

# **Project 3**

## **Constraint satisfaction problems (CSP) - Map Colouring**

### **Team Members**

Monesa Thoguluva Janardhanan – 801167556

Chandan Kumar Reddy Mannem – 801165621

Nourelislam Zouar – 801153922

Aparajitha Sriram – 801169526

## Problem Formulation

The goal of this project is to solve the map colouring problem for the map of United States of America and the Australian map using strategies like Depth-First search alone, Depth First Search with Forward Checking, Depth First Search with forward checking and propagation through singleton domains in a Constraint Satisfaction Problem and also using heuristics along with the above strategies.

## Constraint Satisfaction Problems

A constraint satisfaction problem (or CSP) is defined by a set of variables,  $X_1, X_2, \dots, X_n$ , and a set of constraints,  $C_1, C_2, \dots, C_m$ . Each variable  $X_i$  has a nonempty domain  $D_i$  of possible values. Each constraint  $C_j$  has some subset of the variables and specifies the allowed combinations of values for that subset.

A state of the problem is defined by assigning values to some or all of the variables, like  $\{X_i = v_i, X_j = v_j, \dots\}$  without violating any constraint. An assignment which abides by the constraints is called a consistent or legal assignment. A complete assignment is that in which all variables are mentioned, and a solution to a CSP is a complete assignment that satisfies all the constraints.

## Applications of CSPs

CSP can be used in the n-Queen problem, Sudoku, Crossword, etc. However, a very popular application of CSPs is Map-Colouring.

A **map-colouring problem** is one in which all the subdivisions (like states, districts, etc.) in a map of any region are to be coloured in such a way that no two adjacent regions have the same colour.

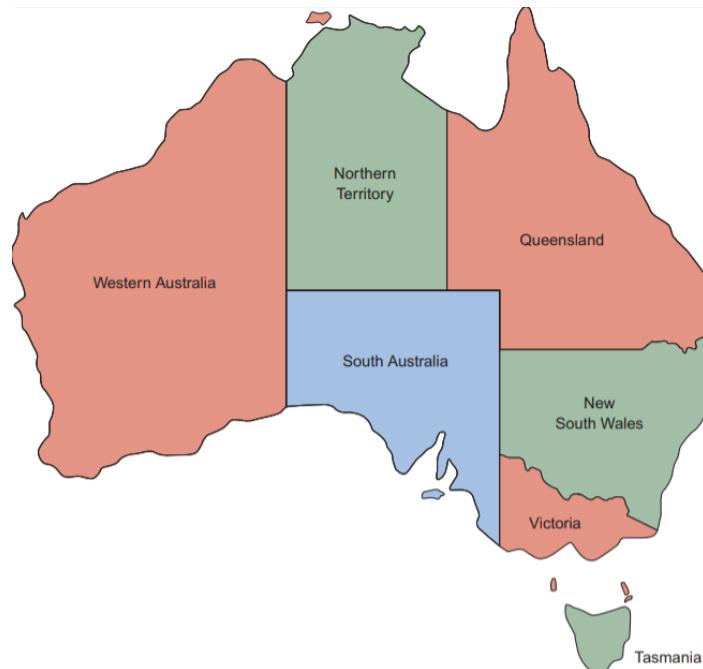


Fig. 1.

The **Chromatic Number** of a map in a map-colouring problem is the minimum number of colours required to colour it entirely according to the constraints of the map-colouring problem.

## Algorithms used for solving a CSP

Backtracking is a technique that helps to solve problems recursively by building the solution incrementally. It tries every possible combination to solve the problem and eliminates those combinations that do not satisfy the constraints specified by the problem. Backtracking maintains a partial assignment of the variables which they are unassigned initially.

The CSP is solved by drawing a search tree whose nodes contain partial solutions. Therefore, it is basically the same as searching a tree for a value that is later backtracked. In order to improve the performance and prevent the complete traversal of the tree, pruning is performed. This also avoids dead ends.

Following are the three combination of strategies that we will use to solve the CSP at hand:

- Depth First Search
- Depth First Search + Forward Checking
- Depth First Search + Forward Checking+ Propagation through singleton domains

### 1. Depth-First Search approach

It is a general algorithmic technique that considers searching every possible combination in order to solve a computational problem. To solve a map-colouring problem, each state is assigned a colour from its domain and checked if it matches the colour of its neighbour. If it matches, then a different colour is assigned, and this is done recursively till all the states have colours assigned which is different from its neighbours. In case there are no more colours to assign a state, then we backtrack to the previously assigned state and change its colour to a new one and repeat the whole process again.

### 2. Forward Checking

In this algorithm, we remove all the conflicting colours from the domains of all the neighbours of the state to which a colour is assigned. If an empty domain is encountered for a particular state, we backtrack to the previous step and assign a different collar and try the whole process again. This helps in early detection of failure.

### 3. Forward Checking and propagation through singleton domains

If during forward checking, a state's domain gets reduced to size 1 (i.e. it has just 1 colour to assign, which is a singleton domain), then the algorithm reserves that value to that state and then the algorithm proceeds to and repeat forward checking from this variable. This effectively helps in preventing backtracking by detecting failures early and also taking action to avoid it.

## Heuristics Used

Various heuristics can be used to choose the next state that is to be picked to assign a colour.

1. **Minimum Remaining Value (MRV)** - This heuristic chooses a state having the minimum legal domain values.
2. **Degree Heuristic** - In case, there is a tie between two variables or states while using MRV, we choose a state having the maximum neighbours or constraints.

3. **Least Constraint Value (LCV)** - Once a domain is chosen, choose its value as the one that rules out the fewest choices for neighbouring variables.

## Program Structure

We use two separate graphs to maintain the states of Australia and USA. These are passed as arguments to the methods that implement the algorithms. The following are the various functions and variables that have been used.

### Functions and Procedures:

The code implements the various algorithms of the map – colouring CSP with and without heuristics.

- *def backTracking\_without\_heuristics(graph, domains, source, length):* This function implements the Depth First Search algorithm with backtracking. It uses a while loop which runs through each state to assign it a colour.
- *def backTracking\_without\_fc\_heuristics(graph, domains, source, length):* This function implements the Depth First Search algorithm with backtracking using the Forward Checking approach without any heuristics.
- *def backTracking\_without\_fc\_singleton\_heuristics(graph, domains, length):* This function implements the Forward Checking approach along with singleton propagation without any heuristics.
- *def mrv(graph, visited\_nodes, domains):* This function returns the best state to colour next based on Minimum Remaining Value heuristics.
- *def find\_source(heuristic, visited\_nodes, graph):* This function returns the next best node to assign a colour to the backtracking algorithm. It in turn gets this state information from the mrv() method.
- *def backTracking\_with\_heuristics(graph, domains, source, length, isHeuristic, heuristicValue):* This function implements the Depth First Search algorithm with backtracking along with the heuristics.
- *def minimum\_remaining\_value(state\_domain\_dict, neighbor\_state\_dict, visited\_node, key) – this function gives the min remaining value for the chosen state.*
- *degree\_heuristic(state\_domain\_dict, neighbor\_state\_dict, visited\_node, key) – this function gives the degree heuristics of the states.*

- *lcv(key\_state, state\_domain, neighbour\_list, selected\_dict)* – implements the LCV algorithm
- *singleton(state\_domain\_dict, neighbor\_state\_dict, key, visited\_node)*: implements the singleton algorithm with FC.

### **Global and Local Variables:**

Global Variables:

*australia* - a graph containing all the states of Australia with their neighbouring states.  
*united\_states\_of\_america* - a graph containing all the states of USA with their neighbouring states.  
*domains* - a dictionary with the corresponding domains of colours for each state.

Local Variables:

*visited\_nodes* – a list that contains the list of states that have been assigned a colour by the algorithm.  
*assigned\_colors* – a dictionary that contains the list of states along with the colour that was assigned to them.  
*backtrack* – a variable that maintains the count of backtracks in the algorithm's execution.  
*source* – the state that is to be assigned a colour. After it is assigned a colour, the chosen neighbour of *source* is assigned to *source*.  
*length* – Length of the variable is the number of states which have children.

## **Observations**

### **Without Heuristics – Australian Map:**

<b>Trials</b>	<b>Backtracking</b>	<b>Backtracking with Forward checking</b>	<b>Forward Checking with singleton</b>
1	Backtrack count: 5  Time Taken: 0.001194s	Backtrack count: 0  Time Taken: 0.002504s	Backtrack count: 0  Time Taken: 0.000356s
2	Backtrack count: 7  Time Taken: 0.001232s	Backtrack count: 0  Time Taken: 0.002530s	Backtrack count: 0  Time Taken: 0.002601s
3	Backtrack count: 5  Time Taken: 0.001187s	Backtrack count: 0  Time Taken: 0.002427s	Backtrack count: 0  Time Taken: 0.003236s

### **Without Heuristics – USA Map:**

<b>Trials</b>	<b>Backtracking</b>	<b>Backtracking with Forward checking</b>	<b>Forward Checking with singleton</b>
1	Backtrack count: 59 Time Taken: 0.031663s	Backtrack count: 37 Time Taken: 0.134886s	Backtrack count: 0 Time Taken: 0.000603s
2	Backtrack count: 81 Time Taken: 0.032295s	Backtrack count: 0 Time Taken: 0.092548s	Backtrack count: 0 Time Taken: 0.000632s
3	Backtrack count: 112 Time Taken: 0.040246s	Backtrack count: 23 Time Taken: 0.132241s	Backtrack count: 0 Time Taken: 0.000695s

#### **With Heuristics – Australian Map:**

<b>Heuristics</b>	<b>Backtracking</b>	<b>Backtracking with Forward checking</b>	<b>Forward Checking with singleton</b>
MRV	Backtrack count: 0 Time Taken: 0.001652s	Backtrack count: 0 Time Taken: 0.001191s	Backtrack count: 0 Time Taken: 0.000223s
Degree Constraints	Backtrack count: 0 Time Taken: 0.002843s	Backtrack count: 0 Time Taken: 0.001328s	Backtrack count: 0 Time Taken: 0.000342s
LCV	Backtrack count: 0 Time Taken: 0.001190s	Backtrack count: 0 Time Taken: 0.001203s	Backtrack count: 0 Time Taken: 0.000365s

#### **With Heuristics – USA Map:**

<b>Heuristics</b>	<b>Backtracking</b>	<b>Backtracking with Forward checking</b>	<b>Forward Checking with singleton</b>
MRV	Backtrack count: 0 Time Taken: 0.007081s	Backtrack count: 0 Time Taken: 0.039299s	Backtrack count: 0 Time Taken: 0.001732s
Degree Constraints	Backtrack count: 0 Time Taken: 0.008056s	Backtrack count: 0 Time Taken: 0.081390s	Backtrack count: 0 Time Taken: 0.000659s
LCV	Backtrack count: 0 Time Taken: 0.006054s	Backtrack count: 0 Time Taken: 0.033866s	Backtrack count: 0 Time Taken: 0.000818s

#### **Conclusion**

We implemented the map-colouring problem for the maps of USA and Australia by formulating them as CSPs. We used three algorithms which are backtracking, backtracking with forward approach and forward approach with singleton propagation, with and without the heuristics - Minimum Remaining Value, Degree heuristics and Least Constraint Value and we have tabulated our observations.

