**Project Report**

On

**Constraint satisfaction problems (CSP) - Map Coloring**

Project Guidance By

**Dr. Dewan Ahmed**

Team Details

**Sriganesh Lokesh Karthik Rangaraj**

**slokesh1@uncc.edu krangar2@uncc.edu**

**801135650 801135834**

**PROBLEM STATEMENT**

Constraint Satisfaction Problems consists of a set of objects which satisfies given constraints. Entities are represented as a collection of finite constraints over variables which are then solved. Variants of search techniques such as backtracking, constraint propagation, and local search are used to solve CSP on finite domains.

The CSP functionality functions in a way similar to that of a search tree. The nodes of the search tree contain partial solutions. The goal is to search the tree. A variable is assigned a value which is represented by the branch which is then backtracked later. Branches are pruned in order to avoid dead ends.

CSP is used to solve the map coloring problem. This project demonstrates 4 variants of CSP which we make use of such as:

* **Depth first search only**: This strategy does not prune any branches. All the values assigned so far are checked to see whether they are consistent with each other or not. Variables which are assigned values are examined to ensure the consistency of the values with respect to the constraints. Backtracking is performed if they are not consistent.
* **Depth first search + forward checking**: Wrong options are eliminated from the neighboring variables. In DFS strategy all the variables are examined once a value is assigned to a variable in order to maintain consistency with the constraints. Backtracking is performed if they are not consistent. In FC strategy All its neighbors are checked once a value is assigned to the variable. Incompatible options are eliminated from the neighbors.
* **Depth first search + forward checking + propagation through singleton domains:** Infeasible/impossible options are eliminated from the neighboring states. This variant also makes use of DFS and FC strategy as mentioned previously in Depth first search + forward checking variant, in addition to which makes use of propagation strategy where neighbors are added to the list of variables to propagate depending on whether any options are eliminated from a neighbor in the previous step and if that neighbor has only one variable left. All the variables in the list are propagated.

Values are crossed off in the neighboring variables which are incompatible with the one remaining option when considering neighbors and its option during propagation of singleton variable. Neighbor is added to list of variables to propagate when the neighbor has one option left after crossing off options in that neighbor.

* **Depth First Search with Heuristic**: This variation performs similar to Depth First Search method. This function makes use of the heuristic in order to decrease the amount of time taken to get our result.
* **Depth First Search with Heuristic and Forward Checking:** This variation performs similar to Depth First Search but implements both heuristic and forward checking. This function makes use of FC with heuristic in order to get our result. Aims to provide a time efficient solution compared to previous methods.
* **Depth First Search with heuristic, Forward Checking and singleton:** This variation aims to provide best solution in least possible time. Any problems in the future would be backtracked. Only one instance of the object is replicated which intern produces other instances. The best result is obtained from the Heuristic function.

**PROGRAM STRUCTURE**

**Global Variables**

•**paint\_true**–

This is a dictionary used to store the color assignment of each state.

•**backtrack** –

Variable which is used to keep track of the number of backtracks.

•**if\_singleton**–

This is used to determine whether singleton is used or not.

•**heuristic**–

This is used to determine whether heuristic is implemented or not.

**Functions**

* **check** – checking if children are connected to themselves.
* **value\_next** – Used to take the next value.
* **color\_assign** – Assigning color to the map.
* **dfs** – Used to implement depth first search.
* **decrease** – removing the color for that particular state.
* **decrease\_for\_forward\_check –** decreasing domain for forward checking
* **d\_validate –** validating the domain values
* **dfs\_forward** – depth first search with forward checking.

**OUTPUT**

**USA**

**1. DFS**

1. USA

2. AUS

Select Country:

1

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

1

Color Assigned R -> Texas

Color Assigned Y -> Oklahoma

Color Assigned G -> Hawaii

Color Assigned Y -> SouthDakota

Color Assigned Y -> Utah

Color Assigned G -> Wyoming

Color Assigned B -> Nebraska

Color Assigned G -> RhodeIsland

Color Assigned R -> Maine

Color Assigned G -> NewHampshire

Color Assigned R -> Vermont

Color Assigned B -> Massachusetts

Color Assigned R -> Connecticut

Color Assigned Y -> Tennessee

Color Assigned B -> Virginia

Color Assigned Y -> WestVirginia

Color Assigned G -> Maryland

Color Assigned Y -> Delaware

Color Assigned B -> NewJersey

Color Assigned G -> NewYork

Color Assigned R -> Pennsylvania

Color Assigned B -> Ohio

Color Assigned G -> Kentucky

Color Assigned R -> Indiana

Color Assigned G -> Michigan

Color Assigned R -> Wisconsin

Color Assigned B -> Illinois

Color Assigned G -> Iowa

Color Assigned B -> Minnesota

Color Assigned R -> NorthDakota

Color Assigned B -> Montana

Color Assigned R -> Idaho

Color Assigned R -> Alaska

Color Assigned G -> Washington

Color Assigned B -> Oregon

Color Assigned G -> Nevada

Color Assigned R -> California

Color Assigned B -> Arizona

Color Assigned G -> NewMexico

Color Assigned R -> Colorado

Color Assigned G -> Kansas

Color Assigned R -> Missouri

Color Assigned B -> Arkansas

Color Assigned G -> Louisiana

Color Assigned R -> Mississippi

Color Assigned G -> Alabama

Color Assigned R -> Florida

Color Assigned B -> Georgia

Color Assigned G -> SouthCarolina

Color Assigned R -> NorthCarolina

Time: 0.37268043200037937

Number of Backtracks 73

**2. DFS + FC**

1. USA

2. AUS

Select Country:

1

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

2

Color Assignment in Progress R -> NorthCarolina

Color Assignment in Progress G -> SouthCarolina

Color Assignment in Progress B -> Georgia

Color Assignment in Progress R -> Florida

Color Assignment in Progress G -> Alabama

Color Assignment in Progress R -> Mississippi

Color Assignment in Progress G -> Louisiana

Color Assignment in Progress B -> Arkansas

Color Assignment in Progress R -> Missouri

Color Assignment in Progress G -> Kansas

Color Assignment in Progress R -> Colorado

Color Assignment in Progress G -> NewMexico

Color Assignment in Progress Y -> Oklahoma

Color Assignment in Progress R -> Texas

Color Assigned R -> Texas

Color Assigned Y -> Oklahoma

Color Assignment in Progress B -> Arizona

Color Assignment in Progress R -> California

Color Assignment in Progress G -> Hawaii

Color Assigned G -> Hawaii

Color Assignment in Progress G -> Nevada

Color Assignment in Progress B -> Oregon

Color Assignment in Progress R -> Washington

Color Assignment in Progress G -> Washington

Color Assignment in Progress R -> Idaho

Color Assignment in Progress G -> Montana

Color Assignment in Progress R -> NorthDakota

Color Assignment in Progress G -> Minnesota

Color Assignment in Progress B -> Iowa

Color Assignment in Progress Y -> Iowa

Color Assignment in Progress B -> Minnesota

Color Assignment in Progress G -> Iowa

Color Assignment in Progress B -> Nebraska

Color Assignment in Progress Y -> Minnesota

Color Assignment in Progress G -> Iowa

Color Assignment in Progress Y -> Nebraska

Color Assignment in Progress B -> NorthDakota

Color Assignment in Progress R -> Minnesota

Color Assignment in Progress G -> Iowa

Color Assignment in Progress B -> Nebraska

Color Assignment in Progress B -> Iowa

Color Assignment in Progress G -> Minnesota

Color Assignment in Progress B -> Iowa

Color Assignment in Progress Y -> Nebraska

Color Assignment in Progress B -> Wyoming

Color Assignment in Progress R -> SouthDakota

Color Assigned R -> SouthDakota

Color Assignment in Progress Y -> Utah

Color Assigned Y -> Utah

Color Assigned B -> Wyoming

Color Assigned Y -> Nebraska

Color Assignment in Progress G -> Illinois

Color Assignment in Progress R -> Wisconsin

Color Assignment in Progress B -> Michigan

Color Assignment in Progress R -> Indiana

Color Assignment in Progress B -> Kentucky

Color Assignment in Progress G -> Ohio

Color Assignment in Progress R -> Pennsylvania

Color Assignment in Progress G -> NewYork

Color Assignment in Progress R -> Connecticut

Color Assignment in Progress B -> Massachusetts

Color Assignment in Progress G -> RhodeIsland

Color Assigned G -> RhodeIsland

Color Assignment in Progress R -> Vermont

Color Assignment in Progress G -> NewHampshire

Color Assignment in Progress R -> Maine

Color Assigned R -> Maine

Color Assigned G -> NewHampshire

Color Assigned R -> Vermont

Color Assigned B -> Massachusetts

Color Assigned R -> Connecticut

Color Assignment in Progress B -> NewJersey

Color Assignment in Progress G -> Delaware

Color Assignment in Progress B -> Maryland

Color Assignment in Progress Y -> WestVirginia

Color Assignment in Progress G -> Virginia

Color Assignment in Progress Y -> Tennessee

Color Assigned Y -> Tennessee

Color Assigned G -> Virginia

Color Assigned Y -> WestVirginia

Color Assigned B -> Maryland

Color Assigned G -> Delaware

Color Assigned B -> NewJersey

Color Assigned G -> NewYork

Color Assigned R -> Pennsylvania

Color Assigned G -> Ohio

Color Assigned B -> Kentucky

Color Assigned R -> Indiana

Color Assigned B -> Michigan

Color Assigned R -> Wisconsin

Color Assigned G -> Illinois

Color Assigned B -> Iowa

Color Assigned G -> Minnesota

Color Assigned B -> NorthDakota

Color Assigned G -> Montana

Color Assigned R -> Idaho

Color Assignment in Progress R -> Alaska

Color Assigned R -> Alaska

Color Assigned G -> Washington

Color Assigned B -> Oregon

Color Assigned G -> Nevada

Color Assigned R -> California

Color Assigned B -> Arizona

Color Assigned G -> NewMexico

Color Assigned R -> Colorado

Color Assigned G -> Kansas

Color Assigned R -> Missouri

Color Assigned B -> Arkansas

Color Assigned G -> Louisiana

Color Assigned R -> Mississippi

Color Assigned G -> Alabama

Color Assigned R -> Florida

Color Assigned B -> Georgia

Color Assigned G -> SouthCarolina

Color Assigned R -> NorthCarolina

Time: 0.4289514929996585

Number of Backtracks 15

**3. DFS + FC + Singleton**

1. USA

2. AUS

Select Country:

