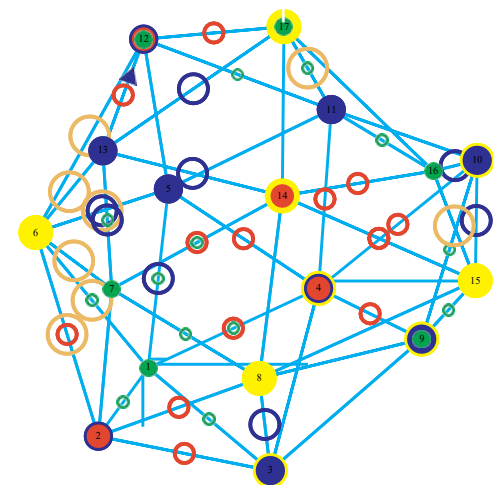
**Figure 84. Instructions:** 261: Place Edge 13→7 Blue Arrow R.



**Figure 87. Instructions:** 270: Color Edge 5–1 Blue, 271: Un Color Vertex 1 Blue.

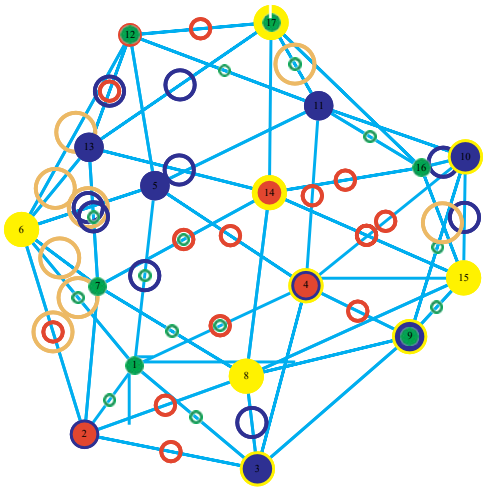


**Figure 85. Instructions:** 264: Color Edge 13–7 Blue, 265: Un Color Vertex 7 Blue.

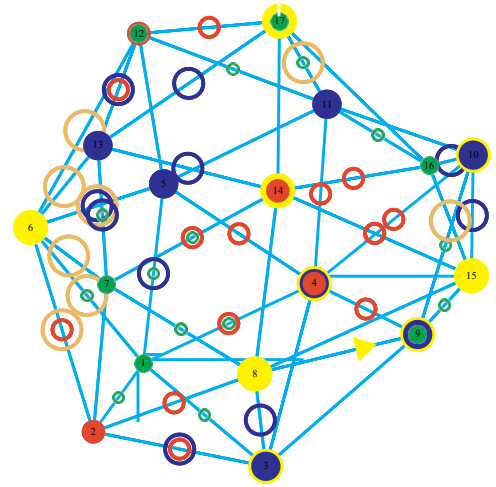


**Figure 88. Instructions:** 273: Place Edge 13→12 Blue Arrow R.

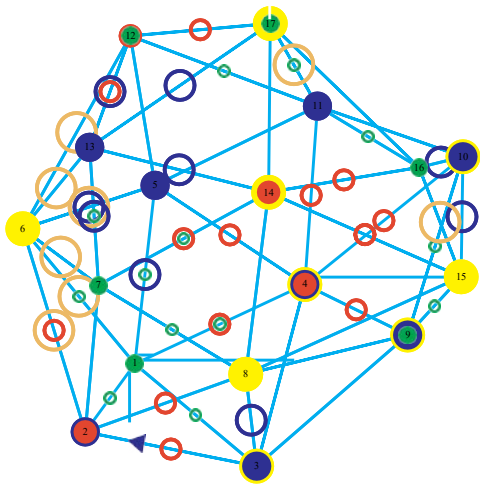




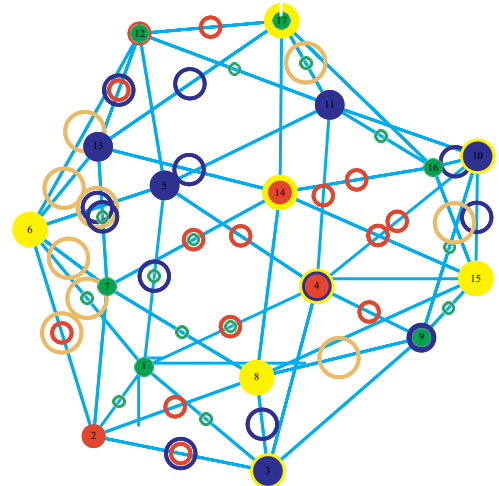
**Figure 89. Instructions:** 276: Color Edge 13–12 Blue, 277: Un Color Vertex 12 Blue.



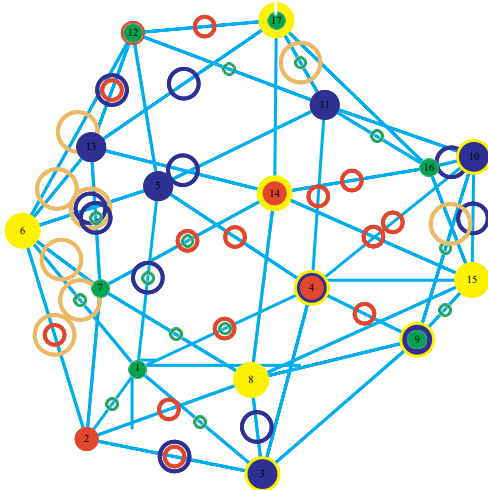
**Figure 92. Instructions:** 285: Place Edge 8→9 Yellow Arrow R.