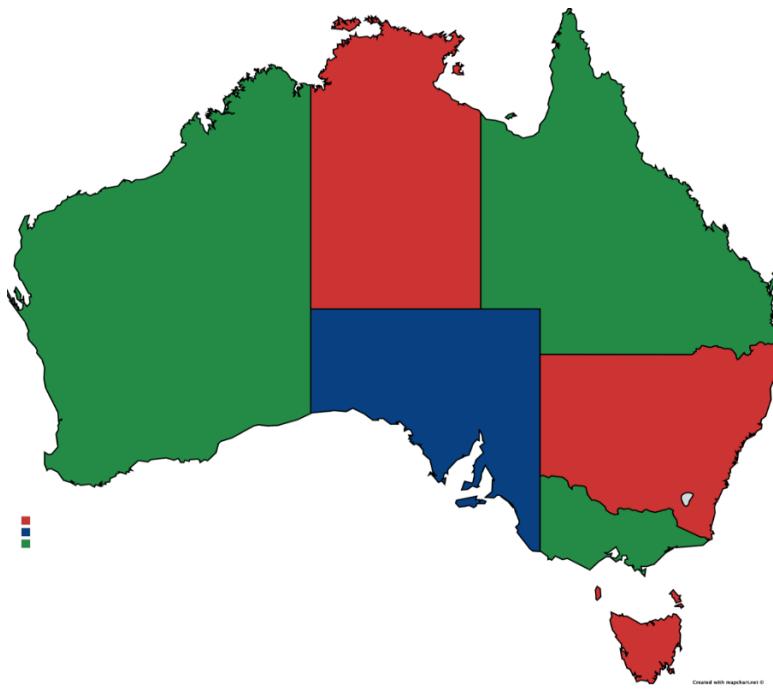
## Output

### 1. Backtracking – Australia (without heuristics)

#### Test Case 1

```
source new south wales
Assigned color-> Red
source victoria
source victoria
Assigned color-> Green
source southern australia
source southern australia
source southern australia
Assigned color-> Blue
source queensland
source queensland
Assigned color-> Green
source northwest territories
Assigned color-> Red
source western australia
source western australia
Assigned color-> Green
source tasmania
Assigned color-> Red
Assigned colors: {'new south wales': 'Red', 'victoria': 'Green', 'southern australia': 'Blue', 'queensland': 'Green', 'northwest territories': 'Red', 'western australia': 'Green', 'tasmania': 'Red'}
Backtrack---> 5
```

Time taken: 0.001194000244140625



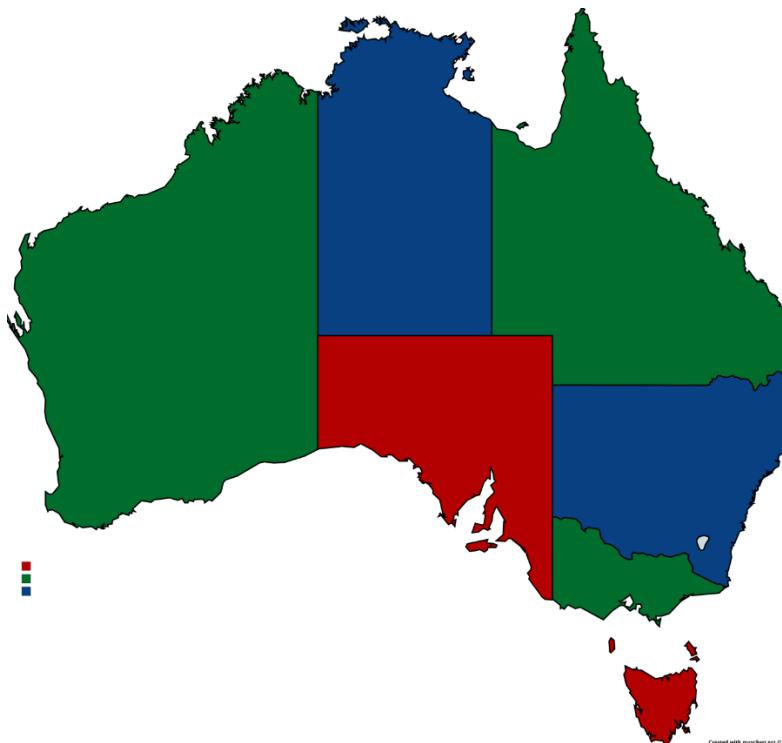
### Test Case 2 - Backtracking – Australia (without heuristics)

```

source southern australia
Assigned color-> Red
source victoria
source victoria
Assigned color-> Green
source new south wales
source new south wales
source new south wales
Assigned color-> Blue
source queensland
source queensland
Assigned color-> Green
source northwest territories
source northwest territories
source northwest territories
Assigned color-> Blue
source western australia
source western australia
Assigned color-> Green
source tasmania
Assigned color-> Red
Assigned colors: {'southern australia': 'Red', 'victoria': 'Green',
'new south wales': 'Blue', 'queensland': 'Green', 'northwest territories': 'Blue',
'western australia': 'Green', 'tasmania': 'Red'}
Backtrack---> 7

```

Time taken: 0.001232147216796875



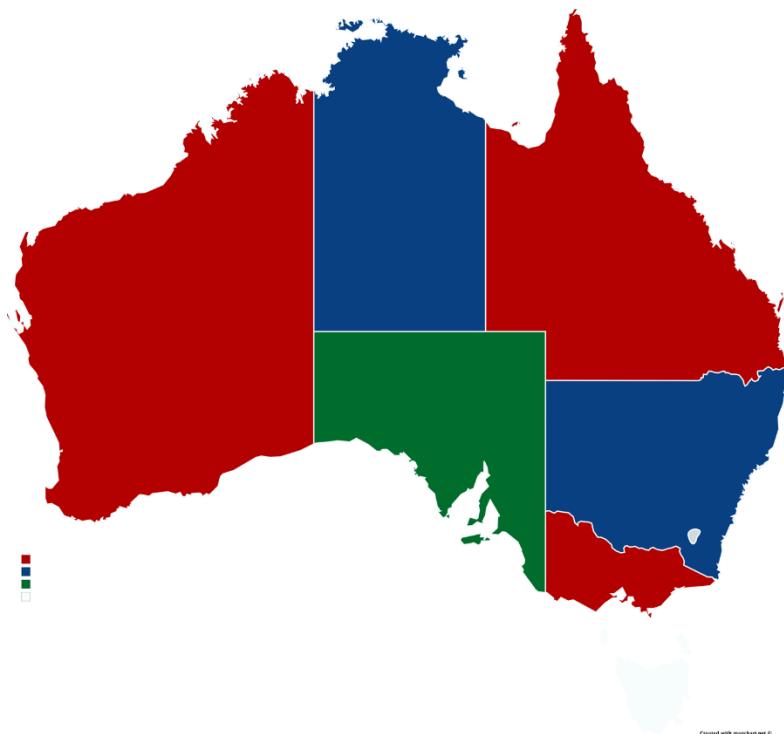
### Test Case 3 - Backtracking – Australia (without heuristics)

```

source western australia
Assigned color-> Red
source southern australia
source southern australia
Assigned color-> Green
source victoria
Assigned color-> Red
source new south wales
source new south wales
source new south wales
Assigned color-> Blue
source queensland
Assigned color-> Red
source northwest territories
source northwest territories
source northwest territories
Assigned color-> Blue
source tasmania
Assigned color-> Red
Assigned colors: {'western australia': 'Red', 'southern australia': 'Green', 'victoria': 'Red', 'new south wales': 'Blue', 'queensland': 'Red', 'northwest territories': 'Blue', 'tasmania': 'Red'}
Backtrack---> 5

```

Time taken: 0.0011870861053466797



## 2. Backtracking + Forward Checking – Australia (without heuristics)

### Test Case 1

```

source northwest territories
Assigned color-> Red
source queensland
Assigned color-> Green
source new south wales
Assigned color-> Red
source victoria
Assigned color-> Green
source southern australia
Assigned color-> Blue
source western australia
Assigned color-> Green
source tasmania
Assigned color-> Red
Assigned colors: {'northwest territories': 'Red', 'queensland': 'Green', 'new south wales': 'Red', 'victoria': 'Green', 'southern australia': 'Blue', 'western australia': 'Green', 'tasmania': 'Red'}
Backtrack---> 0

State: tasmania -> Red

State: western australia -> Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red

State: northwest territories -> Red
Assigned color to Neighbour: Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Green

```

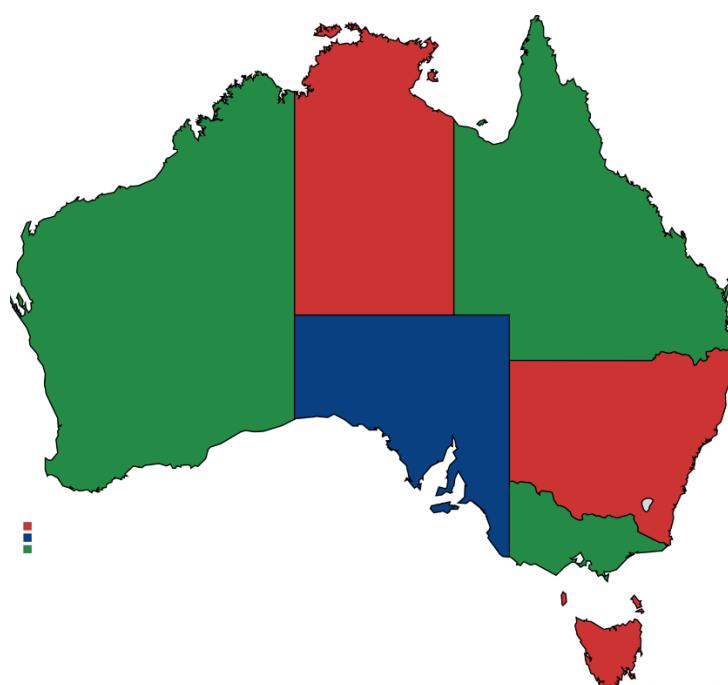
State: southern australia -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: queensland -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: new south wales -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: victoria -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

Time taken: 0.0025048255920410156



**Test Case 2 - Backtracking + Forward Checking – Australia (without heuristics)**

```
source southern australia
Assigned color-> Red
source victoria
Assigned color-> Green
source new south wales
Assigned color-> Blue
source queensland
Assigned color-> Green
source northwest territories
Assigned color-> Blue
source western australia
```

```
Assigned color-> Green
source tasmania
Assigned colors: {'southern australia': 'Red', 'victoria': 'Green',
'new south wales': 'Blue', 'queensland': 'Green', 'northwest
territories': 'Blue', 'western australia': 'Green', 'tasmania':
'Red'}
Backtrack---> 0

State: tasmania -> Red

State: western australia -> Green
Assigned color to Neighbour: Red
Assigned color to Neighbour: Blue

State: northwest territories -> Blue
Assigned color to Neighbour: Green
Assigned color to Neighbour: Red
Assigned color to Neighbour: Green

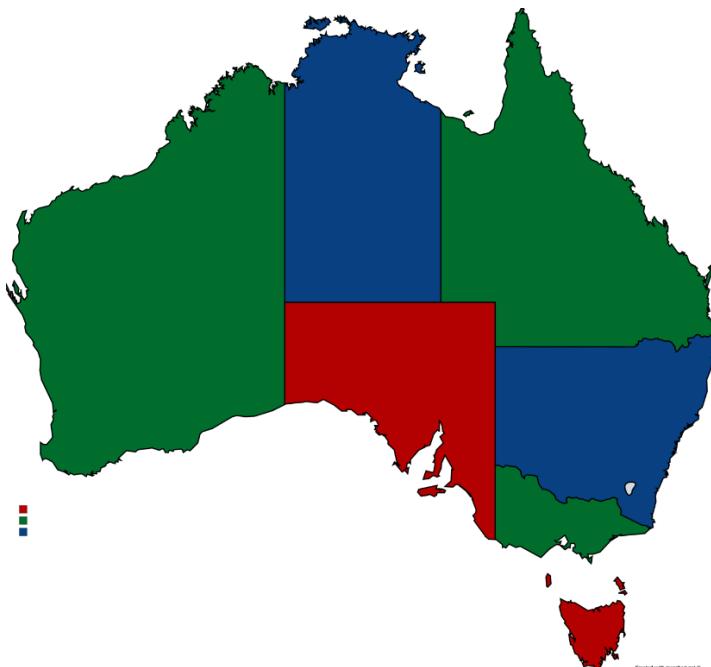
State: southern australia -> Red
Assigned color to Neighbour: Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Green

State: queensland -> Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red
Assigned color to Neighbour: Blue

State: new south wales -> Blue
Assigned color to Neighbour: Green
Assigned color to Neighbour: Green
Assigned color to Neighbour: Red

State: victoria -> Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red

Time taken: 0.0025300979614257812
```



### Test Case 3 - Backtracking + Forward Checking – Australia (without heuristics)

```

source western australia
Assigned color-> Red
source southern australia
Assigned color-> Green
source victoria
Assigned color-> Red
source new south wales
Assigned color-> Blue
source queensland
Assigned color-> Red
source northwest territories
Assigned color-> Blue
source Tasmania
Assigned color-> Red
Assigned colors: {'western australia': 'Red', 'southern australia':
'Green', 'victoria': 'Red', 'new south wales': 'Blue', 'queensland':
'Red', 'northwest territories': 'Blue', 'tasmania': 'Red'}
Backtrack---> 0

State: tasmania -> Red

State: western australia -> Red
Assigned color to Neighbour: Green
Assigned color to Neighbour: Blue

State: northwest territories -> Blue
Assigned color to Neighbour: Red
Assigned color to Neighbour: Green
Assigned color to Neighbour: Red

State: southern australia -> Green
Assigned color to Neighbour: Red
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red