1

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

3

Color Assignment in Progress R -> NorthCarolina

Color Assignment in Progress G -> SouthCarolina

Color Assignment in Progress B -> Georgia

Color Assignment in Progress G -> Tennessee

Color Assignment in Progress B -> Virginia

Color Assignment in Progress R -> Kentucky

Color Assignment in Progress B -> Missouri

Color Assignment in Progress R -> Arkansas

Color Assignment in Progress G -> Oklahoma

Color Assignment in Progress R -> Kansas

Color Assignment in Progress B -> Colorado

Color Assignment in Progress G -> Nebraska

Color Assignment in Progress R -> Iowa

Color Assignment in Progress G -> Illinois

Color Assignment in Progress B -> Wisconsin

Color Assignment in Progress G -> Minnesota

Color Assignment in Progress B -> SouthDakota

Color Assignment in Progress R -> Wyoming

Color Assignment in Progress G -> Montana

Color Assignment in Progress R -> NorthDakota

Color Assigned R -> NorthDakota

Color Assignment in Progress B -> Idaho

Color Assignment in Progress G -> Utah

Color Assignment in Progress R -> NewMexico

Color Assignment in Progress Y -> Arizona

Color Assignment in Progress R -> Nevada

Color Assignment in Progress G -> California

Color Assignment in Progress Y -> Oregon

Color Assignment in Progress R -> Washington

Color Assignment in Progress G -> Alaska

Color Assigned G -> Alaska

Color Assigned R -> Washington

Color Assigned Y -> Oregon

Color Assignment in Progress R -> Hawaii

Color Assigned R -> Hawaii

Color Assigned G -> California

Color Assigned R -> Nevada

Color Assigned Y -> Arizona

Color Assignment in Progress B -> Texas

Color Assignment in Progress G -> Louisiana

Color Assignment in Progress B -> Mississippi

Color Assignment in Progress R -> Alabama

Color Assignment in Progress G -> Florida

Color Assigned G -> Florida

Color Assigned R -> Alabama

Color Assigned B -> Mississippi

Color Assigned G -> Louisiana

Color Assigned B -> Texas

Color Assigned R -> NewMexico

Color Assigned G -> Utah

Color Assigned B -> Idaho

Color Assigned G -> Montana

Color Assigned R -> Wyoming

Color Assigned B -> SouthDakota

Color Assigned G -> Minnesota

Color Assignment in Progress R -> Michigan

Color Assignment in Progress B -> Indiana

Color Assignment in Progress G -> Ohio

Color Assignment in Progress Y -> WestVirginia

Color Assignment in Progress R -> Maryland

Color Assignment in Progress B -> Pennsylvania

Color Assignment in Progress G -> Delaware

Color Assignment in Progress R -> NewJersey

Color Assignment in Progress G -> NewYork

Color Assignment in Progress R -> Connecticut

Color Assignment in Progress B -> Massachusetts

Color Assignment in Progress G -> RhodeIsland

Color Assigned G -> RhodeIsland

Color Assignment in Progress R -> Vermont

Color Assignment in Progress G -> NewHampshire

Color Assignment in Progress R -> Maine

Color Assigned R -> Maine

Color Assigned G -> NewHampshire

Color Assigned R -> Vermont

Color Assigned B -> Massachusetts

Color Assigned R -> Connecticut

Color Assigned G -> NewYork

Color Assigned R -> NewJersey

Color Assigned G -> Delaware

Color Assigned B -> Pennsylvania

Color Assigned R -> Maryland

Color Assigned Y -> WestVirginia

Color Assigned G -> Ohio

Color Assigned B -> Indiana

Color Assigned R -> Michigan

Color Assigned B -> Wisconsin

Color Assigned G -> Illinois

Color Assigned R -> Iowa

Color Assigned G -> Nebraska

Color Assigned B -> Colorado

Color Assigned R -> Kansas

Color Assigned G -> Oklahoma

Color Assigned R -> Arkansas

Color Assigned B -> Missouri

Color Assigned R -> Kentucky

Color Assigned B -> Virginia

Color Assigned G -> Tennessee

Color Assigned B -> Georgia

Color Assigned G -> SouthCarolina

Color Assigned R -> NorthCarolina

Time: 0.41947213700041175

Number of Backtracks 0

**4. DFS + Heuristic**

1. USA

2. AUS

Select Country:

1

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

4

[(-1, -1, 'SouthCarolina'), (-1, -4, 'Virginia'), (-1, -7, 'Tennessee'), (-1, -4, 'Georgia')] ()()()()()

[(-1, -7, 'Tennessee'), (-1, -4, 'Georgia'), (-1, -4, 'Virginia'), (-1, -1, 'SouthCarolina')] --Sort - ()()()()()

[(-1, -5, 'Arkansas'), (-1, -7, 'Missouri'), (-1, -6, 'Kentucky'), (-1, -3, 'Mississippi'), (-2, -3, 'Virginia'), (-1, -3, 'Alabama'), (-2, -3, 'Georgia')] ()()()()()

[(-2, -3, 'Georgia'), (-2, -3, 'Virginia'), (-1, -7, 'Missouri'), (-1, -6, 'Kentucky'), (-1, -5, 'Arkansas'), (-1, -3, 'Alabama'), (-1, -3, 'Mississippi')] --Sort - ()()()()()

[(-1, -1, 'Florida'), (-2, 0, 'SouthCarolina'), (-2, -2, 'Alabama')] ()()()()()

[(-2, -2, 'Alabama'), (-2, 0, 'SouthCarolina'), (-1, -1, 'Florida')] --Sort - ()()()()()

[(-2, 0, 'Florida'), (-2, -2, 'Mississippi')] ()()()()()

[(-2, -2, 'Mississippi'), (-2, 0, 'Florida')] --Sort - ()()()()()

[(-1, -2, 'Louisiana'), (-2, -4, 'Arkansas')] ()()()()()

[(-2, -4, 'Arkansas'), (-1, -2, 'Louisiana')] --Sort - ()()()()()

[(-2, -6, 'Missouri'), (-1, -5, 'Oklahoma'), (-1, -3, 'Texas'), (-2, -1, 'Louisiana')] ()()()()()

[(-2, -6, 'Missouri'), (-2, -1, 'Louisiana'), (-1, -5, 'Oklahoma'), (-1, -3, 'Texas')] --Sort - ()()()()()

[(-1, -3, 'Kansas'), (-1, -5, 'Iowa'), (-2, -4, 'Oklahoma'), (-1, -5, 'Nebraska'), (-1, -5, 'Illinois'), (-2, -5, 'Kentucky')] ()()()()()

[(-2, -5, 'Kentucky'), (-2, -4, 'Oklahoma'), (-1, -5, 'Illinois'), (-1, -5, 'Iowa'), (-1, -5, 'Nebraska'), (-1, -3, 'Kansas')] --Sort - ()()()()()

[(-2, -4, 'Illinois'), (-1, -4, 'Ohio'), (-1, -3, 'Indiana'), (-2, -2, 'Virginia'), (-1, -4, 'WestVirginia')] ()()()()()

[(-2, -4, 'Illinois'), (-2, -2, 'Virginia'), (-1, -4, 'Ohio'), (-1, -4, 'WestVirginia'), (-1, -3, 'Indiana')] --Sort - ()()()()()

[(-2, -4, 'Iowa'), (-1, -3, 'Wisconsin'), (-1, -3, 'Michigan'), (-2, -2, 'Indiana')] ()()()()()

[(-2, -4, 'Iowa'), (-2, -2, 'Indiana'), (-1, -3, 'Michigan'), (-1, -3, 'Wisconsin')] --Sort - ()()()()()

[(-2, -4, 'Nebraska'), (-1, -5, 'SouthDakota'), (-2, -2, 'Wisconsin'), (-1, -3, 'Minnesota')] ()()()()()

[(-2, -4, 'Nebraska'), (-2, -2, 'Wisconsin'), (-1, -5, 'SouthDakota'), (-1, -3, 'Minnesota')] --Sort - ()()()()()

[(-1, -6, 'Colorado'), (-2, -2, 'Kansas'), (-1, -5, 'Wyoming'), (-2, -4, 'SouthDakota')] ()()()()()

[(-2, -4, 'SouthDakota'), (-2, -2, 'Kansas'), (-1, -6, 'Colorado'), (-1, -5, 'Wyoming')] --Sort - ()()()()()

[(-1, -3, 'Montana'), (-2, -4, 'Wyoming'), (-1, -2, 'NorthDakota'), (-2, -2, 'Minnesota')] ()()()()()

[(-2, -4, 'Wyoming'), (-2, -2, 'Minnesota'), (-1, -3, 'Montana'), (-1, -2, 'NorthDakota')] --Sort - ()()()()()

[(-2, -5, 'Colorado'), (-2, -2, 'Montana'), (-1, -5, 'Idaho'), (-1, -5, 'Utah')] ()()()()()

[(-2, -5, 'Colorado'), (-2, -2, 'Montana'), (-1, -5, 'Idaho'), (-1, -5, 'Utah')] --Sort - ()()()()()

[(-1, -4, 'NewMexico'), (-2, -1, 'Kansas'), (-2, -3, 'Oklahoma'), (-1, -4, 'Arizona'), (-2, -4, 'Utah')] ()()()()()

[(-2, -4, 'Utah'), (-2, -3, 'Oklahoma'), (-2, -1, 'Kansas'), (-1, -4, 'Arizona'), (-1, -4, 'NewMexico')] --Sort - ()()()()()

[(-2, -3, 'NewMexico'), (-1, -4, 'Nevada'), (-2, -3, 'Arizona'), (-2, -4, 'Idaho')] ()()()()()

[(-2, -4, 'Idaho'), (-2, -3, 'Arizona'), (-2, -3, 'NewMexico'), (-1, -4, 'Nevada')] --Sort - ()()()()()

[(-2, -1, 'Montana'), (-2, -3, 'Nevada'), (-1, -2, 'Washington'), (-1, -3, 'Oregon')] ()()()()()

[(-2, -3, 'Nevada'), (-2, -1, 'Montana'), (-1, -3, 'Oregon'), (-1, -2, 'Washington')] --Sort - ()()()()()

[(-1, -3, 'California'), (-3, -2, 'Arizona'), (-2, -2, 'Oregon')] ()()()()()

[(-3, -2, 'Arizona'), (-2, -2, 'Oregon'), (-1, -3, 'California')] --Sort - ()()()()()

[(-3, -2, 'NewMexico'), (-2, -2, 'California')] ()()()()()

[(-3, -2, 'NewMexico'), (-2, -2, 'California')] --Sort - ()()()()()

[(-2, -2, 'Oklahoma'), (-1, -2, 'Texas')] ()()()()()

[(-2, -2, 'Oklahoma'), (-1, -2, 'Texas')] --Sort - ()()()()()