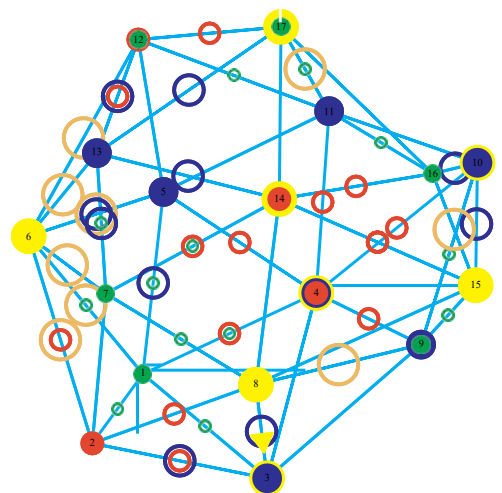
**Figure 90. Instructions:** 279: Place Edge 3→2 Blue Arrow R.



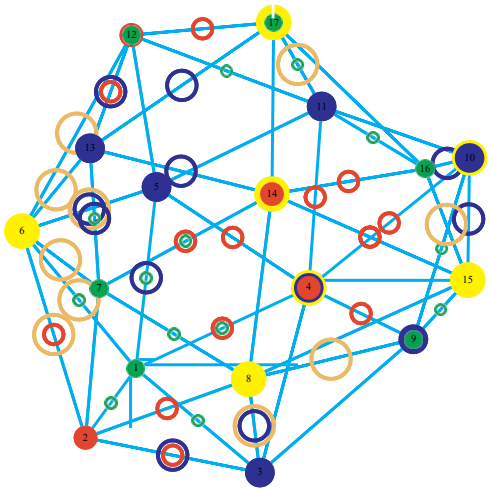
**Figure 93. Instructions:** 288: Color Edge 8–9 Yellow, 289: Un Color Vertex 9 Yellow.



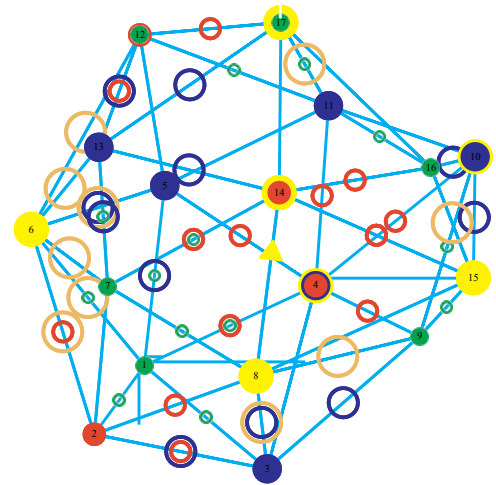
**Figure 91. Instructions:** 282: Color Edge 3–2 Blue, 283: Un Color Vertex 2 Blue.



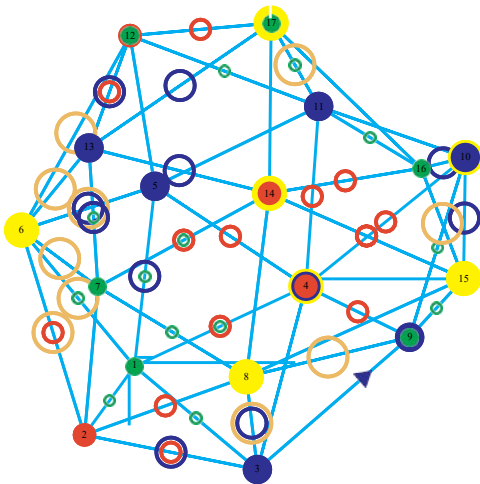
**Figure 94. Instructions:** 291: Place Edge 8→3 Yellow Arrow R.



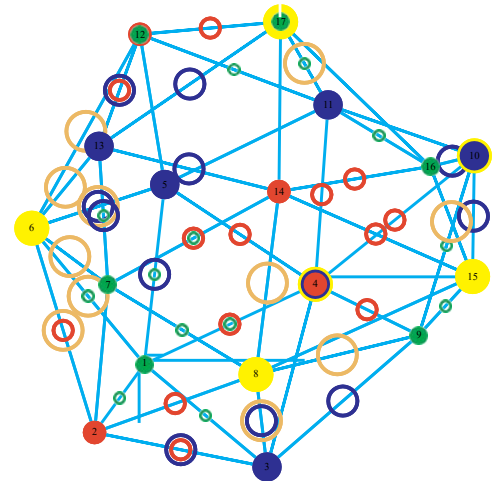
**Figure 95. Instructions:** 294: Color Edge 8-3 Yellow, 295: Un Color Vertex 3 Yellow.