```

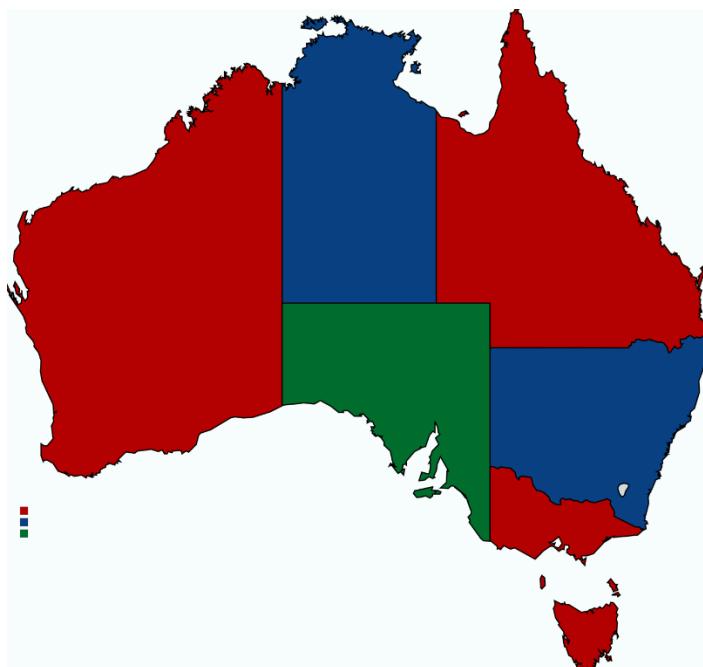
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: queensland -> Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: new south wales -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: victoria -> Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green

Time taken: 0.0024271011352539062



### 3. Backtracking – Australia (with MRV)

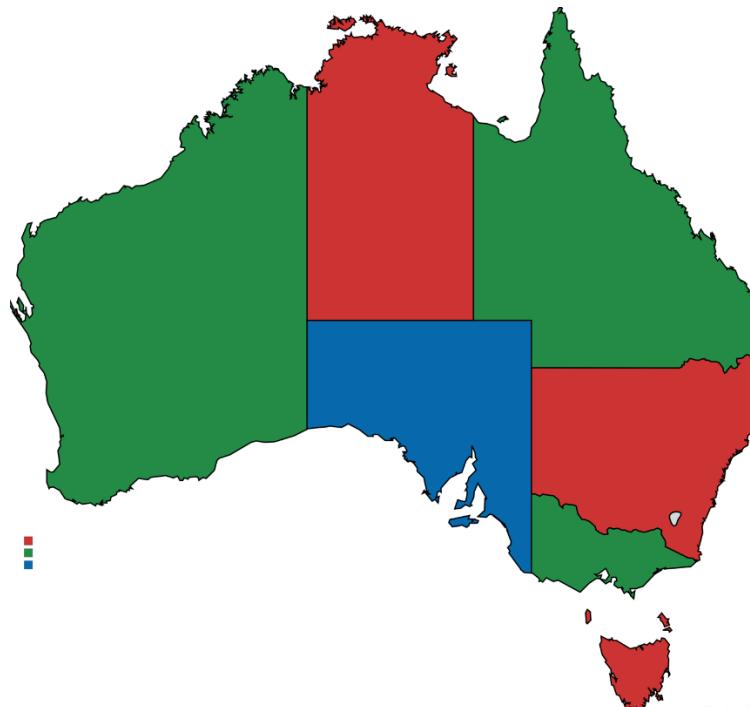
source northwest territories  
Assigned color-> Red  
source western australia  
source western australia  
Assigned color-> Green  
source southern australia  
source southern australia  
source southern australia  
Assigned color-> Blue  
source queensland  
source queensland  
Assigned color-> Green  
source new south wales  
Assigned color-> Red  
source victoria

```

source victoria
Assigned color-> Green
source tasmania
Assigned color-> Red
source empty
Assigned colors: {'northwest territories': 'Red', 'western
australia': 'Green', 'southern australia': 'Blue', 'queensland':
'Green', 'new south wales': 'Red', 'victoria': 'Green', 'tasmania':
'Red'}
Backtrack---> 0

```

Time taken: 0.0016520023345947266



#### 4. Backtracking - Australia (with Degree Constraints)

```

source northwest territories
Assigned color-> Red
source tasmania
Assigned color-> Red
source western australia
source western australia
Assigned color-> Green
source victoria
Assigned color-> Red
source queensland
source queensland
Assigned color-> Green
source new south wales
source new south wales
source new south wales
Assigned color-> Blue
source southern australia
source southern australia
source southern australia

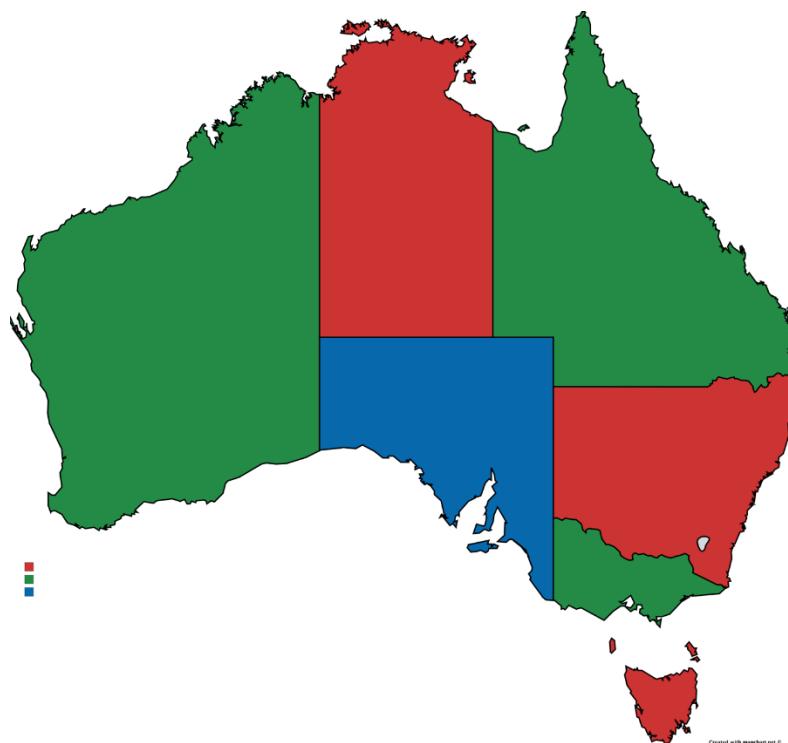
```

```

source southern australia
source new south wales
source queensland
Assigned color-> Blue
source new south wales
source new south wales
Assigned color-> Green
source southern australia
source southern australia
source southern australia
source new south wales
source new south wales
source queensland
source victoria
Assigned color-> Green
source queensland
source queensland
Assigned color-> Green
source new south wales
Assigned color-> Red
source southern australia
source southern australia
source southern australia
Assigned color-> Blue
source empty
Assigned colors: {'northwest territories': 'Red', 'tasmania': 'Red',
'western australia': 'Green', 'victoria': 'Green', 'queensland':
'Green', 'new south wales': 'Red', 'southern australia': 'Blue'}
Backtrack---> 0

```

Time taken: 0.0028438568115234375



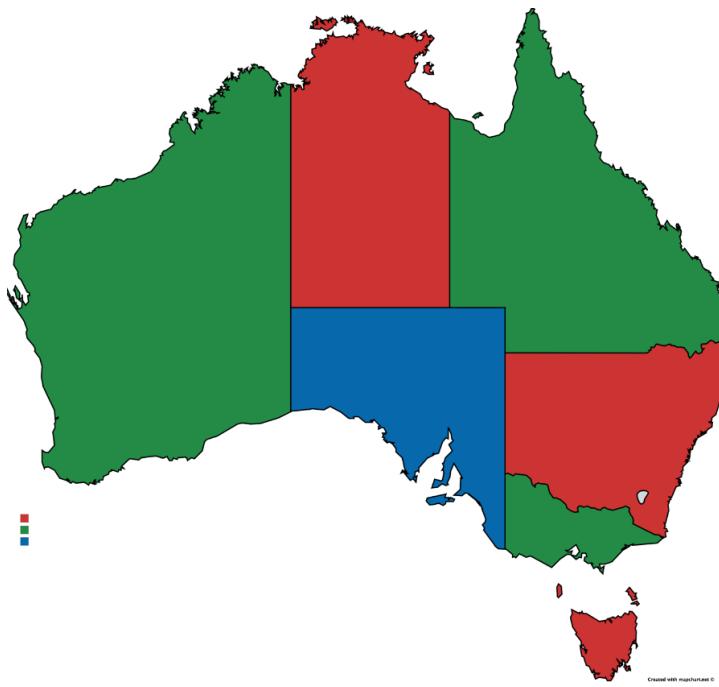
## 5. Backtracking – Australia (with LCV)

```

source northwest territories
Assigned color-> Red
source western australia
source western australia
Assigned color-> Green
source southern australia
source southern australia
source southern australia
Assigned color-> Blue
source queensland
source queensland
Assigned color-> Green
source new south wales
Assigned color-> Red
source victoria
source victoria
Assigned color-> Green
source tasmania
Assigned color-> Red
source empty
Assigned colors: {'northwest territories': 'Red', 'western
australia': 'Green', 'southern australia': 'Blue', 'queensland':
'Green', 'new south wales': 'Red', 'victoria': 'Green', 'tasmania':
'Red'}
Backtrack---> 0

```

Time taken: 0.001190185546875



## 6. Backtracking + Forward Checking – Australia (with MRV)

```

source queensland
Assigned color-> Red
source new south wales
Assigned color-> Green

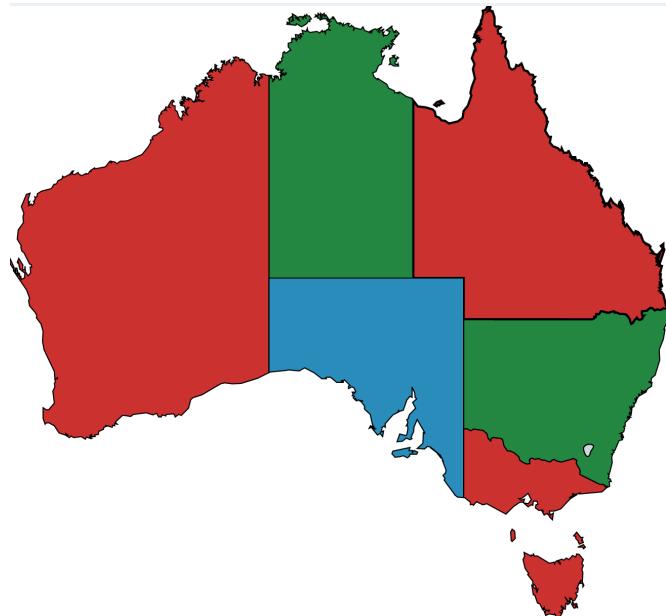
```

```

source victoria
Assigned color-> Red
source southern australia
Assigned color-> Blue
source northwest territories
Assigned color-> Green
source western australia
Assigned color-> Red
source tasmania
Assigned color-> Red
source empty
Assigned colors: {'queensland': 'Red', 'new south wales': 'Green', 'victoria': 'Red', 'southern australia': 'Blue', 'northwest territories': 'Green', 'western australia': 'Red', 'tasmania': 'Red'}
Backtrack---> 0

```

Time taken: 0.001191854476928711



## 7. Backtracking + Forward Checking – Australia (with Degree Constraints)

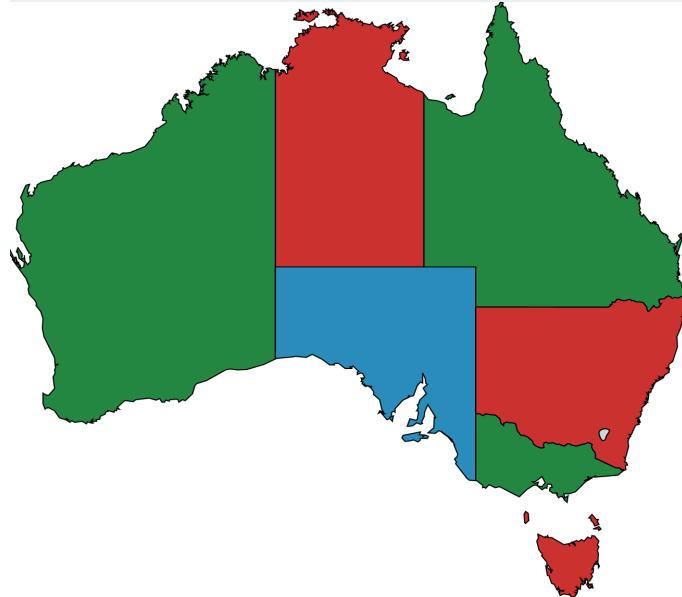
```

source northwest territories
Assigned color-> Red
source queensland
Assigned color-> Green
source new south wales
Assigned color-> Red
source victoria
Assigned color-> Green
source southern australia
Assigned color-> Blue
source western australia
Assigned color-> Green
source tasmania
Assigned color-> Red
source empty

```

```
Assigned colors: {'northwest territories': 'Red', 'queensland': 'Green', 'new south wales': 'Red', 'victoria': 'Green', 'southern australia': 'Blue', 'western australia': 'Green', 'tasmania': 'Red'}  
Backtrack---> 0
```