[(-2, 0, 'Kansas'), (-2, -1, 'Texas')] ()()()()()

[(-2, -1, 'Texas'), (-2, 0, 'Kansas')] --Sort - ()()()()()

[(-2, 0, 'Louisiana')] ()()()()()

[(-2, 0, 'Louisiana')] --Sort - ()()()()()

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Louisiana

Color Assigned B -> Texas

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Kansas

Color Assigned G -> Oklahoma

Color Assigned R -> NewMexico

[(-1, 0, 'Hawaii'), (-3, -1, 'Oregon')] ()()()()()

[(-3, -1, 'Oregon'), (-1, 0, 'Hawaii')] --Sort - ()()()()()

[(-2, -1, 'Washington')] ()()()()()

[(-2, -1, 'Washington')] --Sort - ()()()()()

[(-1, 0, 'Alaska')] ()()()()()

[(-1, 0, 'Alaska')] --Sort - ()()()()()

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Alaska

Color Assigned R -> Washington

Color Assigned Y -> Oregon

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Hawaii

Color Assigned G -> California

Color Assigned Y -> Arizona

Color Assigned R -> Nevada

[(-2, -1, 'NorthDakota')] ()()()()()

[(-2, -1, 'NorthDakota')] --Sort - ()()()()()

[(-2, -1, 'Minnesota')] ()()()()()

[(-2, -1, 'Minnesota')] --Sort - ()()()()()

[(-2, -1, 'Wisconsin')] ()()()()()

[(-2, -1, 'Wisconsin')] --Sort - ()()()()()

[(-2, -2, 'Michigan')] ()()()()()

[(-2, -2, 'Michigan')] --Sort - ()()()()()

[(-2, -1, 'Indiana'), (-1, -3, 'Ohio')] ()()()()()

[(-2, -1, 'Indiana'), (-1, -3, 'Ohio')] --Sort - ()()()()()

[(-2, -2, 'Ohio')] ()()()()()

[(-2, -2, 'Ohio')] --Sort - ()()()()()

[(-1, -5, 'Pennsylvania'), (-2, -3, 'WestVirginia')] ()()()()()

[(-2, -3, 'WestVirginia'), (-1, -5, 'Pennsylvania')] --Sort - ()()()()()

[(-1, -3, 'Maryland'), (-3, -1, 'Virginia'), (-2, -4, 'Pennsylvania')] ()()()()()

[(-3, -1, 'Virginia'), (-2, -4, 'Pennsylvania'), (-1, -3, 'Maryland')] --Sort - ()()()()()

[(-2, -2, 'Maryland')] ()()()()()

[(-2, -2, 'Maryland')] --Sort - ()()()()()

[(-1, -2, 'Delaware'), (-3, -3, 'Pennsylvania')] ()()()()()

[(-3, -3, 'Pennsylvania'), (-1, -2, 'Delaware')] --Sort - ()()()()()

[(-1, -4, 'NewYork'), (-1, -2, 'NewJersey'), (-2, -1, 'Delaware')] ()()()()()

[(-2, -1, 'Delaware'), (-1, -4, 'NewYork'), (-1, -2, 'NewJersey')] --Sort - ()()()()()

[(-2, -1, 'NewJersey')] ()()()()()

[(-2, -1, 'NewJersey')] --Sort - ()()()()()

[(-2, -3, 'NewYork')] ()()()()()

[(-2, -3, 'NewYork')] --Sort - ()()()()()

[(-1, -2, 'Connecticut'), (-1, -2, 'Vermont'), (-1, -4, 'Massachusetts')] ()()()()()

[(-1, -4, 'Massachusetts'), (-1, -2, 'Connecticut'), (-1, -2, 'Vermont')] --Sort - ()()()()()

[(-2, -1, 'Connecticut'), (-1, -1, 'RhodeIsland'), (-2, -1, 'Vermont'), (-1, -2, 'NewHampshire')] ()()()()()

[(-2, -1, 'Connecticut'), (-2, -1, 'Vermont'), (-1, -2, 'NewHampshire'), (-1, -1, 'RhodeIsland')] --Sort - ()()()()()

[(-2, 0, 'RhodeIsland')] ()()()()()

[(-2, 0, 'RhodeIsland')] --Sort - ()()()()()

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> RhodeIsland

Color Assigned B -> Connecticut

[(-2, -1, 'NewHampshire')] ()()()()()

[(-2, -1, 'NewHampshire')] --Sort - ()()()()()

[(-1, 0, 'Maine')] ()()()()()

[(-1, 0, 'Maine')] --Sort - ()()()()()

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Maine

Color Assigned G -> NewHampshire

Color Assigned B -> Vermont

Color Assigned R -> Massachusetts

Color Assigned G -> NewYork

Color Assigned R -> NewJersey

Color Assigned G -> Delaware

Color Assigned Y -> Pennsylvania

Color Assigned R -> Maryland

Color Assigned Y -> Virginia

Color Assigned B -> WestVirginia

Color Assigned G -> Ohio

Color Assigned B -> Indiana

Color Assigned R -> Michigan

Color Assigned B -> Wisconsin

Color Assigned G -> Minnesota

Color Assigned R -> NorthDakota

Color Assigned G -> Montana

Color Assigned B -> Idaho

Color Assigned G -> Utah

Color Assigned B -> Colorado

Color Assigned R -> Wyoming

Color Assigned B -> SouthDakota

Color Assigned G -> Nebraska

Color Assigned R -> Iowa

Color Assigned G -> Illinois

Color Assigned R -> Kentucky

Color Assigned B -> Missouri

Color Assigned R -> Arkansas

Color Assigned B -> Mississippi

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Florida

Color Assigned R -> Alabama

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> SouthCarolina

Color Assigned B -> Georgia

Color Assigned G -> Tennessee

Color Assigned R -> NorthCarolina

Time: 0.4287903370004642

Number of Backtracks 0

**5. DFS + Heuristic + FC**

1. USA

2. AUS

Select Country:

1

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

5

Color Assignment in Progress R -> NorthCarolina

[(-1, -1, 'SouthCarolina'), (-1, -4, 'Virginia'), (-1, -7, 'Tennessee'), (-1, -4, 'Georgia')] ()()()()()

[(-1, -7, 'Tennessee'), (-1, -4, 'Georgia'), (-1, -4, 'Virginia'), (-1, -1, 'SouthCarolina')] --Sort - ()()()()()

Color Assignment in Progress G -> Tennessee

[(-1, -5, 'Arkansas'), (-1, -7, 'Missouri'), (-1, -6, 'Kentucky'), (-1, -3, 'Mississippi'), (-2, -3, 'Virginia'), (-1, -3, 'Alabama'), (-2, -3, 'Georgia')] ()()()()()

[(-2, -3, 'Georgia'), (-2, -3, 'Virginia'), (-1, -7, 'Missouri'), (-1, -6, 'Kentucky'), (-1, -5, 'Arkansas'), (-1, -3, 'Alabama'), (-1, -3, 'Mississippi')] --Sort - ()()()()()

Color Assignment in Progress B -> Georgia

[(-1, -1, 'Florida'), (-2, 0, 'SouthCarolina'), (-2, -2, 'Alabama')] ()()()()()

[(-2, -2, 'Alabama'), (-2, 0, 'SouthCarolina'), (-1, -1, 'Florida')] --Sort - ()()()()()

Color Assignment in Progress R -> Alabama

[(-2, 0, 'Florida'), (-2, -2, 'Mississippi')] ()()()()()

[(-2, -2, 'Mississippi'), (-2, 0, 'Florida')] --Sort - ()()()()()

Color Assignment in Progress B -> Mississippi

[(-1, -2, 'Louisiana'), (-2, -4, 'Arkansas')] ()()()()()

[(-2, -4, 'Arkansas'), (-1, -2, 'Louisiana')] --Sort - ()()()()()

Color Assignment in Progress R -> Arkansas

[(-2, -6, 'Missouri'), (-1, -5, 'Oklahoma'), (-1, -3, 'Texas'), (-2, -1, 'Louisiana')] ()()()()()

[(-2, -6, 'Missouri'), (-2, -1, 'Louisiana'), (-1, -5, 'Oklahoma'), (-1, -3, 'Texas')] --Sort - ()()()()()

Color Assignment in Progress B -> Missouri

[(-1, -3, 'Kansas'), (-1, -5, 'Iowa'), (-2, -4, 'Oklahoma'), (-1, -5, 'Nebraska'), (-1, -5, 'Illinois'), (-2, -5, 'Kentucky')] ()()()()()

[(-2, -5, 'Kentucky'), (-2, -4, 'Oklahoma'), (-1, -5, 'Illinois'), (-1, -5, 'Iowa'), (-1, -5, 'Nebraska'), (-1, -3, 'Kansas')] --Sort - ()()()()()

Color Assignment in Progress R -> Kentucky

[(-2, -4, 'Illinois'), (-1, -4, 'Ohio'), (-1, -3, 'Indiana'), (-2, -2, 'Virginia'), (-1, -4, 'WestVirginia')] ()()()()()

[(-2, -4, 'Illinois'), (-2, -2, 'Virginia'), (-1, -4, 'Ohio'), (-1, -4, 'WestVirginia'), (-1, -3, 'Indiana')] --Sort - ()()()()()

Color Assignment in Progress G -> Illinois

[(-2, -4, 'Iowa'), (-1, -3, 'Wisconsin'), (-1, -3, 'Michigan'), (-2, -2, 'Indiana')] ()()()()()

[(-2, -4, 'Iowa'), (-2, -2, 'Indiana'), (-1, -3, 'Michigan'), (-1, -3, 'Wisconsin')] --Sort - ()()()()()

Color Assignment in Progress R -> Iowa

[(-2, -4, 'Nebraska'), (-1, -5, 'SouthDakota'), (-2, -2, 'Wisconsin'), (-1, -3, 'Minnesota')] ()()()()()

[(-2, -4, 'Nebraska'), (-2, -2, 'Wisconsin'), (-1, -5, 'SouthDakota'), (-1, -3, 'Minnesota')] --Sort - ()()()()()

Color Assignment in Progress G -> Nebraska

[(-1, -6, 'Colorado'), (-2, -2, 'Kansas'), (-1, -5, 'Wyoming'), (-2, -4, 'SouthDakota')] ()()()()()

[(-2, -4, 'SouthDakota'), (-2, -2, 'Kansas'), (-1, -6, 'Colorado'), (-1, -5, 'Wyoming')] --Sort - ()()()()()

Color Assignment in Progress B -> SouthDakota

[(-1, -3, 'Montana'), (-2, -4, 'Wyoming'), (-1, -2, 'NorthDakota'), (-2, -2, 'Minnesota')] ()()()()()