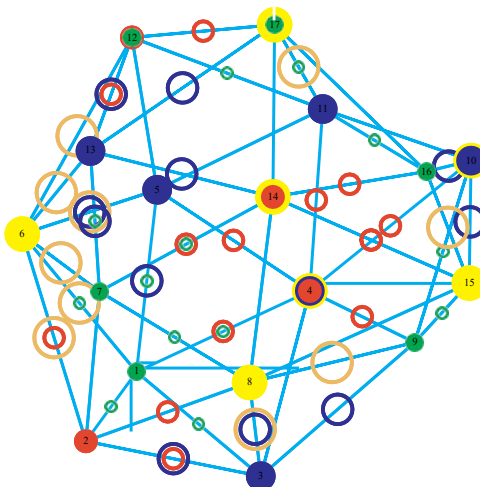
**Figure 98. Instructions:** 303: Place Edge 8→14 Yellow Arrow R.



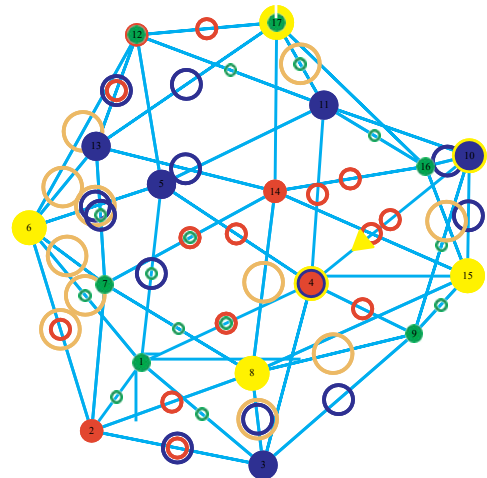
**Figure 96. Instructions:** 297: Place Edge 3→9 Blue Arrow R.



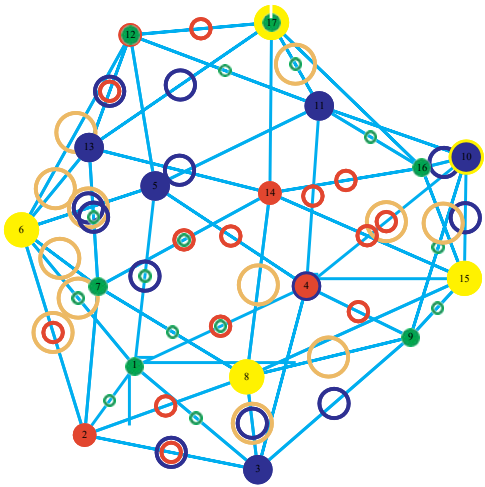
**Figure 99. Instructions:** 306: Color Edge 8-14 Yellow, 307: Un Color Vertex 14 Yellow.



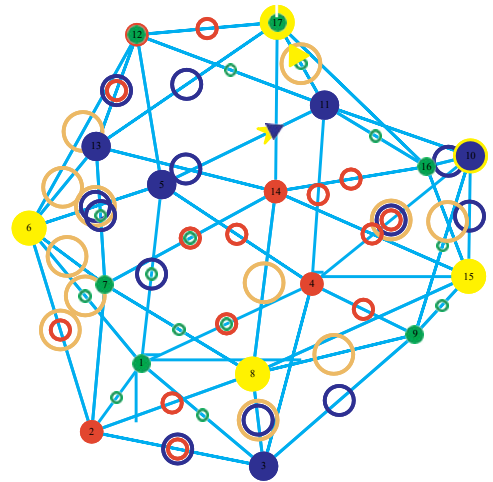
**Figure 97. Instructions:** 300: Color Edge 3-9 Blue, 301: Un Color Vertex 9 Blue.



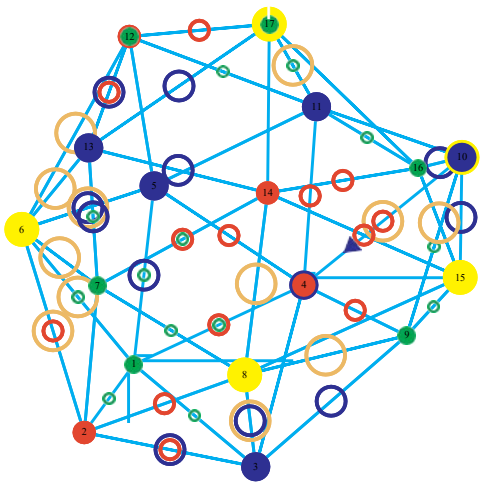
**Figure 100. Instructions:** 309: Place Edge 10→4 Yellow Arrow R.



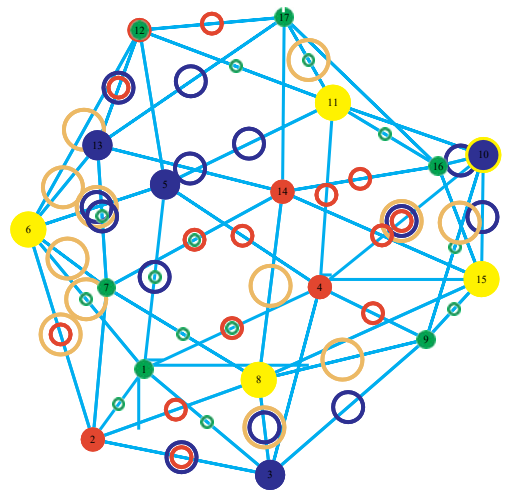
**Figure 101. Instructions:** 312: Color Edge 10–4 Yellow, 313: Un Color Vertex 4 Yellow.