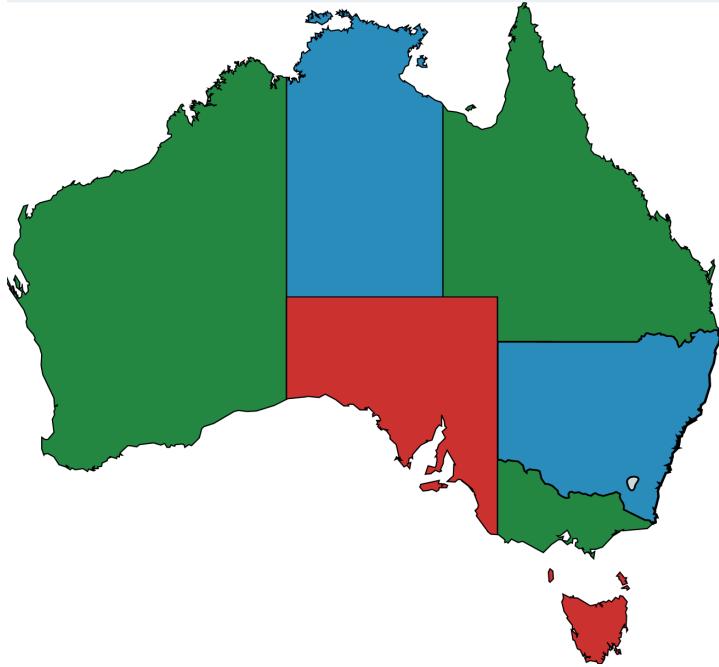
Time taken: 0.0013289451599121094



## 8. Backtracking + Forward Checking – Australia (with LCV)

```
source southern australia  
Assigned color-> Red  
source queensland  
Assigned color-> Green  
source new south wales  
Assigned color-> Blue  
source victoria  
Assigned color-> Green  
source northwest territories  
Assigned color-> Blue  
source western australia  
Assigned color-> Green  
source tasmania  
Assigned color-> Red  
source empty  
Assigned colors: {'southern australia': 'Red', 'queensland': 'Green', 'new south wales': 'Blue', 'victoria': 'Green', 'northwest territories': 'Blue', 'western australia': 'Green', 'tasmania': 'Red'}  
Backtrack---> 0
```

Time taken: 0.0012030601501464844



## 9. Backtracking – USA (without heuristics)

### Test Case 1

```
source Alabama
Assigned color-> Red
source Georgia
source Georgia
Assigned color-> Green
source Tennessee
source Tennessee
source Tennessee
Assigned color-> Blue
source Missouri
Assigned color-> Red
source Kentucky
source Kentucky
Assigned color-> Green
source Ohio
Assigned color-> Red
source Pennsylvania
source Pennsylvania
Assigned color-> Green
source NewYork
Assigned color-> Red
source NewJersey
source NewJersey
source NewJersey
Assigned color-> Blue
source Delaware
Assigned color-> Red
source Maryland
source Maryland
source Maryland
```

Assigned color-> Blue  
source WestVirginia  
source WestVirginia  
source WestVirginia  
source WestVirginia  
Assigned color-> Yellow  
source Virginia  
Assigned color-> Red  
source NorthCarolina  
source NorthCarolina  
source NorthCarolina  
source NorthCarolina  
Assigned color-> Yellow  
source SouthCarolina  
Assigned color-> Red  
source Massachusetts  
source Massachusetts  
Assigned color-> Green  
source NewHampshire  
Assigned color-> Red  
source Maine  
source Maine  
Assigned color-> Green  
source Vermont  
source Vermont  
source Vermont  
Assigned color-> Blue  
source RhodeIsland  
Assigned color-> Red  
source Connecticut  
source Connecticut  
source Connecticut  
Assigned color-> Blue  
source Michigan  
source Michigan  
Assigned color-> Green  
source Wisconsin  
Assigned color-> Red  
source Illinois  
source Illinois  
source Illinois  
Assigned color-> Blue  
source Indiana  
source Indiana  
source Indiana  
source Indiana  
Assigned color-> Yellow  
source Iowa  
source Iowa  
Assigned color-> Green  
source SouthDakota  
Assigned color-> Red  
source Wyoming  
source Wyoming  
Assigned color-> Green  
source Colorado  
Assigned color-> Red  
source Arizona

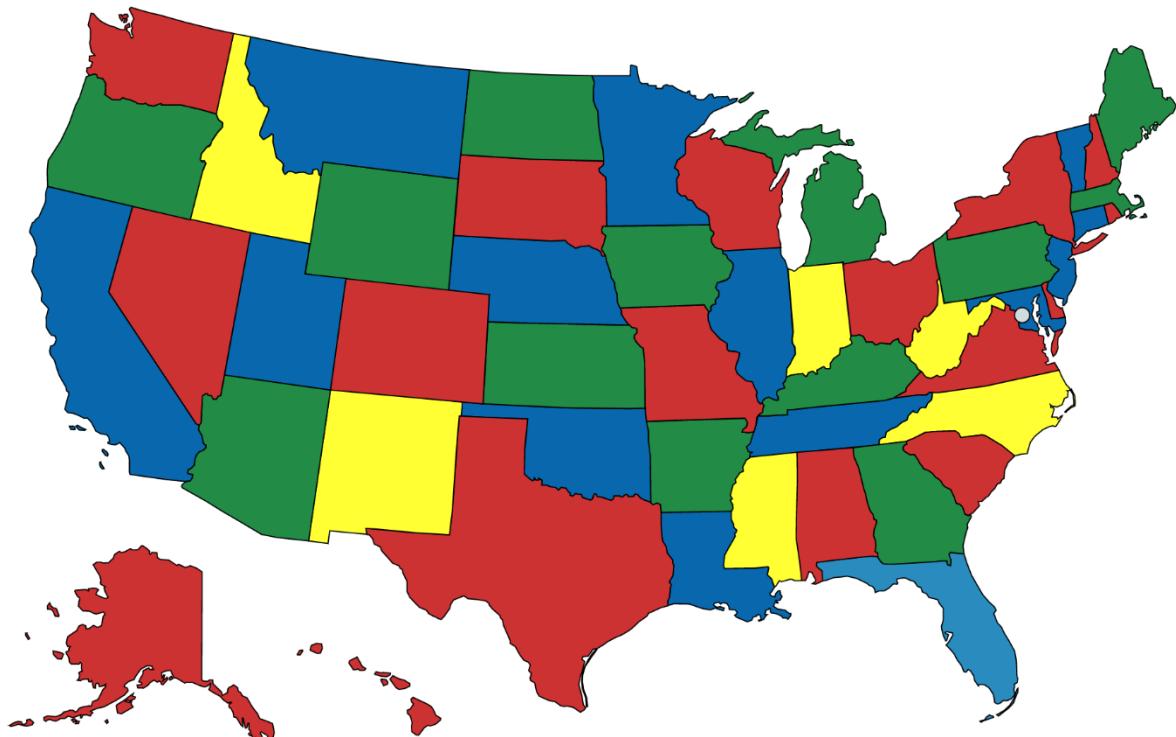
```
source Arizona
Assigned color-> Green
source Utah
source Utah
source Utah
Assigned color-> Blue
source NewMexico
source NewMexico
source NewMexico
source NewMexico
Assigned color-> Yellow
source Texas
Assigned color-> Red
source Arkansas
source Arkansas
Assigned color-> Green
source Mississippi
source Mississippi
source Mississippi
source Mississippi
Assigned color-> Yellow
source Louisiana
source Louisiana
source Louisiana
Assigned color-> Blue
source Oklahoma
source Oklahoma
source Oklahoma
Assigned color-> Blue
source Kansas
source Kansas
Assigned color-> Green
source Nebraska
source Nebraska
source Nebraska
Assigned color-> Blue
source Nevada
Assigned color-> Red
source Oregon
source Oregon
Assigned color-> Green
source California
source California
source California
Assigned color-> Blue
source Washington
Assigned color-> Red
source Idaho
source Idaho
source Idaho
source Idaho
Assigned color-> Yellow
source Montana
source Montana
source Montana
Assigned color-> Blue
source NorthDakota
source NorthDakota
```

```

Assigned color-> Green
source Minnesota
source Minnesota
source Minnesota
Assigned color-> Blue
source Florida
source Florida
source Florida
Assigned color-> Blue
source Florida
Assigned colors: {'Alabama': 'Red', 'Georgia': 'Green', 'Tennessee': 'Blue', 'Missouri': 'Red', 'Kentucky': 'Green', 'Ohio': 'Red', 'Pennsylvania': 'Green', 'NewYork': 'Red', 'NewJersey': 'Blue', 'Delaware': 'Red', 'Maryland': 'Blue', 'WestVirginia': 'Yellow', 'Virginia': 'Red', 'NorthCarolina': 'Yellow', 'SouthCarolina': 'Red', 'Massachusetts': 'Green', 'NewHampshire': 'Red', 'Maine': 'Green', 'Vermont': 'Blue', 'RhodeIsland': 'Red', 'Connecticut': 'Blue', 'Michigan': 'Green', 'Wisconsin': 'Red', 'Illinois': 'Blue', 'Indiana': 'Yellow', 'Iowa': 'Green', 'SouthDakota': 'Red', 'Wyoming': 'Green', 'Colorado': 'Red', 'Arizona': 'Green', 'Utah': 'Blue', 'NewMexico': 'Yellow', 'Texas': 'Red', 'Arkansas': 'Green', 'Mississippi': 'Yellow', 'Louisiana': 'Blue', 'Oklahoma': 'Blue', 'Kansas': 'Green', 'Nebraska': 'Blue', 'Nevada': 'Red', 'Oregon': 'Green', 'California': 'Blue', 'Washington': 'Red', 'Idaho': 'Yellow', 'Montana': 'Blue', 'NorthDakota': 'Green', 'Minnesota': 'Blue', 'Florida': 'Blue', 'Alaska': 'Red', 'Hawaii': 'Red'}
Backtrack---> 59

```

Time taken: 0.03166389465332031 seconds



### Test Case 2 - Backtracking – USA (without heuristics)

```

source Texas
Assigned color-> Red

```

```
source Arkansas
source Arkansas
Assigned color-> Green
source Missouri
Assigned color-> Red
source Tennessee
source Tennessee
source Tennessee
Assigned color-> Blue
source NorthCarolina
Assigned color-> Red
source SouthCarolina
source SouthCarolina
Assigned color-> Green
source Georgia
source Georgia
source Georgia
source Georgia
Assigned color-> Yellow
source Alabama
Assigned color-> Red
source Florida
source Florida
Assigned color-> Green
source Mississippi
source Mississippi
source Mississippi
source Mississippi
Assigned color-> Yellow
source Louisiana
source Louisiana
source Louisiana
Assigned color-> Blue
source Virginia
source Virginia
Assigned color-> Green
source WestVirginia
Assigned color-> Red
source Kentucky
source Kentucky
source Kentucky
source Kentucky
Assigned color-> Yellow
source Ohio
source Ohio
Assigned color-> Green
source Pennsylvania
source Pennsylvania
source Pennsylvania
Assigned color-> Blue
source NewYork
Assigned color-> Red
source NewJersey
source NewJersey
Assigned color-> Green
source Delaware
Assigned color-> Red
source Maryland
```