[(-2, -4, 'Wyoming'), (-2, -2, 'Minnesota'), (-1, -3, 'Montana'), (-1, -2, 'NorthDakota')] --Sort - ()()()()()

Color Assignment in Progress R -> Wyoming

[(-2, -5, 'Colorado'), (-2, -2, 'Montana'), (-1, -5, 'Idaho'), (-1, -5, 'Utah')] ()()()()()

[(-2, -5, 'Colorado'), (-2, -2, 'Montana'), (-1, -5, 'Idaho'), (-1, -5, 'Utah')] --Sort - ()()()()()

Color Assignment in Progress B -> Colorado

[(-1, -4, 'NewMexico'), (-2, -1, 'Kansas'), (-2, -3, 'Oklahoma'), (-1, -4, 'Arizona'), (-2, -4, 'Utah')] ()()()()()

[(-2, -4, 'Utah'), (-2, -3, 'Oklahoma'), (-2, -1, 'Kansas'), (-1, -4, 'Arizona'), (-1, -4, 'NewMexico')] --Sort - ()()()()()

Color Assignment in Progress G -> Utah

[(-2, -3, 'NewMexico'), (-1, -4, 'Nevada'), (-2, -3, 'Arizona'), (-2, -4, 'Idaho')] ()()()()()

[(-2, -4, 'Idaho'), (-2, -3, 'Arizona'), (-2, -3, 'NewMexico'), (-1, -4, 'Nevada')] --Sort - ()()()()()

Color Assignment in Progress B -> Idaho

[(-2, -1, 'Montana'), (-2, -3, 'Nevada'), (-1, -2, 'Washington'), (-1, -3, 'Oregon')] ()()()()()

[(-2, -3, 'Nevada'), (-2, -1, 'Montana'), (-1, -3, 'Oregon'), (-1, -2, 'Washington')] --Sort - ()()()()()

Color Assignment in Progress R -> Nevada

[(-1, -3, 'California'), (-3, -2, 'Arizona'), (-2, -2, 'Oregon')] ()()()()()

[(-3, -2, 'Arizona'), (-2, -2, 'Oregon'), (-1, -3, 'California')] --Sort - ()()()()()

Color Assignment in Progress Y -> Arizona

[(-3, -2, 'NewMexico'), (-2, -2, 'California')] ()()()()()

[(-3, -2, 'NewMexico'), (-2, -2, 'California')] --Sort - ()()()()()

Color Assignment in Progress R -> NewMexico

[(-2, -2, 'Oklahoma'), (-1, -2, 'Texas')] ()()()()()

[(-2, -2, 'Oklahoma'), (-1, -2, 'Texas')] --Sort - ()()()()()

Color Assignment in Progress G -> Oklahoma

[(-2, 0, 'Kansas'), (-2, -1, 'Texas')] ()()()()()

[(-2, -1, 'Texas'), (-2, 0, 'Kansas')] --Sort - ()()()()()

Color Assignment in Progress B -> Texas

[(-2, 0, 'Louisiana')] ()()()()()

[(-2, 0, 'Louisiana')] --Sort - ()()()()()

Color Assignment in Progress G -> Louisiana

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Louisiana

Color Assigned B -> Texas

Color Assignment in Progress R -> Kansas

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Kansas

Color Assigned G -> Oklahoma

Color Assigned R -> NewMexico

Color Assignment in Progress B -> California

[(-1, 0, 'Hawaii'), (-2, -1, 'Oregon')] ()()()()()

[(-2, -1, 'Oregon'), (-1, 0, 'Hawaii')] --Sort - ()()()()()

Color Assignment in Progress G -> Oregon

[(-2, -1, 'Washington')] ()()()()()

[(-2, -1, 'Washington')] --Sort - ()()()()()

Color Assignment in Progress R -> Washington

[(-1, 0, 'Alaska')] ()()()()()

[(-1, 0, 'Alaska')] --Sort - ()()()()()

Color Assignment in Progress G -> Alaska

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Alaska

Color Assigned R -> Washington

Color Assigned G -> Oregon

Color Assignment in Progress R -> Hawaii

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Hawaii

Color Assigned B -> California

Color Assigned Y -> Arizona

Color Assigned R -> Nevada

Color Assignment in Progress G -> Montana

[(-2, -1, 'NorthDakota')] ()()()()()

[(-2, -1, 'NorthDakota')] --Sort - ()()()()()

Color Assignment in Progress R -> NorthDakota

[(-2, -1, 'Minnesota')] ()()()()()

[(-2, -1, 'Minnesota')] --Sort - ()()()()()

Color Assignment in Progress G -> Minnesota

[(-2, -1, 'Wisconsin')] ()()()()()

[(-2, -1, 'Wisconsin')] --Sort - ()()()()()

Color Assignment in Progress B -> Wisconsin

[(-2, -2, 'Michigan')] ()()()()()

[(-2, -2, 'Michigan')] --Sort - ()()()()()

Color Assignment in Progress R -> Michigan

[(-2, -1, 'Indiana'), (-1, -3, 'Ohio')] ()()()()()

[(-2, -1, 'Indiana'), (-1, -3, 'Ohio')] --Sort - ()()()()()

Color Assignment in Progress B -> Indiana

[(-2, -2, 'Ohio')] ()()()()()

[(-2, -2, 'Ohio')] --Sort - ()()()()()

Color Assignment in Progress G -> Ohio

[(-1, -5, 'Pennsylvania'), (-2, -3, 'WestVirginia')] ()()()()()

[(-2, -3, 'WestVirginia'), (-1, -5, 'Pennsylvania')] --Sort - ()()()()()

Color Assignment in Progress B -> WestVirginia

[(-1, -3, 'Maryland'), (-3, -1, 'Virginia'), (-2, -4, 'Pennsylvania')] ()()()()()

[(-3, -1, 'Virginia'), (-2, -4, 'Pennsylvania'), (-1, -3, 'Maryland')] --Sort - ()()()()()

Color Assignment in Progress Y -> Virginia

[(-2, -2, 'Maryland')] ()()()()()

[(-2, -2, 'Maryland')] --Sort - ()()()()()

Color Assignment in Progress G -> Maryland

[(-1, -2, 'Delaware'), (-2, -3, 'Pennsylvania')] ()()()()()

[(-2, -3, 'Pennsylvania'), (-1, -2, 'Delaware')] --Sort - ()()()()()

Color Assignment in Progress R -> Pennsylvania

[(-1, -4, 'NewYork'), (-1, -2, 'NewJersey'), (-2, -1, 'Delaware')] ()()()()()

[(-2, -1, 'Delaware'), (-1, -4, 'NewYork'), (-1, -2, 'NewJersey')] --Sort - ()()()()()

Color Assignment in Progress B -> Delaware

[(-2, -1, 'NewJersey')] ()()()()()

[(-2, -1, 'NewJersey')] --Sort - ()()()()()

Color Assignment in Progress G -> NewJersey

[(-2, -3, 'NewYork')] ()()()()()

[(-2, -3, 'NewYork')] --Sort - ()()()()()

Color Assignment in Progress B -> NewYork

[(-1, -2, 'Connecticut'), (-1, -2, 'Vermont'), (-1, -4, 'Massachusetts')] ()()()()()

[(-1, -4, 'Massachusetts'), (-1, -2, 'Connecticut'), (-1, -2, 'Vermont')] --Sort - ()()()()()

Color Assignment in Progress R -> Massachusetts

[(-2, -1, 'Connecticut'), (-1, -1, 'RhodeIsland'), (-2, -1, 'Vermont'), (-1, -2, 'NewHampshire')] ()()()()()

[(-2, -1, 'Connecticut'), (-2, -1, 'Vermont'), (-1, -2, 'NewHampshire'), (-1, -1, 'RhodeIsland')] --Sort - ()()()()()

Color Assignment in Progress G -> Connecticut

[(-2, 0, 'RhodeIsland')] ()()()()()

[(-2, 0, 'RhodeIsland')] --Sort - ()()()()()

Color Assignment in Progress B -> RhodeIsland

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned B -> RhodeIsland

Color Assigned G -> Connecticut

Color Assignment in Progress G -> Vermont

[(-2, -1, 'NewHampshire')] ()()()()()

[(-2, -1, 'NewHampshire')] --Sort - ()()()()()

Color Assignment in Progress B -> NewHampshire

[(-1, 0, 'Maine')] ()()()()()

[(-1, 0, 'Maine')] --Sort - ()()()()()

Color Assignment in Progress R -> Maine

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Maine

Color Assigned B -> NewHampshire

Color Assigned G -> Vermont

Color Assigned R -> Massachusetts

Color Assigned B -> NewYork

Color Assigned G -> NewJersey

Color Assigned B -> Delaware

Color Assigned R -> Pennsylvania

Color Assigned G -> Maryland

Color Assigned Y -> Virginia

Color Assigned B -> WestVirginia

Color Assigned G -> Ohio

Color Assigned B -> Indiana

Color Assigned R -> Michigan

Color Assigned B -> Wisconsin

Color Assigned G -> Minnesota

Color Assigned R -> NorthDakota

Color Assigned G -> Montana

Color Assigned B -> Idaho

Color Assigned G -> Utah

Color Assigned B -> Colorado

Color Assigned R -> Wyoming

Color Assigned B -> SouthDakota

Color Assigned G -> Nebraska

Color Assigned R -> Iowa

Color Assigned G -> Illinois

Color Assigned R -> Kentucky

Color Assigned B -> Missouri

Color Assigned R -> Arkansas

Color Assigned B -> Mississippi

Color Assignment in Progress G -> Florida

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Florida

Color Assigned R -> Alabama

Color Assignment in Progress G -> SouthCarolina

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> SouthCarolina

Color Assigned B -> Georgia

Color Assigned G -> Tennessee

Color Assigned R -> NorthCarolina

Time: 0.4583968460001415

Number of Backtracks 0

**6. DFS + Heuristic + Singleton**

1. USA

2. AUS

Select Country:

1

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

6

Color Assignment in Progress R -> NorthCarolina

[(-1, -1, 4, 'SouthCarolina'), (-1, -4, 4, 'Virginia'), (-1, -7, 4, 'Tennessee'), (-1, -4, 4, 'Georgia')] ()()()()()

[(-1, -7, 4, 'Tennessee'), (-1, -4, 4, 'Georgia'), (-1, -4, 4, 'Virginia'), (-1, -1, 4, 'SouthCarolina')] --Sort - ()()()()()

Color Assignment in Progress G -> Tennessee

[(-1, -5, 4, 'Arkansas'), (-1, -7, 4, 'Missouri'), (-1, -6, 4, 'Kentucky'), (-1, -3, 4, 'Mississippi'), (-2, -3, 3, 'Virginia'), (-1, -3, 4, 'Alabama'), (-2, -3, 3, 'Georgia')] ()()()()()