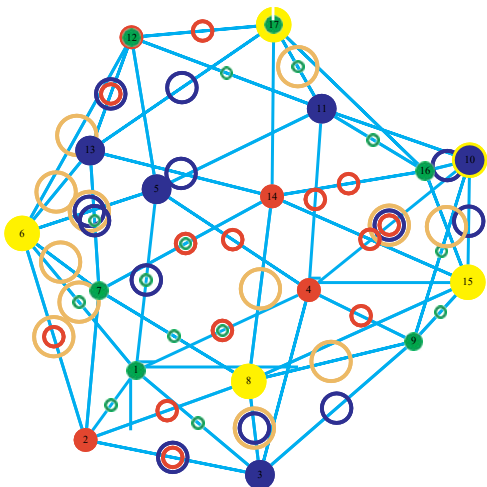
**Figure 104. Instructions:** 321: Place Edge 5→11 Blue Arrow R, 322: Place Edge 5→11 Yellow Arrow I, 323: Place Edge 11→17 Yellow Arrow R.



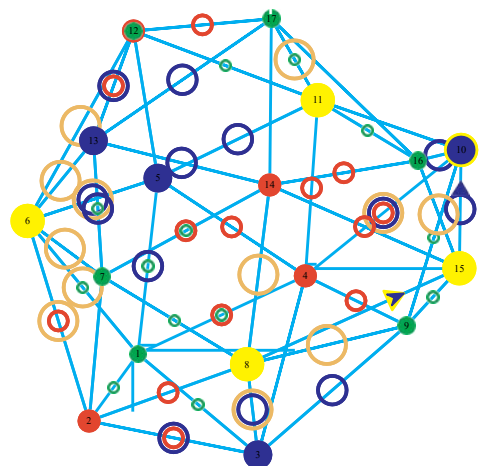
**Figure 102. Instructions:** 315: Place Edge 10→4 Blue Arrow R.



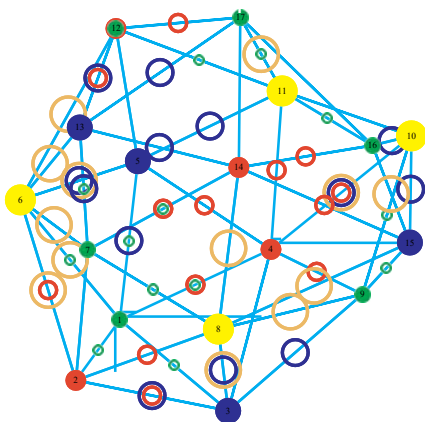
**Figure 105. Instructions:** 328: Color Edge 5–11 Blue, 329: Un Color Vertex 11 Blue, 330: Color Vertex 11 Yellow, 331: Un Color Vertex 17 Yellow.



**Figure 103. Instructions:** 318: Color Edge 10–4 Blue, 319: Un Color Vertex 4 Blue.

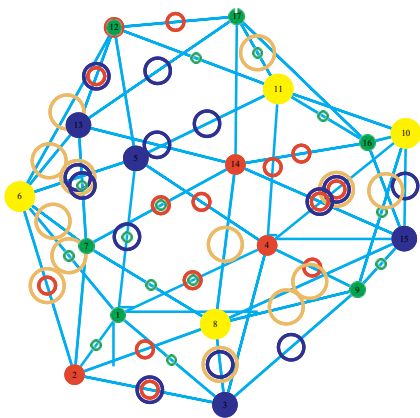


**Figure 106. Instructions:** 333: Place Edge 8→15 Yellow Arrow R, 334: Place Edge 8→15 Blue Arrow I, 335: Place Edge 15→10 Blue Arrow R.



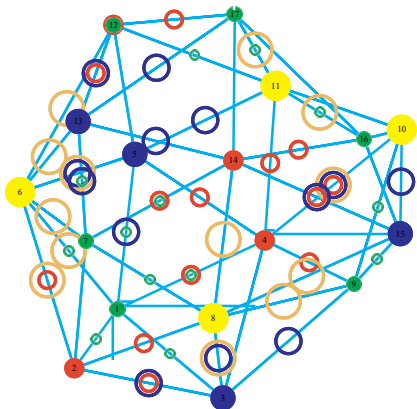
**Figure 107. Instructions:** 340: Color Edge 8–15 Yellow, 341: Un Color Vertex 15 Yellow, 342: Color Vertex 15 Blue, 343: Un Color Vertex 10 Blue.

Here property B is not satisfied for there is a blue circle on edge 10-16 but no blue checker on either of its vertices. The situation is remedied as follows.



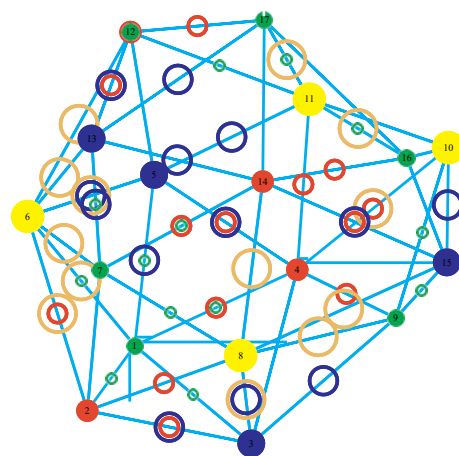
**Figure 108. Instructions:** 347: Color Edge 15–14 Blue.