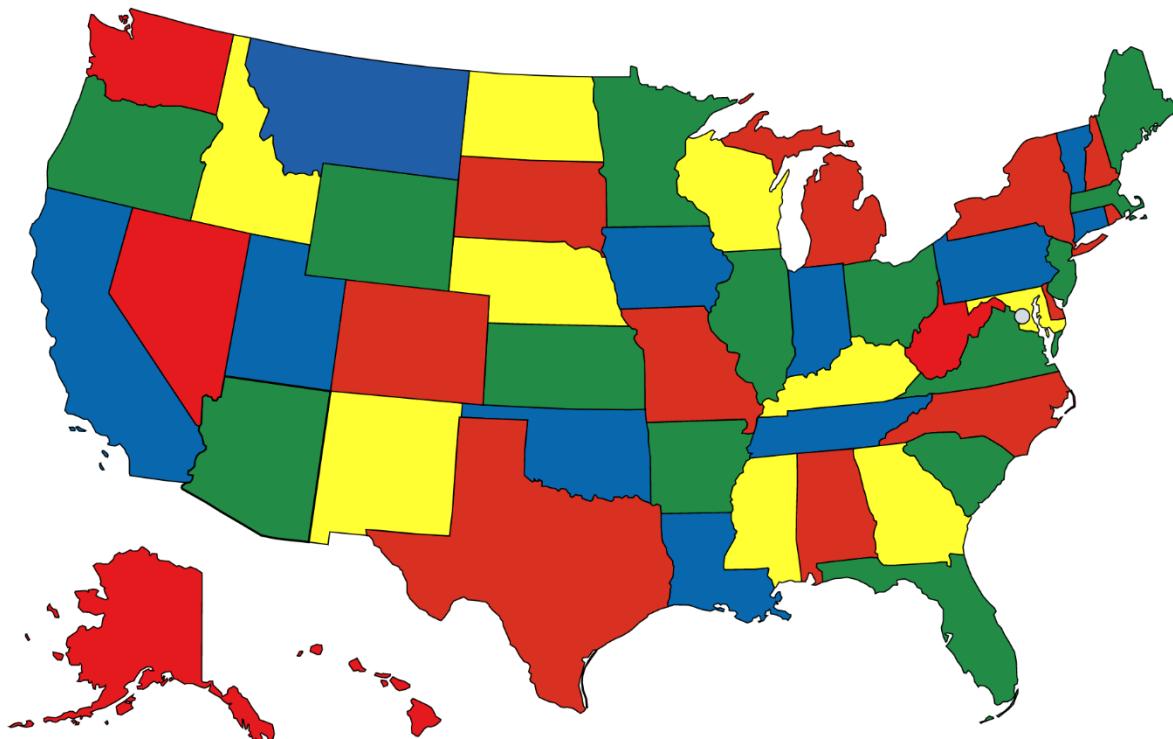
source Maryland  
source Maryland  
source Maryland  
Assigned color-> Yellow  
source Massachusetts  
source Massachusetts  
Assigned color-> Green  
source NewHampshire  
Assigned color-> Red  
source Maine  
source Maine  
Assigned color-> Green  
source Vermont  
source Vermont  
source Vermont  
Assigned color-> Blue  
source RhodeIsland  
Assigned color-> Red  
source Connecticut  
source Connecticut  
source Connecticut  
Assigned color-> Blue  
source Michigan  
Assigned color-> Red  
source Wisconsin  
source Wisconsin  
Assigned color-> Green  
source Illinois  
source Illinois  
source Illinois  
Assigned color-> Blue  
source Indiana  
source Indiana  
source Indiana  
source Indiana  
source Indiana  
source Illinois  
source Illinois  
source Wisconsin  
Assigned color-> Blue  
source Illinois  
source Illinois  
Assigned color-> Green  
source Indiana  
source Indiana  
source Indiana  
source Indiana  
source Illinois  
source Illinois  
source Wisconsin  
Assigned color-> Yellow  
source Illinois  
source Illinois  
Assigned color-> Green  
source Indiana  
source Indiana  
source Indiana  
Assigned color-> Blue

```
source Iowa
source Iowa
source Iowa
Assigned color-> Blue
source SouthDakota
Assigned color-> Red
source Wyoming
source Wyoming
Assigned color-> Green
source Colorado
Assigned color-> Red
source Arizona
source Arizona
Assigned color-> Green
source Utah
source Utah
source Utah
Assigned color-> Blue
source NewMexico
source NewMexico
source NewMexico
source NewMexico
Assigned color-> Yellow
source Oklahoma
source Oklahoma
source Oklahoma
Assigned color-> Blue
source Kansas
source Kansas
Assigned color-> Green
source Nebraska
source Nebraska
source Nebraska
source Nebraska
Assigned color-> Yellow
source Nevada
Assigned color-> Red
source Oregon
source Oregon
Assigned color-> Green
source California
source California
source California
Assigned color-> Blue
source Washington
Assigned color-> Red
source Idaho
source Idaho
source Idaho
source Idaho
Assigned color-> Yellow
source Montana
source Montana
source Montana
Assigned color-> Blue
source NorthDakota
source NorthDakota
Assigned color-> Green
```

```

source Minnesota
source Minnesota
source Minnesota
source Minnesota
source Minnesota
source NorthDakota
source NorthDakota
Assigned color-> Yellow
source Minnesota
source Minnesota
Assigned color-> Green
source Minnesota
Assigned colors: {'Texas': 'Red', 'Arkansas': 'Green', 'Missouri': 'Red', 'Tennessee': 'Blue', 'NorthCarolina': 'Red', 'SouthCarolina': 'Green', 'Georgia': 'Yellow', 'Alabama': 'Red', 'Florida': 'Green', 'Mississippi': 'Yellow', 'Louisiana': 'Blue', 'Virginia': 'Green', 'WestVirginia': 'Red', 'Kentucky': 'Yellow', 'Ohio': 'Green', 'Pennsylvania': 'Blue', 'NewYork': 'Red', 'NewJersey': 'Green', 'Delaware': 'Red', 'Maryland': 'Yellow', 'Massachusetts': 'Green', 'NewHampshire': 'Red', 'Maine': 'Green', 'Vermont': 'Blue', 'RhodeIsland': 'Red', 'Connecticut': 'Blue', 'Michigan': 'Red', 'Wisconsin': 'Yellow', 'Illinois': 'Green', 'Indiana': 'Blue', 'Iowa': 'Blue', 'SouthDakota': 'Red', 'Wyoming': 'Green', 'Colorado': 'Red', 'Arizona': 'Green', 'Utah': 'Blue', 'NewMexico': 'Yellow', 'Oklahoma': 'Blue', 'Kansas': 'Green', 'Nebraska': 'Yellow', 'Nevada': 'Red', 'Oregon': 'Green', 'California': 'Blue', 'Washington': 'Red', 'Idaho': 'Yellow', 'Montana': 'Blue', 'NorthDakota': 'Yellow', 'Minnesota': 'Green', 'Alaska': 'Red', 'Hawaii': 'Red'}
Backtrack---> 81
Time taken: 0.032295942306518555 seconds

```



**Test Case 3 - Backtracking – USA (without heuristics)**

```
source Ohio
Assigned color-> Red
source Kentucky
source Kentucky
Assigned color-> Green
source Missouri
Assigned color-> Red
source Tennessee
source Tennessee
source Tennessee
Assigned color-> Blue
source NorthCarolina
Assigned color-> Red
source SouthCarolina
source SouthCarolina
Assigned color-> Green
source Georgia
source Georgia
source Georgia
source Georgia
Assigned color-> Yellow
source Alabama
Assigned color-> Red
source Florida
source Florida
Assigned color-> Green
source Mississippi
source Mississippi
Assigned color-> Green
source Arkansas
source Arkansas
source Arkansas
source Arkansas
Assigned color-> Yellow
source Texas
Assigned color-> Red
source Oklahoma
source Oklahoma
Assigned color-> Green
source Colorado
Assigned color-> Red
source Arizona
source Arizona
Assigned color-> Green
source Utah
source Utah
source Utah
Assigned color-> Blue
source Wyoming
source Wyoming
Assigned color-> Green
source SouthDakota
Assigned color-> Red
source NorthDakota
source NorthDakota
Assigned color-> Green
source Montana
```

```
source Montana
source Montana
Assigned color-> Blue
source Idaho
Assigned color-> Red
source Washington
source Washington
Assigned color-> Green
source Oregon
source Oregon
source Oregon
Assigned color-> Blue
source California
Assigned color-> Red
source Nevada
source Nevada
source Nevada
source Nevada
Assigned color-> Yellow
source Minnesota
source Minnesota
source Minnesota
Assigned color-> Blue
source Wisconsin
Assigned color-> Red
source Michigan
source Michigan
Assigned color-> Green
source Illinois
source Illinois
source Illinois
Assigned color-> Blue
source Indiana
source Indiana
source Indiana
source Indiana
Assigned color-> Yellow
source Iowa
source Iowa
Assigned color-> Green
source Nebraska
source Nebraska
source Nebraska
Assigned color-> Blue
source Kansas
source Kansas
source Kansas
source Kansas
Assigned color-> Yellow
source NewMexico
source NewMexico
source NewMexico
source NewMexico
Assigned color-> Yellow
source Louisiana
source Louisiana
source Louisiana
Assigned color-> Blue
```

```
source Virginia
source Virginia
source Virginia
Assigned color-> Yellow
source WestVirginia
source WestVirginia
source WestVirginia
source WestVirginia
Assigned color-> Blue
source Pennsylvania
source Pennsylvania
Assigned color-> Green
source NewYork
Assigned color-> Red
source NewJersey
source NewJersey
source NewJersey
Assigned color-> Blue
source Delaware
Assigned color-> Red
source Maryland
source Maryland
source Maryland
source Maryland
source Maryland
source Delaware
source Delaware
source Delaware
Assigned color-> Yellow
source Maryland
source Maryland
source Maryland
source Maryland
source Maryland
source Delaware
source NewJersey
Assigned color-> Yellow
source Delaware
Assigned color-> Red
source Maryland
source Maryland
source Maryland
source Maryland
source Delaware
source Delaware
Assigned color-> Blue
source Maryland
source Maryland
source Maryland
source Maryland
source Delaware
source NewJersey
source NewYork
source NewYork
Assigned color-> Blue
source NewJersey
Assigned color-> Red
source Delaware
source Delaware
```

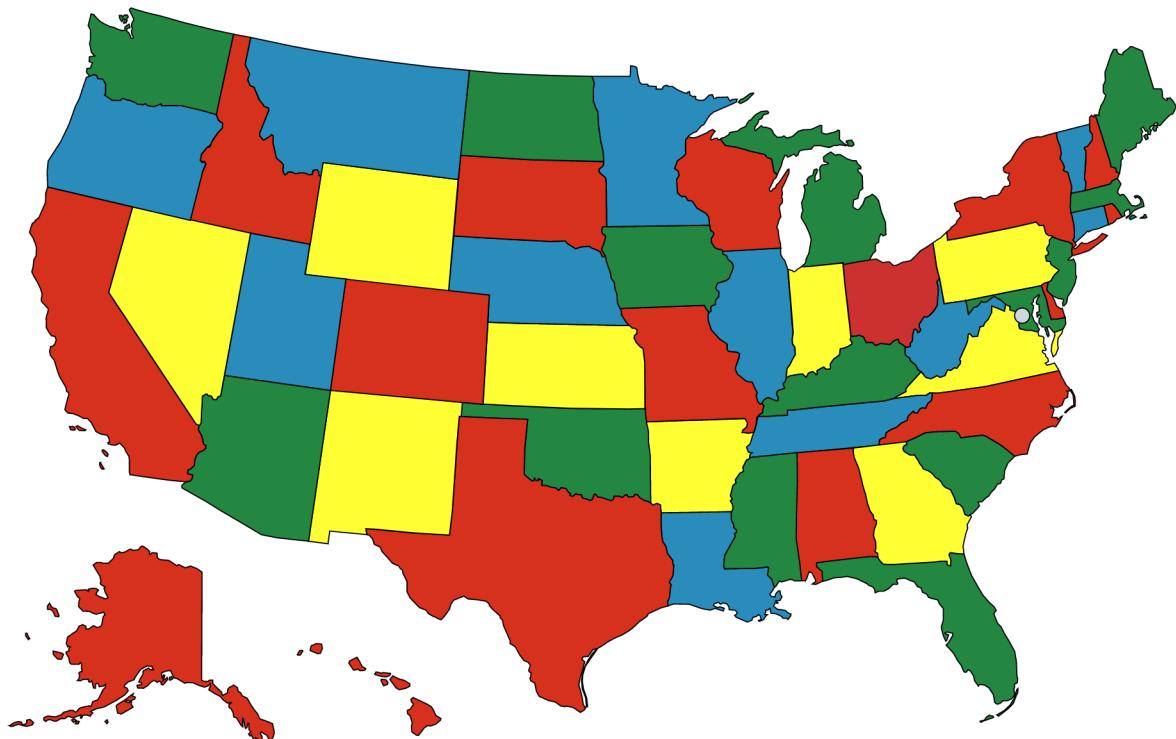
```
source Delaware
Assigned color-> Blue
source Maryland
source Maryland
source Maryland
source Maryland
source Delaware
source NewJersey
source NewJersey
source NewJersey
source NewYork
Assigned color-> Yellow
source NewJersey
Assigned color-> Red
source Delaware
source Delaware
source Delaware
Assigned color-> Blue
source Maryland
source Maryland
source Maryland
source Maryland
source Delaware
source NewJersey
source NewJersey
Assigned color-> Blue
source Delaware
Assigned color-> Red
source Maryland
source Maryland
source Maryland
source Maryland
source Delaware
source Delaware
source NewJersey
source NewYork
source Pennsylvania
Assigned color-> Blue
source NewYork
Assigned color-> Red
source NewJersey
source NewJersey
Assigned color-> Green
source Delaware
Assigned color-> Red
source Maryland
source Maryland
Assigned color-> Green
source Massachusetts
source Massachusetts
Assigned color-> Green
source NewHampshire
Assigned color-> Red
source Maine
source Maine
Assigned color-> Green
source Vermont
```

```

source Vermont
source Vermont
Assigned color-> Blue
source RhodeIsland
Assigned color-> Red
source Connecticut
source Connecticut
source Connecticut
Assigned color-> Blue
source Connecticut
Assigned colors: {'Ohio': 'Red', 'Kentucky': 'Green', 'Missouri': 'Red', 'Tennessee': 'Blue', 'NorthCarolina': 'Red', 'SouthCarolina': 'Green', 'Georgia': 'Yellow', 'Alabama': 'Red', 'Florida': 'Green', 'Mississippi': 'Green', 'Arkansas': 'Yellow', 'Texas': 'Red', 'Oklahoma': 'Green', 'Colorado': 'Red', 'Arizona': 'Green', 'Utah': 'Blue', 'Wyoming': 'Green', 'SouthDakota': 'Red', 'NorthDakota': 'Green', 'Montana': 'Blue', 'Idaho': 'Red', 'Washington': 'Green', 'Oregon': 'Blue', 'California': 'Red', 'Nevada': 'Yellow', 'Minnesota': 'Blue', 'Wisconsin': 'Red', 'Michigan': 'Green', 'Illinois': 'Blue', 'Indiana': 'Yellow', 'Iowa': 'Green', 'Nebraska': 'Blue', 'Kansas': 'Yellow', 'NewMexico': 'Yellow', 'Louisiana': 'Blue', 'Virginia': 'Yellow', 'WestVirginia': 'Blue', 'Pennsylvania': 'Blue', 'NewYork': 'Red', 'NewJersey': 'Green', 'Delaware': 'Red', 'Maryland': 'Green', 'Massachusetts': 'Green', 'NewHampshire': 'Red', 'Maine': 'Green', 'Vermont': 'Blue', 'RhodeIsland': 'Red', 'Connecticut': 'Blue'}
Backtrack---> 112