[(-2, -3, 3, 'Georgia'), (-2, -3, 3, 'Virginia'), (-1, -7, 4, 'Missouri'), (-1, -6, 4, 'Kentucky'), (-1, -5, 4, 'Arkansas'), (-1, -3, 4, 'Alabama'), (-1, -3, 4, 'Mississippi')] --Sort - ()()()()()

Color Assignment in Progress B -> Georgia

[(-1, -1, 4, 'Florida'), (-2, 0, 3, 'SouthCarolina'), (-2, -2, 3, 'Alabama')] ()()()()()

[(-2, -2, 3, 'Alabama'), (-2, 0, 3, 'SouthCarolina'), (-1, -1, 4, 'Florida')] --Sort - ()()()()()

Color Assignment in Progress R -> Alabama

[(-2, 0, 3, 'Florida'), (-2, -2, 3, 'Mississippi')] ()()()()()

[(-2, -2, 3, 'Mississippi'), (-2, 0, 3, 'Florida')] --Sort - ()()()()()

Color Assignment in Progress B -> Mississippi

[(-1, -2, 4, 'Louisiana'), (-2, -4, 3, 'Arkansas')] ()()()()()

[(-2, -4, 3, 'Arkansas'), (-1, -2, 4, 'Louisiana')] --Sort - ()()()()()

Color Assignment in Progress R -> Arkansas

[(-2, -6, 3, 'Missouri'), (-1, -5, 4, 'Oklahoma'), (-1, -3, 4, 'Texas'), (-2, -1, 3, 'Louisiana')] ()()()()()

[(-2, -6, 3, 'Missouri'), (-2, -1, 3, 'Louisiana'), (-1, -5, 4, 'Oklahoma'), (-1, -3, 4, 'Texas')] --Sort - ()()()()()

Color Assignment in Progress B -> Missouri

[(-1, -3, 4, 'Kansas'), (-1, -5, 4, 'Iowa'), (-2, -4, 3, 'Oklahoma'), (-1, -5, 4, 'Nebraska'), (-1, -5, 4, 'Illinois'), (-2, -5, 3, 'Kentucky')] ()()()()()

[(-2, -5, 3, 'Kentucky'), (-2, -4, 3, 'Oklahoma'), (-1, -5, 4, 'Illinois'), (-1, -5, 4, 'Iowa'), (-1, -5, 4, 'Nebraska'), (-1, -3, 4, 'Kansas')] --Sort - ()()()()()

Color Assignment in Progress R -> Kentucky

[(-2, -4, 3, 'Illinois'), (-1, -4, 4, 'Ohio'), (-1, -3, 4, 'Indiana'), (-2, -2, 2, 'Virginia'), (-1, -4, 4, 'WestVirginia')] ()()()()()

[(-2, -4, 3, 'Illinois'), (-2, -2, 2, 'Virginia'), (-1, -4, 4, 'Ohio'), (-1, -4, 4, 'WestVirginia'), (-1, -3, 4, 'Indiana')] --Sort - ()()()()()

Color Assignment in Progress G -> Illinois

[(-2, -4, 3, 'Iowa'), (-1, -3, 4, 'Wisconsin'), (-1, -3, 4, 'Michigan'), (-2, -2, 3, 'Indiana')] ()()()()()

[(-2, -4, 3, 'Iowa'), (-2, -2, 3, 'Indiana'), (-1, -3, 4, 'Michigan'), (-1, -3, 4, 'Wisconsin')] --Sort - ()()()()()

Color Assignment in Progress R -> Iowa

[(-2, -4, 3, 'Nebraska'), (-1, -5, 4, 'SouthDakota'), (-2, -2, 3, 'Wisconsin'), (-1, -3, 4, 'Minnesota')] ()()()()()

[(-2, -4, 3, 'Nebraska'), (-2, -2, 3, 'Wisconsin'), (-1, -5, 4, 'SouthDakota'), (-1, -3, 4, 'Minnesota')] --Sort - ()()()()()

Color Assignment in Progress G -> Nebraska

[(-1, -6, 4, 'Colorado'), (-2, -2, 3, 'Kansas'), (-1, -5, 4, 'Wyoming'), (-2, -4, 3, 'SouthDakota')] ()()()()()

[(-2, -4, 3, 'SouthDakota'), (-2, -2, 3, 'Kansas'), (-1, -6, 4, 'Colorado'), (-1, -5, 4, 'Wyoming')] --Sort - ()()()()()

Color Assignment in Progress B -> SouthDakota

[(-1, -3, 4, 'Montana'), (-2, -4, 3, 'Wyoming'), (-1, -2, 4, 'NorthDakota'), (-2, -2, 3, 'Minnesota')] ()()()()()

[(-2, -4, 3, 'Wyoming'), (-2, -2, 3, 'Minnesota'), (-1, -3, 4, 'Montana'), (-1, -2, 4, 'NorthDakota')] --Sort - ()()()()()

Color Assignment in Progress R -> Wyoming

[(-2, -5, 3, 'Colorado'), (-2, -2, 3, 'Montana'), (-1, -5, 4, 'Idaho'), (-1, -5, 4, 'Utah')] ()()()()()

[(-2, -5, 3, 'Colorado'), (-2, -2, 3, 'Montana'), (-1, -5, 4, 'Idaho'), (-1, -5, 4, 'Utah')] --Sort - ()()()()()

Color Assignment in Progress B -> Colorado

[(-1, -4, 4, 'NewMexico'), (-2, -1, 2, 'Kansas'), (-2, -3, 2, 'Oklahoma'), (-1, -4, 4, 'Arizona'), (-2, -4, 3, 'Utah')] ()()()()()

[(-2, -4, 3, 'Utah'), (-2, -3, 2, 'Oklahoma'), (-2, -1, 2, 'Kansas'), (-1, -4, 4, 'Arizona'), (-1, -4, 4, 'NewMexico')] --Sort - ()()()()()

Color Assignment in Progress G -> Utah

[(-2, -3, 3, 'NewMexico'), (-1, -4, 4, 'Nevada'), (-2, -3, 3, 'Arizona'), (-2, -4, 3, 'Idaho')] ()()()()()

[(-2, -4, 3, 'Idaho'), (-2, -3, 3, 'Arizona'), (-2, -3, 3, 'NewMexico'), (-1, -4, 4, 'Nevada')] --Sort - ()()()()()

Color Assignment in Progress B -> Idaho

[(-2, -1, 2, 'Montana'), (-2, -3, 3, 'Nevada'), (-1, -2, 4, 'Washington'), (-1, -3, 4, 'Oregon')] ()()()()()

[(-2, -3, 3, 'Nevada'), (-2, -1, 2, 'Montana'), (-1, -3, 4, 'Oregon'), (-1, -2, 4, 'Washington')] --Sort - ()()()()()

Color Assignment in Progress R -> Nevada

[(-1, -3, 4, 'California'), (-3, -2, 2, 'Arizona'), (-2, -2, 3, 'Oregon')] ()()()()()

[(-3, -2, 2, 'Arizona'), (-2, -2, 3, 'Oregon'), (-1, -3, 4, 'California')] --Sort - ()()()()()

Color Assignment in Progress Y -> Arizona

[(-3, -2, 2, 'NewMexico'), (-2, -2, 3, 'California')] ()()()()()

[(-3, -2, 2, 'NewMexico'), (-2, -2, 3, 'California')] --Sort - ()()()()()

Color Assignment in Progress R -> NewMexico

[(-2, -2, 2, 'Oklahoma'), (-1, -2, 3, 'Texas')] ()()()()()

[(-2, -2, 2, 'Oklahoma'), (-1, -2, 3, 'Texas')] --Sort - ()()()()()

Color Assignment in Progress G -> Oklahoma

[(-2, 0, 2, 'Kansas'), (-2, -1, 3, 'Texas')] ()()()()()

[(-2, -1, 3, 'Texas'), (-2, 0, 2, 'Kansas')] --Sort - ()()()()()

Color Assignment in Progress B -> Texas

[(-2, 0, 2, 'Louisiana')] ()()()()()

[(-2, 0, 2, 'Louisiana')] --Sort - ()()()()()

Color Assignment in Progress G -> Louisiana

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Louisiana

Color Assigned B -> Texas

Color Assignment in Progress R -> Kansas

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Kansas

Color Assigned G -> Oklahoma

Color Assigned R -> NewMexico

Color Assignment in Progress B -> California

[(-1, 0, 4, 'Hawaii'), (-2, -1, 2, 'Oregon')] ()()()()()

[(-2, -1, 2, 'Oregon'), (-1, 0, 4, 'Hawaii')] --Sort - ()()()()()

Color Assignment in Progress G -> Oregon

[(-2, -1, 3, 'Washington')] ()()()()()

[(-2, -1, 3, 'Washington')] --Sort - ()()()()()

Color Assignment in Progress R -> Washington

[(-1, 0, 4, 'Alaska')] ()()()()()

[(-1, 0, 4, 'Alaska')] --Sort - ()()()()()

Color Assignment in Progress G -> Alaska

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Alaska

Color Assigned R -> Washington

Color Assigned G -> Oregon

Color Assignment in Progress R -> Hawaii

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Hawaii

Color Assigned B -> California

Color Assigned Y -> Arizona

Color Assigned R -> Nevada

Color Assignment in Progress G -> Montana

[(-2, -1, 3, 'NorthDakota')] ()()()()()

[(-2, -1, 3, 'NorthDakota')] --Sort - ()()()()()

Color Assignment in Progress R -> NorthDakota

[(-2, -1, 2, 'Minnesota')] ()()()()()

[(-2, -1, 2, 'Minnesota')] --Sort - ()()()()()

Color Assignment in Progress G -> Minnesota

[(-2, -1, 2, 'Wisconsin')] ()()()()()

[(-2, -1, 2, 'Wisconsin')] --Sort - ()()()()()

Color Assignment in Progress B -> Wisconsin

[(-2, -2, 3, 'Michigan')] ()()()()()

[(-2, -2, 3, 'Michigan')] --Sort - ()()()()()

Color Assignment in Progress R -> Michigan

[(-2, -1, 2, 'Indiana'), (-1, -3, 3, 'Ohio')] ()()()()()

[(-2, -1, 2, 'Indiana'), (-1, -3, 3, 'Ohio')] --Sort - ()()()()()

Color Assignment in Progress B -> Indiana

[(-2, -2, 3, 'Ohio')] ()()()()()

[(-2, -2, 3, 'Ohio')] --Sort - ()()()()()