The blue circle on edge 10-16 is flipped to edge 14-15. Similarly, the Yellow circle on edge 15-16 is flipped to edge 11-16.

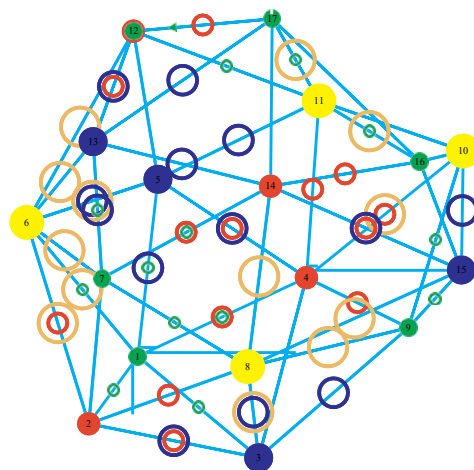


**Figure 109. Instructions:** 351: Color Edge 16–11 Yellow.

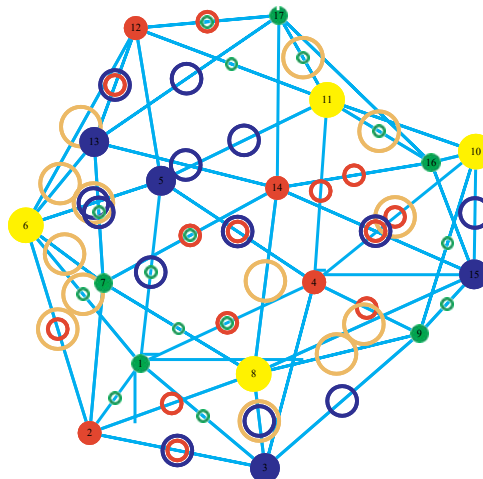
Similarly, the Blue circle on edge 10-4 is flipped to edge 4-5



**Figure 110. Instructions:** 355: Color Edge 5–4 Blue, and Property B is Restored.

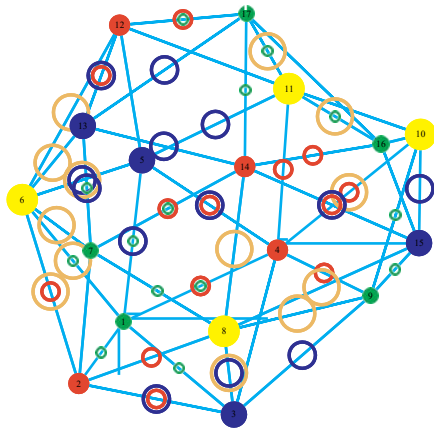


**Figure 111. Instructions:** 357: Place Edge 17→12 Green Arrow R.

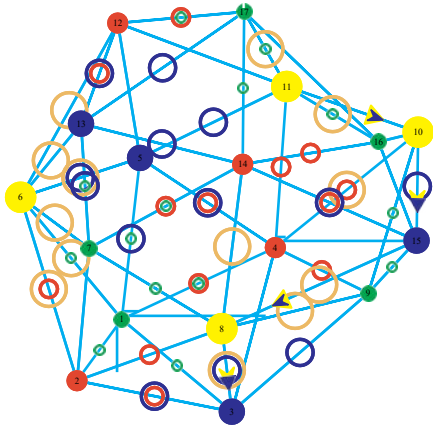


**Figure 112. Instructions:** 360: Color Edge 17–12 Green, 361: Un Color Vertex 12 Green,

After executing the previous instruction property B fails on edge 11-12. However, it is restored by moving the green circle on edge 11-12 to edge 14-17.

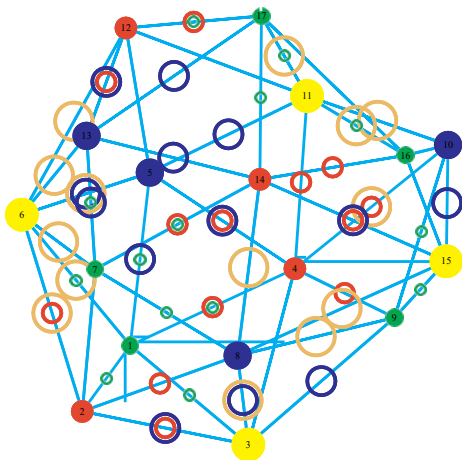


**Figure 113. Instructions:** 365: Color Edge 14–17 Green,



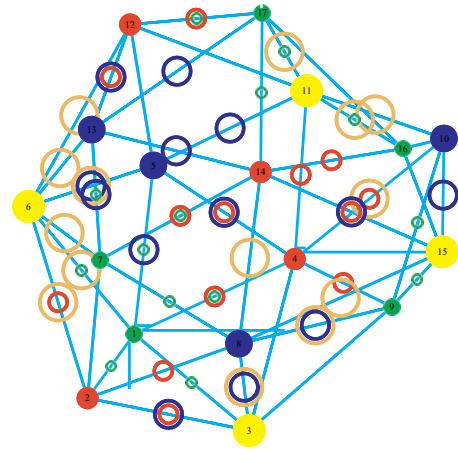
**Figure 114. Instructions:** 367: Place Edge 11→10 Yellow Arrow R, 368: Place Edge 11→10 Blue Arrow I, 369: Place Edge 10→15 Blue Arrow R, 370: Place Edge 10→15 Yellow Arrow I, 371: Place Edge 15→8 Blue Arrow I, 372: Place Edge 15→8 Yellow Arrow R, 373: Place Edge 8→3 Blue Arrow R, 374: Place Edge 8→3 Yellow Arrow I,

Execution of this alternating chain will cause property B to fail. But it is restored in the usual manner.