```

Time taken: 0.04024696350097656 seconds



## 10. Backtracking + Forward Checking – USA (without heuristics)

### Test Case 1

```
source Alabama
Assigned color-> Red
source Georgia
Assigned color-> Green
source SouthCarolina
Assigned color-> Red
source NorthCarolina
Assigned color-> Blue
source Virginia
Assigned color-> Red
source Maryland
Assigned color-> Green
source Ohio
Assigned color-> Red
source Kentucky
Assigned color-> Green
source Missouri
Assigned color-> Red
source Kansas
Assigned color-> Green
source Nebraska
Assigned color-> Blue
source SouthDakota
Assigned color-> Red
source Iowa
Assigned color-> Green
source Wisconsin
Assigned color-> Red
source Michigan
Assigned color-> Green
source Illinois
Assigned color-> Blue
source Indiana
Assigned color-> Yellow
source Minnesota
Assigned color-> Blue
source NorthDakota
Assigned color-> Green
source Montana
Assigned color-> Blue
source Wyoming
Assigned color-> Green
source Utah
Assigned color-> Red
source Idaho
Assigned color-> Yellow
source Nevada
Assigned color-> Green
source Oregon
Assigned color-> Red
source California
Assigned color-> Blue
source Arizona
Assigned color-> Yellow
source NewMexico
Assigned color-> Green
source Colorado
```

```
Parent node-> NewMexico
source NewMexico
Assigned color-> Blue
source Colorado
Parent node-> NewMexico
source NewMexico
Parent node-> Arizona
source Arizona
Parent node-> California
source California
Assigned color-> Yellow
source Arizona
Assigned color-> Blue
source NewMexico
Assigned color-> Yellow
source Colorado
Parent node-> NewMexico
source NewMexico
Parent node-> Arizona
source Arizona
Parent node-> California
source California
Parent node-> Oregon
source Oregon
Assigned color-> Blue
source California
Assigned color-> Red
source Arizona
Assigned color-> Yellow
source NewMexico
Assigned color-> Blue
source Colorado
Parent node-> NewMexico
source NewMexico
Parent node-> Arizona
source Arizona
Parent node-> California
source California
Parent node-> Oregon
source Oregon
Parent node-> Nevada
source Nevada
Assigned color-> Blue
source Oregon
Assigned color-> Green
source California
Parent node-> Oregon
source Oregon
Parent node-> Nevada
source Nevada
Parent node-> Idaho
source Idaho
Parent node-> Utah
source Utah
Assigned color-> Blue
source Idaho
Assigned color-> Red
source Nevada
```

Assigned color-> Yellow  
source Oregon  
Assigned color-> Blue  
source California  
Assigned color-> Green  
source Arizona  
Assigned color-> Red  
source NewMexico  
Assigned color-> Yellow  
source Colorado  
Parent node-> NewMexico  
source NewMexico  
Parent node-> Arizona  
source Arizona  
Parent node-> California  
source California  
Parent node-> Oregon  
source Oregon  
Parent node-> Nevada  
source Nevada  
Parent node-> Idaho  
source Idaho  
Parent node-> Utah  
source Utah  
Assigned color-> Yellow  
source Idaho  
Parent node-> Utah  
source Utah  
Parent node-> Wyoming  
source Wyoming  
Assigned color-> Yellow  
source Utah  
Assigned color-> Green  
source Idaho  
Parent node-> Utah  
source Utah  
Parent node-> Wyoming  
source Wyoming  
Parent node-> Montana  
source Montana  
Assigned color-> Yellow  
source Wyoming  
Parent node-> Montana  
source Montana  
Parent node-> NorthDakota  
source NorthDakota  
Assigned color-> Yellow  
source Montana  
Assigned color-> Green  
source Wyoming  
Assigned color-> Yellow  
source Utah  
Parent node-> Wyoming  
source Wyoming  
Parent node-> Montana  
source Montana  
Parent node-> NorthDakota  
source NorthDakota

Parent node-> Minnesota  
source Minnesota  
Assigned color-> Yellow  
source NorthDakota  
Assigned color-> Blue  
source Montana  
Assigned color-> Yellow  
source Wyoming  
Assigned color-> Green  
source Utah  
Assigned color-> Yellow  
source Idaho  
Assigned color-> Blue  
source Nevada  
Assigned color-> Red  
source Oregon  
Assigned color-> Yellow  
source California  
Assigned color-> Blue  
source Arizona  
Assigned color-> Green  
source NewMexico  
Assigned color-> Red  
source Colorado  
Parent node-> NewMexico  
source NewMexico  
Assigned color-> Blue  
source Colorado  
Assigned color-> Red  
source Oklahoma  
Assigned color-> Yellow  
source Arkansas  
Assigned color-> Green  
source Mississippi  
Assigned color-> Blue  
source Louisiana  
Assigned color-> Red  
source Texas  
Parent node-> Louisiana  
source Louisiana  
Assigned color-> Yellow  
source Texas  
Assigned color-> Red  
source Tennessee  
Assigned color-> Yellow  
source Washington  
Assigned color-> Green  
source WestVirginia  
Assigned color-> Blue  
source Pennsylvania  
Assigned color-> Yellow  
source NewJersey  
Assigned color-> Red  
source NewYork  
Assigned color-> Green  
source Massachusetts  
Assigned color-> Red  
source NewHampshire

```
Assigned color-> Green
source Vermont
Assigned color-> Blue
source Maine
Assigned color-> Red
source RhodeIsland
Assigned color-> Green
source Connecticut
Assigned color-> Blue
source Delaware
Assigned color-> Blue
source Florida
Assigned color-> Blue
source Florida
Assigned colors: {'Alabama': 'Red', 'Georgia': 'Green', 'SouthCarolina': 'Red', 'NorthCarolina': 'Blue', 'Virginia': 'Red', 'Maryland': 'Green', 'Ohio': 'Red', 'Kentucky': 'Green', 'Missouri': 'Red', 'Kansas': 'Green', 'Nebraska': 'Blue', 'SouthDakota': 'Red', 'Iowa': 'Green', 'Wisconsin': 'Red', 'Michigan': 'Green', 'Illinois': 'Blue', 'Indiana': 'Yellow', 'Minnesota': 'Yellow', 'NorthDakota': 'Blue', 'Montana': 'Yellow', 'Wyoming': 'Green', 'Utah': 'Yellow', 'Idaho': 'Blue', 'Nevada': 'Red', 'Oregon': 'Yellow', 'California': 'Blue', 'Arizona': 'Green', 'NewMexico': 'Blue', 'Colorado': 'Red', 'Oklahoma': 'Yellow', 'Arkansas': 'Green', 'Mississippi': 'Blue', 'Louisiana': 'Yellow', 'Texas': 'Red', 'Tennessee': 'Yellow', 'Washington': 'Green', 'WestVirginia': 'Blue', 'Pennsylvania': 'Yellow', 'NewJersey': 'Red', 'NewYork': 'Green', 'Massachusetts': 'Red', 'NewHampshire': 'Green', 'Vermont': 'Blue', 'Maine': 'Red', 'RhodeIsland': 'Green', 'Connecticut': 'Blue', 'Delaware': 'Blue', 'Florida': 'Blue'}
Backtrack---> 37
```

```
State: Alabama -> Red
Assigned color to Neighbour: Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Yellow
Assigned color to Neighbour: Blue
```

```
State: Alaska -> Red
```

```
State: Arizona -> Green
Assigned color to Neighbour: Yellow
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red
Assigned color to Neighbour: Red
Assigned color to Neighbour: Blue
```

```
State: Arkansas -> Green
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red
Assigned color to Neighbour: Yellow
Assigned color to Neighbour: Red
Assigned color to Neighbour: Yellow
Assigned color to Neighbour: Yellow
```

```
State: California -> Blue
Assigned color to Neighbour: Red
Assigned color to Neighbour: Yellow
Assigned color to Neighbour: Green
```

State: Colorado -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green

State: Connecticut -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: Delaware -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Florida -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red

State: Georgia -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Hawaii -> Red

State: Idaho -> Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green

State: Illinois -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow

State: Indiana -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

State: Iowa -> Green  
Assigned color to Neighbour: Red

Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Kansas -> Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Kentucky -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

State: Louisiana -> Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green

State: Maine -> Red  
Assigned color to Neighbour: Green

State: Maryland -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Massachusetts -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Michigan -> Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Minnesota -> Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red

State: Mississippi -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

State: Missouri -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

State: Montana -> Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: Nebraska -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red

State: Nevada -> Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: NewHampshire -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: NewJersey -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: NewMexico -> Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green

State: NewYork -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: NorthCarolina -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow

State: NorthDakota -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

State: Ohio -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow

State: Oklahoma -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red

State: Oregon -> Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: Pennsylvania -> Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: RhodeIsland -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

State: SouthCarolina -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: SouthDakota -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Tennessee -> Yellow

Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green

State: Texas -> Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Utah -> Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: Vermont -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green

State: Virginia -> Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

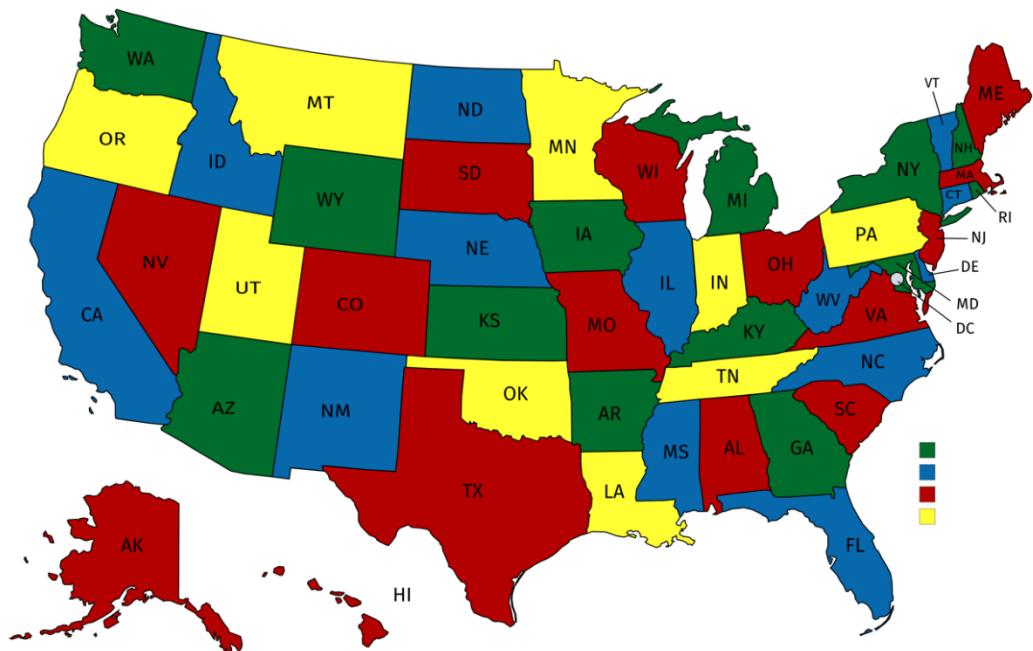
State: Washington -> Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: WestVirginia -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green