Color Assignment in Progress G -> Ohio

[(-1, -5, 4, 'Pennsylvania'), (-2, -3, 3, 'WestVirginia')] ()()()()()

[(-2, -3, 3, 'WestVirginia'), (-1, -5, 4, 'Pennsylvania')] --Sort - ()()()()()

Color Assignment in Progress B -> WestVirginia

[(-1, -3, 4, 'Maryland'), (-3, -1, 2, 'Virginia'), (-2, -4, 3, 'Pennsylvania')] ()()()()()

[(-3, -1, 2, 'Virginia'), (-2, -4, 3, 'Pennsylvania'), (-1, -3, 4, 'Maryland')] --Sort - ()()()()()

Color Assignment in Progress Y -> Virginia

[(-2, -2, 3, 'Maryland')] ()()()()()

[(-2, -2, 3, 'Maryland')] --Sort - ()()()()()

Color Assignment in Progress G -> Maryland

[(-1, -2, 4, 'Delaware'), (-2, -3, 2, 'Pennsylvania')] ()()()()()

[(-2, -3, 2, 'Pennsylvania'), (-1, -2, 4, 'Delaware')] --Sort - ()()()()()

Color Assignment in Progress R -> Pennsylvania

[(-1, -4, 4, 'NewYork'), (-1, -2, 4, 'NewJersey'), (-2, -1, 3, 'Delaware')] ()()()()()

[(-2, -1, 3, 'Delaware'), (-1, -4, 4, 'NewYork'), (-1, -2, 4, 'NewJersey')] --Sort - ()()()()()

Color Assignment in Progress B -> Delaware

[(-2, -1, 3, 'NewJersey')] ()()()()()

[(-2, -1, 3, 'NewJersey')] --Sort - ()()()()()

Color Assignment in Progress G -> NewJersey

[(-2, -3, 3, 'NewYork')] ()()()()()

[(-2, -3, 3, 'NewYork')] --Sort - ()()()()()

Color Assignment in Progress B -> NewYork

[(-1, -2, 4, 'Connecticut'), (-1, -2, 4, 'Vermont'), (-1, -4, 4, 'Massachusetts')] ()()()()()

[(-1, -4, 4, 'Massachusetts'), (-1, -2, 4, 'Connecticut'), (-1, -2, 4, 'Vermont')] --Sort - ()()()()()

Color Assignment in Progress R -> Massachusetts

[(-2, -1, 3, 'Connecticut'), (-1, -1, 4, 'RhodeIsland'), (-2, -1, 3, 'Vermont'), (-1, -2, 4, 'NewHampshire')] ()()()()()

[(-2, -1, 3, 'Connecticut'), (-2, -1, 3, 'Vermont'), (-1, -2, 4, 'NewHampshire'), (-1, -1, 4, 'RhodeIsland')] --Sort - ()()()()()

Color Assignment in Progress G -> Connecticut

[(-2, 0, 3, 'RhodeIsland')] ()()()()()

[(-2, 0, 3, 'RhodeIsland')] --Sort - ()()()()()

Color Assignment in Progress B -> RhodeIsland

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned B -> RhodeIsland

Color Assigned G -> Connecticut

Color Assignment in Progress G -> Vermont

[(-2, -1, 3, 'NewHampshire')] ()()()()()

[(-2, -1, 3, 'NewHampshire')] --Sort - ()()()()()

Color Assignment in Progress B -> NewHampshire

[(-1, 0, 4, 'Maine')] ()()()()()

[(-1, 0, 4, 'Maine')] --Sort - ()()()()()

Color Assignment in Progress R -> Maine

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Maine

Color Assigned B -> NewHampshire

Color Assigned G -> Vermont

Color Assigned R -> Massachusetts

Color Assigned B -> NewYork

Color Assigned G -> NewJersey

Color Assigned B -> Delaware

Color Assigned R -> Pennsylvania

Color Assigned G -> Maryland

Color Assigned Y -> Virginia

Color Assigned B -> WestVirginia

Color Assigned G -> Ohio

Color Assigned B -> Indiana

Color Assigned R -> Michigan

Color Assigned B -> Wisconsin

Color Assigned G -> Minnesota

Color Assigned R -> NorthDakota

Color Assigned G -> Montana

Color Assigned B -> Idaho

Color Assigned G -> Utah

Color Assigned B -> Colorado

Color Assigned R -> Wyoming

Color Assigned B -> SouthDakota

Color Assigned G -> Nebraska

Color Assigned R -> Iowa

Color Assigned G -> Illinois

Color Assigned R -> Kentucky

Color Assigned B -> Missouri

Color Assigned R -> Arkansas

Color Assigned B -> Mississippi

Color Assignment in Progress G -> Florida

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> Florida

Color Assigned R -> Alabama

Color Assignment in Progress G -> SouthCarolina

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned G -> SouthCarolina

Color Assigned B -> Georgia

Color Assigned G -> Tennessee

Color Assigned R -> NorthCarolina

Time: 0.5130860879999091

Number of Backtracks 0

**For Australia**

**1. DFS**

1. USA

2. AUS

Select Country:

2

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

1

Color Assigned G -> WestAustralia

Color Assigned R -> NorthTerritory

Color Assigned G -> Queensland

Color Assigned B -> SouthAustralia

Color Assigned R -> Tasmania

Color Assigned G -> Victoria

Color Assigned R -> NewSouthWales

Time: 0.0013495219991455087

Number of Backtracks 0

**2. DFS + FC**

1. USA

2. AUS

Select Country:

2

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

2

Color Assignment in Progress R -> NewSouthWales

Color Assignment in Progress G -> Victoria

Color Assignment in Progress B -> SouthAustralia

Color Assignment in Progress G -> Queensland

Color Assignment in Progress R -> NorthTerritory

Color Assignment in Progress G -> WestAustralia

Color Assigned G -> WestAustralia

Color Assigned R -> NorthTerritory

Color Assigned G -> Queensland

Color Assigned B -> SouthAustralia

Color Assignment in Progress R -> Tasmania

Color Assigned R -> Tasmania

Color Assigned G -> Victoria

Color Assigned R -> NewSouthWales

Time: 0.001243454000359634

Number of Backtracks 0

**3. DFS + FC + Singleton**

1. USA

2. AUS

Select Country:

2

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

3

Color Assignment in Progress R -> NewSouthWales

Color Assignment in Progress G -> Victoria

Color Assignment in Progress B -> SouthAustralia

Color Assignment in Progress G -> Queensland

Color Assignment in Progress R -> NorthTerritory

Color Assignment in Progress G -> WestAustralia

Color Assigned G -> WestAustralia

Color Assigned R -> NorthTerritory

Color Assigned G -> Queensland

Color Assigned B -> SouthAustralia

Color Assignment in Progress R -> Tasmania

Color Assigned R -> Tasmania

Color Assigned G -> Victoria

Color Assigned R -> NewSouthWales

Time: 0.004226635000122769

Number of Backtracks 0

**4. DFS + Heuristic**

1. USA

2. AUS

Select Country:

2

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

4

[(-1, -2, 'Victoria'), (-1, -2, 'Queensland'), (-1, -4, 'SouthAustralia')] ()()()()()

[(-1, -4, 'SouthAustralia'), (-1, -2, 'Queensland'), (-1, -2, 'Victoria')] --Sort - ()()()()()

[(-2, -1, 'Queensland'), (-1, -1, 'WestAustralia'), (-1, -2, 'NorthTerritory'), (-2, -1, 'Victoria')] ()()()()()

[(-2, -1, 'Queensland'), (-2, -1, 'Victoria'), (-1, -2, 'NorthTerritory'), (-1, -1, 'WestAustralia')] --Sort - ()()()()()

[(-2, -1, 'NorthTerritory')] ()()()()()

[(-2, -1, 'NorthTerritory')] --Sort - ()()()()()

[(-2, 0, 'WestAustralia')] ()()()()()

[(-2, 0, 'WestAustralia')] --Sort - ()()()()()

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned B -> WestAustralia

Color Assigned R -> NorthTerritory

Color Assigned B -> Queensland

[(-1, 0, 'Tasmania')] ()()()()()

[(-1, 0, 'Tasmania')] --Sort - ()()()()()

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Tasmania

Color Assigned B -> Victoria

Color Assigned G -> SouthAustralia

Color Assigned R -> NewSouthWales

Time: 0.001831579999816313

Number of Backtracks 0

**5. DFS + Heuristic + FC**

1. USA

2. AUS

Select Country:

2

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

5

Color Assignment in Progress R -> NewSouthWales

[(-1, -2, 'Victoria'), (-1, -2, 'Queensland'), (-1, -4, 'SouthAustralia')] ()()()()()

[(-1, -4, 'SouthAustralia'), (-1, -2, 'Queensland'), (-1, -2, 'Victoria')] --Sort - ()()()()()

Color Assignment in Progress G -> SouthAustralia

[(-2, -1, 'Queensland'), (-1, -1, 'WestAustralia'), (-1, -2, 'NorthTerritory'), (-2, -1, 'Victoria')] ()()()()()

[(-2, -1, 'Queensland'), (-2, -1, 'Victoria'), (-1, -2, 'NorthTerritory'), (-1, -1, 'WestAustralia')] --Sort - ()()()()()

Color Assignment in Progress B -> Queensland

[(-2, -1, 'NorthTerritory')] ()()()()()

[(-2, -1, 'NorthTerritory')] --Sort - ()()()()()

Color Assignment in Progress R -> NorthTerritory

[(-2, 0, 'WestAustralia')] ()()()()()

[(-2, 0, 'WestAustralia')] --Sort - ()()()()()

Color Assignment in Progress B -> WestAustralia

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned B -> WestAustralia

Color Assigned R -> NorthTerritory

Color Assigned B -> Queensland

Color Assignment in Progress B -> Victoria

[(-1, 0, 'Tasmania')] ()()()()()

[(-1, 0, 'Tasmania')] --Sort - ()()()()()

Color Assignment in Progress R -> Tasmania

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Tasmania

Color Assigned B -> Victoria

Color Assigned G -> SouthAustralia

Color Assigned R -> NewSouthWales

Time: 0.0029856450000806944

Number of Backtracks 0

**6. DFS + Heuristic, FC + Singleton**

1. USA

2. AUS

Select Country:

2

1. DFS

2. DFS + FC

3. DFS + FC + Singleton

4. DFS + Heuristic

5. DFS + Heuristic + FC

6. DFS + heuristic, FC + Singleton

Choose the Algorithm:

6

Color Assignment in Progress R -> NewSouthWales

[(-1, -2, 3, 'Victoria'), (-1, -2, 3, 'Queensland'), (-1, -4, 3, 'SouthAustralia')] ()()()()()