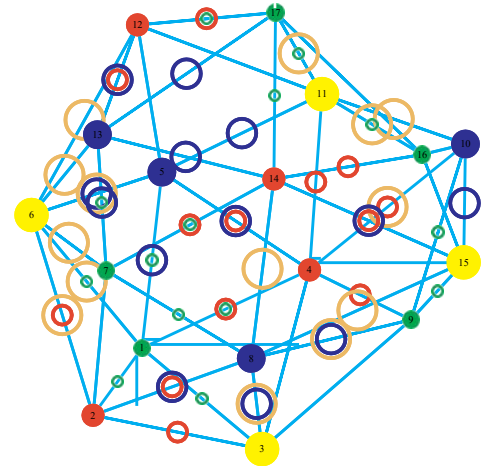


**Figure 115. Instructions:** 384: Color Edge 11–10 Yellow, 385: Un Color Vertex 10 Yellow, 386: Color Vertex 10 Blue, 387: Un

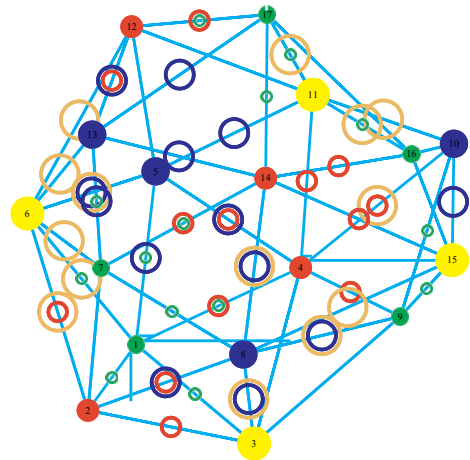
Color Vertex 15 Blue, 388: Color Vertex 15 Yellow, 389: Un Color Vertex 8 Yellow, 390: Color Vertex 8 Blue, 391: Un Color Vertex 3 Blue, 392: Color Vertex 3 Yellow,



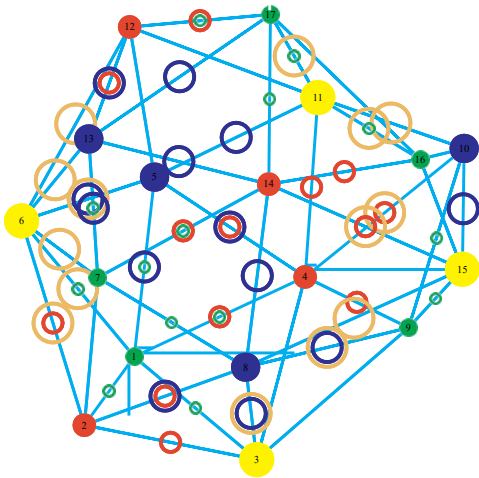
**Figure 116. Instructions:** 396: Color Edge 9–8 Blue,



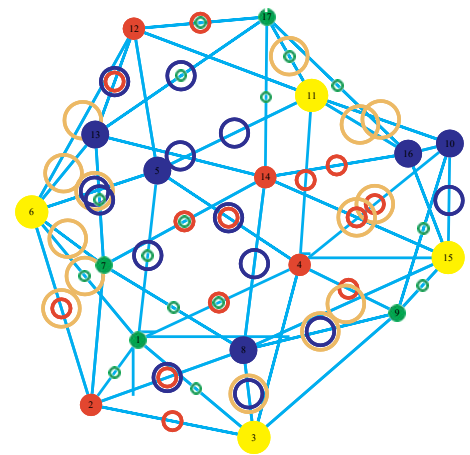
**Figure 117. Instructions:** 400: Color Edge 2–8 Blue,



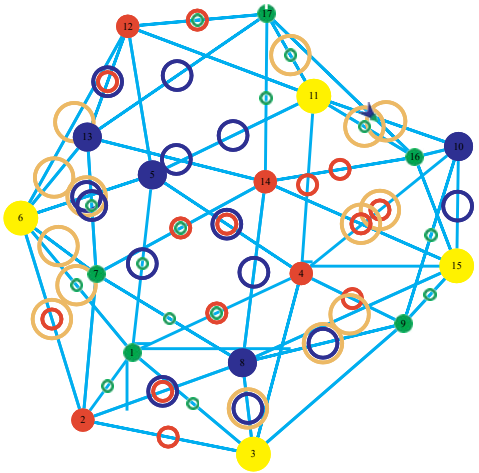
**Figure 118. Instructions:** 404: Color Edge 8–14 Blue,