State: Wisconsin -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

State: Wyoming -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

Time taken: 0.1348869800567627



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## Test Case 2 - Backtracking + Forward Checking – USA (without heuristics)

```
source California
Assigned color-> Red
source Nevada
Assigned color-> Green
source Utah
Assigned color-> Red
source Idaho
Assigned color-> Blue
source Wyoming
Assigned color-> Green
source SouthDakota
Assigned color-> Red
source Iowa
Assigned color-> Green
source Missouri
Assigned color-> Red
source Kentucky
Assigned color-> Green
source Ohio
Assigned color-> Red
source Michigan
Assigned color-> Green
source Illinois
Assigned color-> Blue
```

```
source Wisconsin
Assigned color-> Red
source Minnesota
Assigned color-> Blue
source NorthDakota
Assigned color-> Green
source Montana
Assigned color-> Yellow
source Indiana
Assigned color-> Yellow
source WestVirginia
Assigned color-> Blue
source Virginia
Assigned color-> Red
source NorthCarolina
Assigned color-> Green
source Georgia
Assigned color-> Red
source Alabama
Assigned color-> Green
source Florida
Assigned color-> Blue
source Tennessee
Assigned color-> Blue
source Mississippi
Assigned color-> Red
source Arkansas
Assigned color-> Green
source Louisiana
Assigned color-> Blue
source Texas
Assigned color-> Red
source Oklahoma
Assigned color-> Blue
source Kansas
Assigned color-> Green
source Nebraska
Assigned color-> Blue
source Colorado
Assigned color-> Yellow
source NewMexico
Assigned color-> Green
source Arizona
Assigned color-> Blue
source SouthCarolina
Assigned color-> Blue
source Maryland
Assigned color-> Green
source Pennsylvania
Assigned color-> Yellow
source NewJersey
Assigned color-> Red
source NewYork
Assigned color-> Green
source Massachusetts
Assigned color-> Red
source NewHampshire
Assigned color-> Green
```

```

source Vermont
Assigned color-> Blue
source Maine
Assigned color-> Red
source RhodeIsland
Assigned color-> Green
source Connecticut
Assigned color-> Blue
source Delaware
Assigned color-> Blue
source Oregon
Assigned color-> Yellow
source Washington
Assigned color-> Red
source Washington
Assigned colors: {'California': 'Red', 'Nevada': 'Green', 'Utah': 'Red', 'Idaho': 'Blue', 'Wyoming': 'Green', 'SouthDakota': 'Red', 'Iowa': 'Green', 'Missouri': 'Red', 'Kentucky': 'Green', 'Ohio': 'Red', 'Michigan': 'Green', 'Illinois': 'Blue', 'Wisconsin': 'Red', 'Minnesota': 'Blue', 'NorthDakota': 'Green', 'Montana': 'Yellow', 'Indiana': 'Yellow', 'WestVirginia': 'Blue', 'Virginia': 'Red', 'NorthCarolina': 'Green', 'Georgia': 'Red', 'Alabama': 'Green', 'Florida': 'Blue', 'Tennessee': 'Blue', 'Mississippi': 'Red', 'Arkansas': 'Green', 'Louisiana': 'Blue', 'Texas': 'Red', 'Oklahoma': 'Blue', 'Kansas': 'Green', 'Nebraska': 'Blue', 'Colorado': 'Yellow', 'NewMexico': 'Green', 'Arizona': 'Blue', 'SouthCarolina': 'Blue', 'Maryland': 'Green', 'Pennsylvania': 'Yellow', 'NewJersey': 'Red', 'NewYork': 'Green', 'Massachusetts': 'Red', 'NewHampshire': 'Green', 'Vermont': 'Blue', 'Maine': 'Red', 'RhodeIsland': 'Green', 'Connecticut': 'Blue', 'Delaware': 'Blue', 'Oregon': 'Yellow', 'Washington': 'Red'}
Backtrack---> 0

State: Alabama -> Green
Assigned color to Neighbour: Red
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red

State: Alaska -> Red

State: Arizona -> Blue
Assigned color to Neighbour: Red
Assigned color to Neighbour: Green
Assigned color to Neighbour: Green
Assigned color to Neighbour: Yellow
Assigned color to Neighbour: Red

State: Arkansas -> Green
Assigned color to Neighbour: Red
Assigned color to Neighbour: Red
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Red
Assigned color to Neighbour: Blue
Assigned color to Neighbour: Blue

State: California -> Red
Assigned color to Neighbour: Green

```

Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Colorado -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Connecticut -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: Delaware -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Florida -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: Georgia -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Hawaii -> Red

State: Idaho -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Illinois -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow

State: Indiana -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

State: Iowa -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Kansas -> Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Kentucky -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Louisiana -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: Maine -> Red  
Assigned color to Neighbour: Green

State: Maryland -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Massachusetts -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Michigan -> Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Minnesota -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red

State: Mississippi -> Red

Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Missouri -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Montana -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: Nebraska -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow

State: Nevada -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: NewHampshire -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: NewJersey -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: NewMexico -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: NewYork -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

Assigned color to Neighbour: Blue

State: NorthCarolina -> Green

Assigned color to Neighbour: Red

Assigned color to Neighbour: Red

Assigned color to Neighbour: Blue

Assigned color to Neighbour: Blue

State: NorthDakota -> Green

Assigned color to Neighbour: Red

Assigned color to Neighbour: Blue

Assigned color to Neighbour: Yellow

State: Ohio -> Red

Assigned color to Neighbour: Green

Assigned color to Neighbour: Green

Assigned color to Neighbour: Blue

Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Green

Assigned color to Neighbour: Yellow

State: Oklahoma -> Blue

Assigned color to Neighbour: Green

Assigned color to Neighbour: Red

Assigned color to Neighbour: Green

Assigned color to Neighbour: Green

Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Red

State: Oregon -> Yellow

Assigned color to Neighbour: Green

Assigned color to Neighbour: Red

Assigned color to Neighbour: Red

Assigned color to Neighbour: Blue

State: Pennsylvania -> Yellow

Assigned color to Neighbour: Red

Assigned color to Neighbour: Red

Assigned color to Neighbour: Blue

Assigned color to Neighbour: Green

Assigned color to Neighbour: Green

Assigned color to Neighbour: Blue

State: RhodeIsland -> Green

Assigned color to Neighbour: Red

Assigned color to Neighbour: Blue

State: SouthCarolina -> Blue

Assigned color to Neighbour: Red

Assigned color to Neighbour: Green

State: SouthDakota -> Red

Assigned color to Neighbour: Green

Assigned color to Neighbour: Green

Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Green

Assigned color to Neighbour: Blue

Assigned color to Neighbour: Blue

State: Tennessee -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red

State: Texas -> Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green

State: Utah -> Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Vermont -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green

State: Virginia -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: Washington -> Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

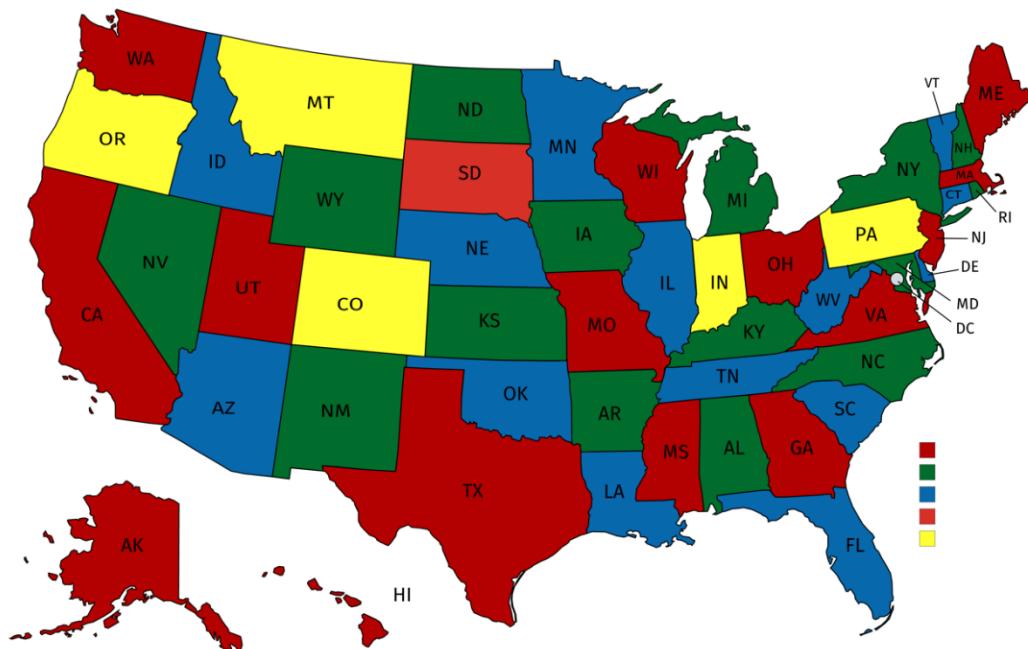
State: WestVirginia -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green

State: Wisconsin -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Wyoming -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

Time taken: 0.09254813194274902



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### Test Case 3 - Backtracking + Forward Checking – USA (without heuristics)

```
source Arkansas
Assigned color-> Red
source Mississippi
Assigned color-> Green
source Alabama
Assigned color-> Red
source Georgia
Assigned color-> Green
source SouthCarolina
Assigned color-> Red
source NorthCarolina
Assigned color-> Blue
source Virginia
Assigned color-> Red
source Maryland
Assigned color-> Green
source Ohio
Assigned color-> Red
source Kentucky
Assigned color-> Green
source Missouri
Assigned color-> Blue
```

```
source Kansas
Assigned color-> Red
source Nebraska
Assigned color-> Green
source SouthDakota
Assigned color-> Red
source Iowa
Assigned color-> Yellow
source Wisconsin
Assigned color-> Red
source Michigan
Assigned color-> Green
source Illinois
Parent node-> Michigan
source Michigan
Assigned color-> Blue
source Illinois
Parent node-> Michigan
source Michigan
Assigned color-> Yellow
source Illinois
Parent node-> Michigan
source Michigan
Parent node-> Wisconsin
source Wisconsin
Assigned color-> Green
source Michigan
Parent node-> Wisconsin
source Wisconsin
Assigned color-> Blue
source Michigan
Assigned color-> Green
source Illinois
Assigned color-> Red
source Indiana
Assigned color-> Yellow
source Minnesota
Assigned color-> Green
source NorthDakota
Assigned color-> Blue
source Montana
Assigned color-> Green
source Wyoming
Assigned color-> Blue
source Utah
Assigned color-> Red
source Idaho
Assigned color-> Yellow
source Nevada
Assigned color-> Green
source Oregon
Assigned color-> Red
source California
Assigned color-> Blue
source Arizona
Assigned color-> Yellow
source NewMexico
Assigned color-> Green
```

```
source Colorado
Parent node-> NewMexico
source NewMexico
Assigned color-> Blue
source Colorado
Parent node-> NewMexico
source NewMexico
Parent node-> Arizona
source Arizona
Parent node-> California
source California
Assigned color-> Yellow
source Arizona
Assigned color-> Blue
source NewMexico
Assigned color-> Yellow
source Colorado
Parent node-> NewMexico
source NewMexico
Parent node-> Arizona
source Arizona
Parent node-> California
source California
Parent node-> Oregon
source Oregon
Assigned color-> Blue
source California
Assigned color-> Red
source Arizona
Assigned color-> Yellow
source NewMexico
Assigned color-> Blue
source Colorado
Parent node-> NewMexico
source NewMexico
Parent node-> Arizona
source Arizona
Parent node-> California
source California
Parent node-> Oregon
source Oregon
Parent node-> Nevada
source Nevada
Assigned color-> Blue
source Oregon
Assigned color-> Green
source California
Parent node-> Oregon
source Oregon
Parent node-> Nevada
source Nevada
Parent node-> Idaho
source Idaho
Parent node-> Utah
source Utah
Assigned color-> Green
source Idaho
Assigned color-> Red
```

```
source Nevada
Assigned color-> Yellow
source Oregon
Assigned color-> Blue
source California
Assigned color-> Green
source Arizona
Assigned color-> Blue
source NewMexico
Assigned color-> Yellow
source Colorado
Parent node-> NewMexico
source NewMexico
Assigned color-> Red
source Colorado
Assigned color-> Yellow
source Oklahoma
Assigned color-> Green
source Texas
Assigned color-> Blue
source Louisiana
Assigned color-> Yellow
source Washington
Assigned color-> Green
source Tennessee
Assigned color-> Yellow
source WestVirginia
Assigned color-> Blue
source Pennsylvania
Assigned color-> Yellow
source NewJersey
Assigned color-> Red
source NewYork
Assigned color-> Green
source Massachusetts
Assigned color-> Red
source NewHampshire
Assigned color-> Green
source Vermont
Assigned color-> Blue
source Maine
Assigned color-> Red
source RhodeIsland
Assigned color-> Green
source Connecticut
Assigned color-> Blue
source Delaware
Assigned color-> Blue
source Florida
Assigned color-> Blue
source Florida
Assigned colors: {'Arkansas': 'Red', 'Mississippi': 'Green',
'Alabama': 'Red', 'Georgia': 'Green', 'SouthCarolina': 'Red',
'NorthCarolina': 'Blue', 'Virginia': 'Red', 'Maryland': 'Green',
'Ohio': 'Red', 'Kentucky': 'Green', 'Missouri': 'Blue', 'Kansas':
'Red', 'Nebraska': 'Green', 'SouthDakota': 'Red', 'Iowa': 'Yellow',
'Wisconsin': 'Blue', 'Michigan': 'Green', 'Illinois': 'Red',
'Indiana': 'Yellow', 'Minnesota': 'Green', 'NorthDakota': 'Blue',
```

```
'Montana': 'Green', 'Wyoming': 'Blue', 'Utah': 'Green', 'Idaho': 'Red', 'Nevada': 'Yellow', 'Oregon': 'Blue', 'California': 'Green', 'Arizona': 'Blue', 'NewMexico': 'Red', 'Colorado': 'Yellow', 'Oklahoma': 'Green', 'Texas': 'Blue', 'Louisiana': 'Yellow', 'Washington': 'Green', 'Tennessee': 'Yellow', 'WestVirginia': 'Blue', 'Pennsylvania': 'Yellow', 'NewJersey': 'Red', 'NewYork': 'Green', 'Massachusetts': 'Red', 'NewHampshire': 'Green', 'Vermont': 'Blue', 'Maine': 'Red', 'RhodeIsland': 'Green', 'Connecticut': 'Blue', 'Delaware': 'Blue', 'Florida': 'Blue'}
```