[(-1, -4, 3, 'SouthAustralia'), (-1, -2, 3, 'Queensland'), (-1, -2, 3, 'Victoria')] --Sort - ()()()()()

Color Assignment in Progress G -> SouthAustralia

[(-2, -1, 2, 'Queensland'), (-1, -1, 3, 'WestAustralia'), (-1, -2, 3, 'NorthTerritory'), (-2, -1, 2, 'Victoria')] ()()()()()

[(-2, -1, 2, 'Queensland'), (-2, -1, 2, 'Victoria'), (-1, -2, 3, 'NorthTerritory'), (-1, -1, 3, 'WestAustralia')] --Sort - ()()()()()

Color Assignment in Progress B -> Queensland

[(-2, -1, 2, 'NorthTerritory')] ()()()()()

[(-2, -1, 2, 'NorthTerritory')] --Sort - ()()()()()

Color Assignment in Progress R -> NorthTerritory

[(-2, 0, 2, 'WestAustralia')] ()()()()()

[(-2, 0, 2, 'WestAustralia')] --Sort - ()()()()()

Color Assignment in Progress B -> WestAustralia

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned B -> WestAustralia

Color Assigned R -> NorthTerritory

Color Assigned B -> Queensland

Color Assignment in Progress B -> Victoria

[(-1, 0, 3, 'Tasmania')] ()()()()()

[(-1, 0, 3, 'Tasmania')] --Sort - ()()()()()

Color Assignment in Progress R -> Tasmania

[] ()()()()()

[] --Sort - ()()()()()

Color Assigned R -> Tasmania

Color Assigned B -> Victoria

Color Assigned G -> SouthAustralia

Color Assigned R -> NewSouthWales

Time: 0.0023720449999018456

Number of Backtracks 0

**OUTPUT TABLE**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Country** | **With Heuristics** | **DFS** | **DFS+FC** | **DFS+FC+Singleton** | **Backtrack** | **Time** |
| AUSTRALIA | Yes | Yes | No | No | 0 | 0.001831579999816 |
| AUSTRALIA | Yes | Yes | Yes | No | 0 | 0.00298564500008 |
| AUSTRALIA | Yes | Yes | Yes | Yes | 0 | 0.002372044999901845 |
| AUSTRALIA | No | Yes | No | No | 0 | 0.001349521999145508 |
| AUSTRALIA | No | Yes | Yes | No | 0 | 0. 00124345400035963 |
| AUSTRALIA | No | Yes | Yes | Yes | 0 | 0. 00422663500012276 |
| USA | Yes | Yes | No | No | 0 | 0.4287903370004642 |
| USA | Yes | Yes | Yes | No | 0 | 0.4583968460001415 |
| USA | Yes | Yes | Yes | Yes | 0 | 0.5130860879999091 |
| USA | No | Yes | No | No | 73 | 0.37268043200037937 |
| USA | No | Yes | Yes | No | 15 | 0.428951492999658 |
| USA | No | Yes | Yes | Yes | 0 | 0.41947213700041175 |

**SOURCE CODE**

import matplotlib.pyplot as plt

import matplotlib.pyplot as plt1

from mpl\_toolkits.basemap import Basemap

from matplotlib.patches import Polygon

import networkx as nx

import copy

import webbrowser

import timeit

paint\_true = {}

backtrack = 0

if\_singleton = 0

heuristic = 0

basemap = Basemap(llcrnrlon=-119, llcrnrlat=22, urcrnrlon=-64, urcrnrlat=49, projection='lcc', lat\_1=33, lat\_2=45,

lon\_0=-95)

basemap.readshapefile(r'''/Users/sriganeshlokesh/anaconda3/lib/python3.7/site-packages/mpl\_toolkits/basemap/st99\_d00''', name='states', drawbounds=True)

states = []

for s\_dict in basemap.states\_info:

states.append(s\_dict['NAME'])

ax = plt.gca()

def check(map):

for c, a in map.items():

assert (c not in a)

for l in a:

assert (l in map and c in map[l])

def value\_next(r, n, assignment):

if heuristic == 0:

return n[r]

else:

if if\_singleton == 0:

inf = [

(

-len({paint\_true[next] for next in n[number] if next in paint\_true}),

-len({next for next in n[number] if next not in paint\_true}),

number

) for number in n[r] if number not in paint\_true]

else:

inf = [

(

-len({paint\_true[next] for next in n[number] if next in paint\_true}),

-len({next for next in n[number] if next not in paint\_true}),

len(assignment[number]),

number

) for number in n[r] if number not in paint\_true]

print(inf, "()()()()()")

inf.sort()

print(inf, "--Sort - ()()()()()")

if if\_singleton == 0:

candidates = [number for \_, \_, number in inf]

else:

candidates = [number for \_, \_, \_, number in inf]

return candidates

def color\_assign(r, n, assignment):

if heuristic == 0:

return assignment[r]

else:

a = []

for s\_color in assignment[r]:

c\_total = 0

a.append([s\_color])

for next in n[r]:

if s\_color in assignment[next]:

c\_total = c\_total + len(assignment[next]) - 1

else:

c\_total = c\_total + len(assignment[next])

a[a.index([s\_color])].append(c\_total)

a = sorted(a, key=lambda a\_sort: a\_sort[1], reverse=True)

a = [a\_sort[0] for a\_sort in a]

return a

def dfs(r, n, assignment):

add\_color = 0

w = 0

global backtrack

for s\_color in color\_assign(r, n, assignment):

for j in n[r]:

if j in paint\_true and paint\_true[j] == s\_color:

add\_color = 1

break

if add\_color == 1:

add\_color = 0

continue

paint\_true[r] = s\_color

for k in value\_next(r, n, assignment):

if k not in paint\_true:

if (dfs(k, n, assignment) == False):

paint\_true.pop(r)

w = 1

break

if w == 0:

print("Color Assigned %s -> %s" % (paint\_true[r], r))

return True

else:

w = 0

continue

backtrack = backtrack + 1

return False

def decrease(r, n, a\_c):

for j in n[r]:

if paint\_true[r] in a\_c[j]:

a\_c[j].remove(paint\_true[r])

def decrease\_for\_forward\_check(s\_color, r, n, a\_c):

copy\_a = copy.deepcopy(a\_c)

for j in n[r]:

if s\_color in copy\_a[j]:

copy\_a[j].remove(s\_color)

if not d\_validate(j, copy\_a):

return False

return True

def d\_validate(r, a\_c):

if not (a\_c[r]):

return False

return True

def dfs\_forward(r, n, assignment):

w = 0

d = copy.deepcopy(assignment)

global backtrack

for s\_color in color\_assign(r, n, assignment):

a = copy.deepcopy(d)

if decrease\_for\_forward\_check(s\_color, r, n, a) == False:

continue

paint\_true[r] = s\_color

print("Color Assignment in Progress %s -> %s" % (s\_color, r))

decrease(r, n, a)

a[r] = s\_color

if if\_singleton == 1 and heuristic == 0:

n[r] = sorted(n[r], key=lambda a\_sort: len(assignment[a\_sort]),

reverse=False)

for next in value\_next(r, n, assignment):

if next not in paint\_true:

if (dfs\_forward(next, n, a)) == False:

paint\_true.pop(r)

w = 1

break

if w == 0:

print("Color Assigned %s -> %s" % (paint\_true[r], r))

return True

else:

w = 0

continue

backtrack = backtrack + 1

return False

WestAustralia = 'WestAustralia'

NorthTerritory = 'NorthTerritory'

SouthAustralia = 'SouthAustralia'

Queensland = 'Queensland'

NewSouthWales = 'NewSouthWales'

Victoria = 'Victoria'

Tasmania = 'Tasmania'

Aussie = {

Tasmania: {Victoria},

WestAustralia: {NorthTerritory, SouthAustralia},

NorthTerritory: {WestAustralia, Queensland, SouthAustralia},

SouthAustralia: {WestAustralia, NorthTerritory, Queensland, NewSouthWales, Victoria},

Queensland: {NorthTerritory, SouthAustralia, NewSouthWales},

NewSouthWales: {Queensland, SouthAustralia, Victoria},

Victoria: {SouthAustralia, NewSouthWales, Tasmania}

}

aussie\_color = {

Tasmania: ['R', 'G', 'B'],

WestAustralia: ['R', 'G', 'B'],

NorthTerritory: ['R', 'G', 'B'],

SouthAustralia: ['R', 'G', 'B'],

Queensland: ['R', 'G', 'B'],

NewSouthWales: ['R', 'G', 'B'],

Victoria: ['R', 'G', 'B']

}

Alabama = "Alabama"

Alaska = "Alaska"

Arizona = "Arizona"

Arkansas = "Arkansas"

California = "California"

Colorado = "Colorado"

Connecticut = "Connecticut"

Delaware = "Delaware"

Florida = "Florida"

Georgia = "Georgia"

Hawaii = "Hawaii"

Idaho = "Idaho"

Illinois = "Illinois"

Indiana = "Indiana"

Iowa = "Iowa"

Kansas = "Kansas"

Kentucky = "Kentucky"

Louisiana = "Louisiana"

Maine = "Maine"

Maryland = "Maryland"

Massachusetts = "Massachusetts"

Michigan = "Michigan"

Minnesota = "Minnesota"

Mississippi = "Mississippi"

Missouri = "Missouri"

Montana = "Montana"

Nebraska = "Nebraska"

Nevada = "Nevada"

NewHampshire = "NewHampshire"

NewJersey = "NewJersey"

NewMexico = "NewMexico"

NewYork = "NewYork"

NorthCarolina = "NorthCarolina"

NorthDakota = "NorthDakota"

Ohio = "Ohio"

Oklahoma = "Oklahoma"

Oregon = "Oregon"

Pennsylvania = "Pennsylvania"

RhodeIsland = "RhodeIsland"

SouthCarolina = "SouthCarolina"

SouthDakota = "SouthDakota"

Tennessee = "Tennessee"

Texas = "Texas"

Utah = "Utah"

Virginia = "Virginia"

Vermont = "Vermont"

Washington = "Washington"

WestVirginia = "WestVirginia"

Wisconsin = "Wisconsin"

Wyoming = "Wyoming"