**Figure 119. Instructions:** 408: Color Edge 15–14 Yellow,

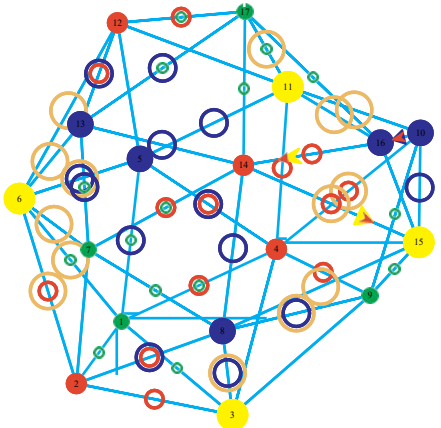


**Figure 122. Instructions:** 421: Color Edge 17–13 Green,



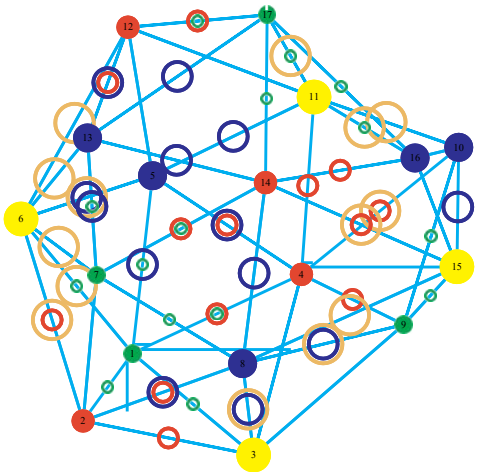
**Figure 120. Instructions:** 410: Place Edge 17→16 Green Arrow R, 411: Place Edge 17→16 Blue Arrow I,

Execution of this alternating chain will cause property B to fail. But it is restored in the usual manner.

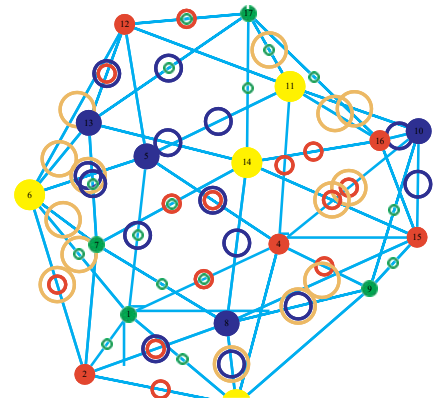


**Figure 123. Instructions:** 423: Place Edge 10→16 Blue Arrow R, 424: Place Edge 10→16 Red Arrow I, 425: Place Edge 16→14 Red Arrow R, 426: Place Edge 16→14 Yellow Arrow I, 427: Place Edge 14→15 Red Arrow I, 428: Place Edge 14→15 Yellow Arrow R,

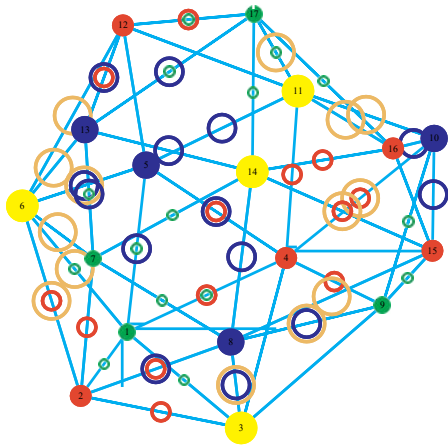
Execution of this alternating chain will cause property B to fail. But it is restored in the usual manner.



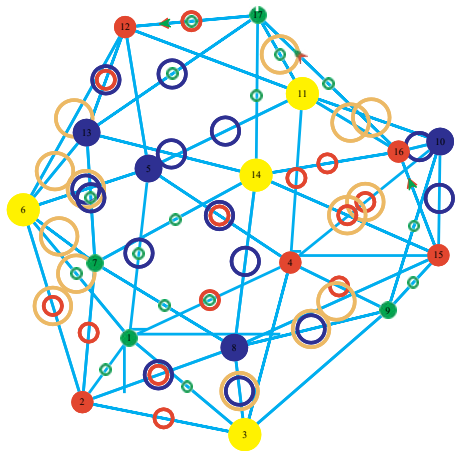
**Figure 121. Instructions:** 415: Color Edge 17–16 Green, 416: Un Color Vertex 16 Green, 417: Color Vertex 16 Blue,



**Figure 124. Instructions:** 436: Color Edge 10–16 Blue, 437: Un Color Vertex 16 Blue, 438: Color Vertex 16 Red, 439: Un Color Vertex 14 Red, 440: Color Vertex 14 Yellow, 441: Un Color Vertex 15 Yellow, 442: Color Vertex 15 Red,

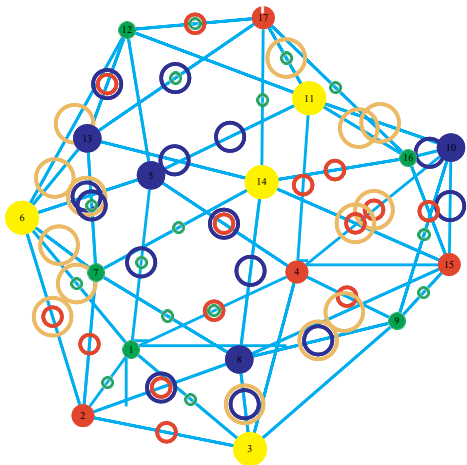


**Figure 125. Instructions:** 446: Color Edge 7-2 Red,



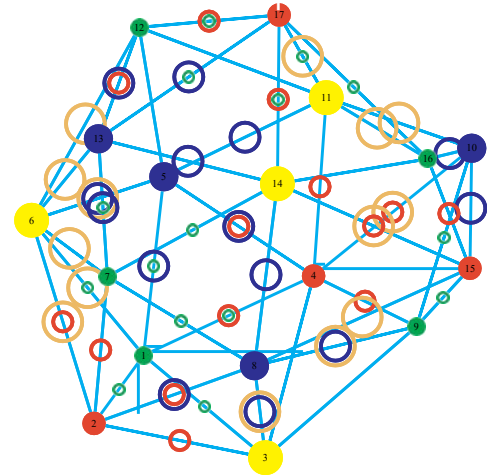
**Figure 126. Instructions:** 448: Place Edge 15→16 Red Arrow R, 449: Place Edge 15→16 Green Arrow I, 450: Place Edge 16→17 Green Arrow R, 451: Place Edge 16→17 Red Arrow I, 452: Place Edge 17→12 Green Arrow I, 453: Place Edge 17→12 Red Arrow R,

Execution of this alternating chain will cause property B to fail. But it is restored in the usual manner.

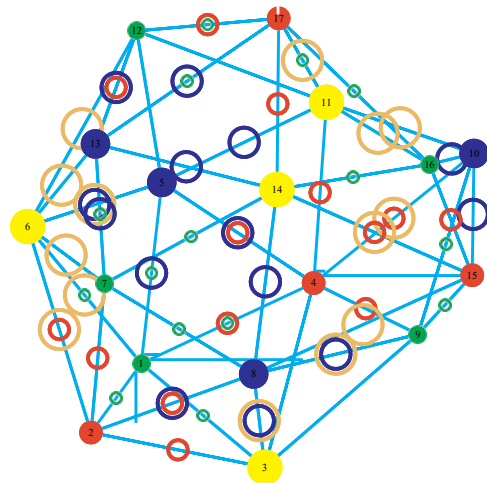


**Figure 127. Instructions:** 461: Color Edge 15-16 Red, 462: Un

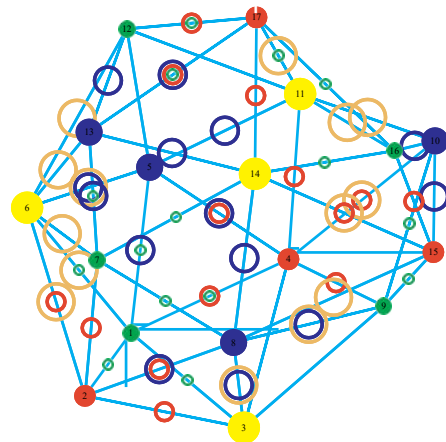
Color Vertex 16 Red, 463: Color Vertex 16 Green, 464: Un Color Vertex 17 Green, 465: Color Vertex 17 Red, 466: Un Color Vertex 12 Red, 467: Color Vertex 12 Green



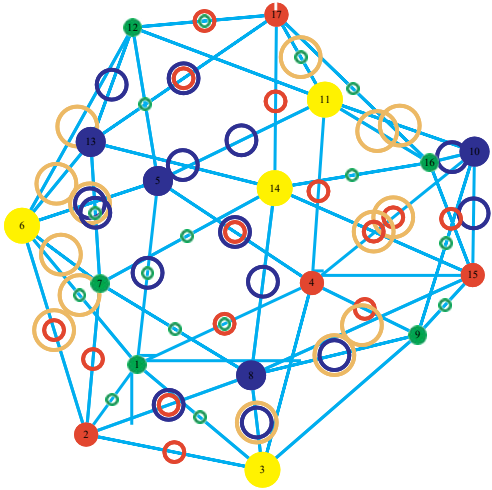
**Figure 128. Instructions:** 471: Color Edge 17-14 Red,



**Figure 129. Instructions:** 475: Color Edge 16-14 Green,



**Figure 130. Instructions:** 479: Color Edge 17-13 Red,



**Figure 131. Instructions:** 483: Color Edge 12–5 Green, Finally, we have properly four colored the graph.

## 2. Observations

It is property B that makes it easy to find the next alternating chain because it eliminates the problem of self conflicting chains.

At certain points it looks as though you could grab extra territory by placing an extra circle on an edge without violating property A, or B. But this would be a mistake. By adding an extra circle gratuitously, you would have spent a cartridge with nothing to show for it in the form of work done, a gross inefficiency. The algorithm is designed to break the problem into components and to solve one component at a time. Since it is easy to find the right alternating chain by sight for a human, it should be "easy" algorithmically.

## 3. Future Work

This example was made by writing individual instructions which were then executed by a computer program. This needs to be automated piecemeal so that the algorithm handles everything without the need for human intervention. It will take a lot of work to arrive at a fully fleshed out algorithm, a lot of programming and testing, too much work for a single individual I think. I believe that if people give it a try they will like how nicely it works. This would be a great project for students, a lot of progress can be made just by using the method of individual instructions used here. I would be very interested in any counterexamples. The ultimate goal would be a completed algorithm, which I believe would provide a simple proof of the four-color theorem.

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