USA\_S = {

Alabama: {Georgia, Florida, Tennessee, Mississippi},

Alaska: {Washington},

Arizona: {California, Nevada, Utah, Colorado, NewMexico},

Arkansas: {Missouri, Oklahoma, Texas, Louisiana, Tennessee, Mississippi},

California: {Oregon, Nevada, Arizona, Hawaii},

Colorado: {Wyoming, Nebraska, Kansas, Oklahoma, NewMexico, Arizona, Utah},

Connecticut: {NewYork, RhodeIsland, Massachusetts},

Delaware: {Maryland, Pennsylvania, NewJersey},

Florida: {Alabama, Georgia},

Georgia: {SouthCarolina, NorthCarolina, Tennessee, Alabama, Florida},

Hawaii: {California},

Idaho: {Washington, Montana, Oregon, Wyoming, Utah, Nevada},

Illinois: {Wisconsin, Iowa, Missouri, Kentucky, Indiana, Michigan},

Indiana: {Michigan, Illinois, Kentucky, Ohio},

Iowa: {Minnesota, SouthDakota, Nebraska, Missouri, Wisconsin, Illinois},

Kansas: {Nebraska, Colorado, Oklahoma, Missouri},

Kentucky: {Indiana, Illinois, Missouri, Tennessee, Ohio, WestVirginia, Virginia},

Louisiana: {Arkansas, Texas, Mississippi},

Maine: {NewHampshire},

Maryland: {Pennsylvania, WestVirginia, Virginia, Delaware},

Massachusetts: {NewYork, Vermont, NewHampshire, Connecticut, RhodeIsland},

Michigan: {Illinois, Wisconsin, Indiana, Ohio},

Minnesota: {NorthDakota, SouthDakota, Iowa, Wisconsin},

Mississippi: {Tennessee, Arkansas, Louisiana, Alabama},

Missouri: {Iowa, Nebraska, Kansas, Oklahoma, Arkansas, Illinois, Kentucky, Tennessee},

Montana: {Idaho, Wyoming, SouthDakota, NorthDakota},

Nebraska: {SouthDakota, Colorado, Wyoming, Kansas, Missouri, Iowa},

Nevada: {Oregon, Idaho, Utah, Arizona, California},

NewHampshire: {Maine, Vermont, Massachusetts},

NewJersey: {NewYork, Pennsylvania, Delaware},

NewMexico: {Arizona, Utah, Colorado, Oklahoma, Texas},

NewYork: {Pennsylvania, NewJersey, Connecticut, Massachusetts, Vermont},

NorthCarolina: {Georgia, Tennessee, SouthCarolina, Virginia},

NorthDakota: {Montana, SouthDakota, Minnesota},

Ohio: {Michigan, Indiana, Kentucky, WestVirginia, Pennsylvania},

Oklahoma: {Kansas, Colorado, NewMexico, Texas, Arkansas, Missouri},

Oregon: {Washington, Idaho, Nevada, California},

Pennsylvania: {Ohio, WestVirginia, Delaware, NewJersey, NewYork, Maryland},

RhodeIsland: {Connecticut, Massachusetts},

SouthCarolina: {Georgia, NorthCarolina},

SouthDakota: {NorthDakota, Montana, Wyoming, Nebraska, Minnesota, Iowa},

Tennessee: {Kentucky, Arkansas, Mississippi, Missouri, Alabama, Georgia, NorthCarolina, Virginia},

Texas: {Oklahoma, NewMexico, Arkansas, Louisiana},

Utah: {Idaho, Nevada, Wyoming, Colorado, Arizona, NewMexico},

Vermont: {Massachusetts, NewYork, NewHampshire},

Virginia: {WestVirginia, Kentucky, NorthCarolina, Tennessee, Maryland},

Washington: {Oregon, Idaho, Alaska},

WestVirginia: {Ohio, Virginia, Kentucky, Pennsylvania, Maryland},

Wisconsin: {Minnesota, Illinois, Michigan, Iowa},

Wyoming: {Montana, SouthDakota, Nebraska, Colorado, Utah, Idaho},

}

US\_colors = {

Alabama: ['R', 'G', 'B', 'Y'],

Alaska: ['R', 'G', 'B', 'Y'],

Arizona: ['R', 'G', 'B', 'Y'],

Arkansas: ['R', 'G', 'B', 'Y'],

California: ['R', 'G', 'B', 'Y'],

Colorado: ['R', 'G', 'B', 'Y'],

Connecticut: ['R', 'G', 'B', 'Y'],

Delaware: ['R', 'G', 'B', 'Y'],

Florida: ['R', 'G', 'B', 'Y'],

Georgia: ['R', 'G', 'B', 'Y'],

Hawaii: ['R', 'G', 'B', 'Y'],

Idaho: ['R', 'G', 'B', 'Y'],

Illinois: ['R', 'G', 'B', 'Y'],

Indiana: ['R', 'G', 'B', 'Y'],

Iowa: ['R', 'G', 'B', 'Y'],

Kansas: ['R', 'G', 'B', 'Y'],

Kentucky: ['R', 'G', 'B', 'Y'],

Louisiana: ['R', 'G', 'B', 'Y'],

Maine: ['R', 'G', 'B', 'Y'],

Maryland: ['R', 'G', 'B', 'Y'],

Massachusetts: ['R', 'G', 'B', 'Y'],

Michigan: ['R', 'G', 'B', 'Y'],

Minnesota: ['R', 'G', 'B', 'Y'],

Mississippi: ['R', 'G', 'B', 'Y'],

Missouri: ['R', 'G', 'B', 'Y'],

Montana: ['R', 'G', 'B', 'Y'],

Nebraska: ['R', 'G', 'B', 'Y'],

Nevada: ['R', 'G', 'B', 'Y'],

NewHampshire: ['R', 'G', 'B', 'Y'],

NewJersey: ['R', 'G', 'B', 'Y'],

NewMexico: ['R', 'G', 'B', 'Y'],

NewYork: ['R', 'G', 'B', 'Y'],

NorthCarolina: ['R', 'G', 'B', 'Y'],

NorthDakota: ['R', 'G', 'B', 'Y'],

Ohio: ['R', 'G', 'B', 'Y'],

Oklahoma: ['R', 'G', 'B', 'Y'],

Oregon: ['R', 'G', 'B', 'Y'],

Pennsylvania: ['R', 'G', 'B', 'Y'],

RhodeIsland: ['R', 'G', 'B', 'Y'],

SouthCarolina: ['R', 'G', 'B', 'Y'],

SouthDakota: ['R', 'G', 'B', 'Y'],

Tennessee: ['R', 'G', 'B', 'Y'],

Texas: ['R', 'G', 'B', 'Y'],

Utah: ['R', 'G', 'B', 'Y'],

Virginia: ['R', 'G', 'B', 'Y'],

Vermont: ['R', 'G', 'B', 'Y'],

Washington: ['R', 'G', 'B', 'Y'],

WestVirginia: ['R', 'G', 'B', 'Y'],

Wisconsin: ['R', 'G', 'B', 'Y'],

Wyoming: ['R', 'G', 'B', 'Y'],

}

USA\_S = {number: next for number, next in USA\_S.items() if next}

def build\_graph():

g = nx.Graph()

for e in tempList:

g.add(e[0], e[1])

return g

def paint\_graph(G, paint\_true):

pos = nx.spring\_layout(G)

val = paint\_true.values()

nx.draw(G, pos, with\_labels=True, node\_size=500, node\_color=val, edge\_color='black', width=1,

alpha=.7)

if \_\_name\_\_ == '\_\_main\_\_':

print("\n1. USA")

print("2. AUS")

n\_name = int(input("\nSelect Country:\n "))

country = ""

complete = {}

s\_color = {}

short = ""

if n\_name == 1:

country = "USA"

complete = USA\_S

s\_color = US\_colors

short = NorthCarolina

flag = 1

elif n\_name == 2:

country = "AUS"

complete = Aussie

s\_color = aussie\_color

short = NSW

flag = 2

else:

print("Invalid!, Enter Valid Value")

exit(0)

check(USA\_S)

print("\n1. DFS")

print("2. DFS + FC")

print("3. DFS + FC + Singleton")

print("4. DFS + Heuristic")

print("5. DFS + Heuristic + FC")

print("6. DFS + heuristic, FC + Singleton")

algo = int(input("\nChoose the Algorithm:\n"))

start = timeit.default\_timer()

if algo == 1:

if (dfs(short, complete, s\_color)):

stt = list(paint\_true.keys())

clr = list(paint\_true.values())

if flag == 1:

for i in range(len(paint\_true.keys())):

seg = basemap.states[states.index(stt[i])]

p = Polygon(seg, facecolor=(clr[i]), edgecolor=clr[i])

ax.add\_patch(p)

plt.show()

elif algo == 2:

if (dfs\_forward(short, complete, s\_color)):

stt = list(paint\_true.keys())

clr = list(paint\_true.values())

if flag == 1:

for i in range(len(paint\_true.keys())):

seg = basemap.states[states.index(stt[i])]

p = Polygon(seg, facecolor=(clr[i]), edgecolor=clr[i])

ax.add\_patch(p)

plt.show()

elif algo == 3:

if\_singleton = 1

if dfs\_forward(short, complete, s\_color):

stt = list(paint\_true.keys())

clr = list(paint\_true.values())

if flag == 1:

for i in range(len(paint\_true.keys())):

seg = basemap.states[states.index(stt[i])]

p = Polygon(seg, facecolor=(clr[i]), edgecolor=clr[i])

ax.add\_patch(p)

plt.show()

elif algo == 4:

heuristic = 1

if (dfs(short, complete, s\_color)):

stt = list(paint\_true.keys())

clr = list(paint\_true.values())

if flag == 1:

for i in range(len(paint\_true.keys())):

seg = basemap.states[states.index(stt[i])]

p = Polygon(seg, facecolor=(clr[i]), edgecolor=clr[i])

ax.add\_patch(p)

plt.show()

elif algo == 5:

heuristic = 1

if (dfs\_forward(short, complete, s\_color)):

stt = list(paint\_true.keys())

clr = list(paint\_true.values())

if flag == 1:

for i in range(len(paint\_true.keys())):

seg = basemap.states[states.index(stt[i])]

p = Polygon(seg, facecolor=(clr[i]), edgecolor=clr[i])

ax.add\_patch(p)

plt.show()

elif algo == 6:

heuristic = 1

if\_singleton = 1

if (dfs\_forward(short, complete, s\_color)):

stt = list(paint\_true.keys())

clr = list(paint\_true.values())

if flag == 1:

for i in range(len(paint\_true.keys())):

seg = basemap.states[states.index(stt[i])]

p = Polygon(seg, facecolor=(clr[i]), edgecolor=clr[i])

ax.add\_patch(p)

plt.show()

else:

print("Invalid Value, Enter Valid Value")

exit(0)

timer\_stop = timeit.default\_timer()

print('\nTime: ', timer\_stop - start)

print("Number of Backtracks", backtrack)

paint\_true.clear()

**CITATION**

* Map Coloring a Problem, Geeks for Geeks.
* Map Coloring Problem, Wikipedia.