Backtrack---> 23

State: Alabama -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green

State: Alaska -> Red

State: Arizona -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green

State: Arkansas -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow

State: California -> Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Colorado -> Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: Connecticut -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: Delaware -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Florida -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red

State: Georgia -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Hawaii -> Red

State: Idaho -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green

State: Illinois -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Indiana -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: Iowa -> Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green

State: Kansas -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow

State: Kentucky -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

State: Louisiana -> Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red

State: Maine -> Red  
Assigned color to Neighbour: Green

State: Maryland -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Massachusetts -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: Michigan -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Minnesota -> Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

State: Mississippi -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

State: Missouri -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow

State: Montana -> Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: Nebraska -> Green

Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow

State: Nevada -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green

State: NewHampshire -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red

State: NewJersey -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: NewMexico -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: NewYork -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Blue

State: NorthCarolina -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow

State: NorthDakota -> Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green

State: Ohio -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Yellow

State: Oklahoma -> Green

Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue

State: Oregon -> Blue  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red

State: Pennsylvania -> Yellow  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: RhodeIsland -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue

State: SouthCarolina -> Red  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue

State: SouthDakota -> Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green

State: Tennessee -> Yellow  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Green

State: Texas -> Blue  
Assigned color to Neighbour: Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Red

State: Utah -> Green  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Blue  
Assigned color to Neighbour: Red  
Assigned color to Neighbour: Yellow  
Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Blue

State: Vermont -> Blue

Assigned color to Neighbour: Red

Assigned color to Neighbour: Green

Assigned color to Neighbour: Green

State: Virginia -> Red

Assigned color to Neighbour: Blue

Assigned color to Neighbour: Green

Assigned color to Neighbour: Green

Assigned color to Neighbour: Blue

State: Washington -> Green

Assigned color to Neighbour: Blue

Assigned color to Neighbour: Red

State: WestVirginia -> Blue

Assigned color to Neighbour: Red

Assigned color to Neighbour: Green

Assigned color to Neighbour: Red

Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Green

State: Wisconsin -> Blue

Assigned color to Neighbour: Green

Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Red

Assigned color to Neighbour: Green

Assigned color to Neighbour: Yellow

State: Wyoming -> Blue

Assigned color to Neighbour: Red

Assigned color to Neighbour: Green

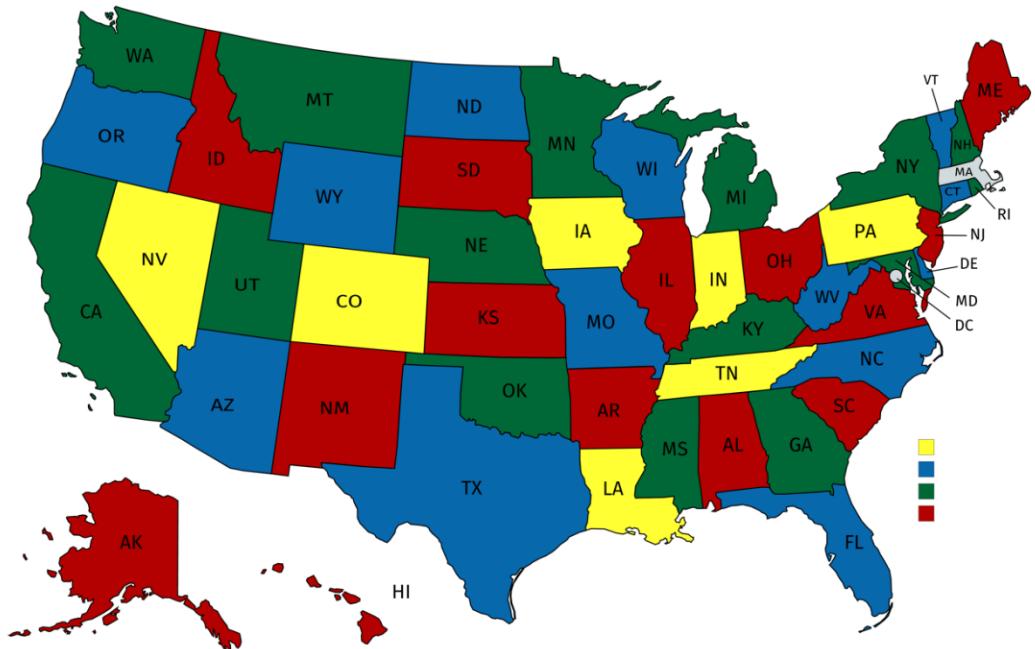
Assigned color to Neighbour: Red

Assigned color to Neighbour: Green

Assigned color to Neighbour: Yellow

Assigned color to Neighbour: Green

Time taken: 0.13224101066589355



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## 11. Backtracking – USA (with MRV)

```

source Alabama
Assigned color-> Red
source Georgia
source Georgia
Assigned color-> Green
source Tennessee
source Tennessee
source Tennessee
Assigned color-> Blue
source NorthCarolina
Assigned color-> Red
source SouthCarolina
source SouthCarolina
source SouthCarolina
Assigned color-> Blue
source Florida
source Florida
source Florida
Assigned color-> Blue
source Mississippi
source Mississippi
Assigned color-> Green
source Arkansas
Assigned color-> Red
source Louisiana
source Louisiana
source Louisiana

```

Assigned color-> Blue  
source Missouri  
source Missouri  
Assigned color-> Green  
source Oklahoma  
source Oklahoma  
source Oklahoma  
Assigned color-> Blue  
source Kansas  
Assigned color-> Red  
source Nebraska  
source Nebraska  
source Nebraska  
Assigned color-> Blue  
source Colorado  
source Colorado  
Assigned color-> Green  
source NewMexico  
Assigned color-> Red  
source Arizona  
source Arizona  
source Arizona  
Assigned color-> Blue  
source Utah  
source Utah  
source Utah  
source Utah  
Assigned color-> Yellow  
source Wyoming  
Assigned color-> Red  
source Idaho  
source Idaho  
Assigned color-> Green  
source Nevada  
Assigned color-> Red  
source California  
source California  
Assigned color-> Green  
source Montana  
source Montana  
source Montana  
Assigned color-> Blue  
source SouthDakota  
source SouthDakota  
Assigned color-> Green  
source Oregon  
source Oregon  
source Oregon  
Assigned color-> Blue  
source Iowa  
Assigned color-> Red  
source Minnesota  
source Minnesota  
source Minnesota  
Assigned color-> Blue  
source Illinois  
source Illinois  
source Illinois

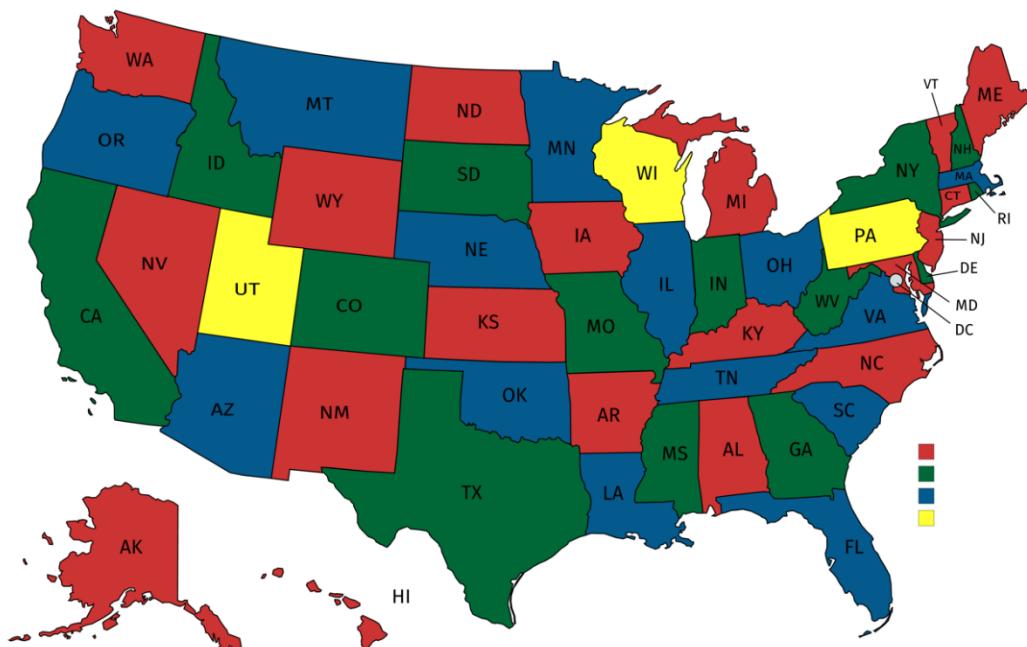
Assigned color-> Blue  
source NorthDakota  
Assigned color-> Red  
source Kentucky  
Assigned color-> Red  
source Indiana  
source Indiana  
Assigned color-> Green  
source Wisconsin  
source Wisconsin  
source Wisconsin  
source Wisconsin  
Assigned color-> Yellow  
source Michigan  
Assigned color-> Red  
source Washington  
Assigned color-> Red  
source Ohio  
source Ohio  
source Ohio  
Assigned color-> Blue  
source WestVirginia  
source WestVirginia  
Assigned color-> Green  
source Maryland  
Assigned color-> Red  
source Pennsylvania  
source Pennsylvania  
source Pennsylvania  
source Pennsylvania  
Assigned color-> Yellow  
source Texas  
source Texas  
Assigned color-> Green  
source Virginia  
source Virginia  
source Virginia  
Assigned color-> Blue  
source Delaware  
source Delaware  
Assigned color-> Green  
source NewJersey  
Assigned color-> Red  
source NewYork  
source NewYork  
Assigned color-> Green  
source Vermont  
Assigned color-> Red  
source Massachusetts  
source Massachusetts  
source Massachusetts  
Assigned color-> Blue  
source NewHampshire  
source NewHampshire  
Assigned color-> Green  
source Connecticut  
Assigned color-> Red  
source RhodeIsland

```

source RhodeIsland
Assigned color-> Green
source Maine
Assigned color-> Red
source Alaska
Assigned color-> Red
source Hawaii
Assigned color-> Red
source empty
Assigned colors: {'Alabama': 'Red', 'Georgia': 'Green', 'Tennessee': 'Blue', 'NorthCarolina': 'Red', 'SouthCarolina': 'Blue', 'Florida': 'Blue', 'Mississippi': 'Green', 'Arkansas': 'Red', 'Louisiana': 'Blue', 'Missouri': 'Green', 'Oklahoma': 'Blue', 'Kansas': 'Red', 'Nebraska': 'Blue', 'Colorado': 'Green', 'NewMexico': 'Red', 'Arizona': 'Blue', 'Utah': 'Yellow', 'Wyoming': 'Red', 'Idaho': 'Green', 'Nevada': 'Red', 'California': 'Green', 'Montana': 'Blue', 'SouthDakota': 'Green', 'Oregon': 'Blue', 'Iowa': 'Red', 'Minnesota': 'Blue', 'Illinois': 'Blue', 'NorthDakota': 'Red', 'Kentucky': 'Red', 'Indiana': 'Green', 'Wisconsin': 'Yellow', 'Michigan': 'Red', 'Washington': 'Red', 'Ohio': 'Blue', 'WestVirginia': 'Green', 'Maryland': 'Red', 'Pennsylvania': 'Yellow', 'Texas': 'Green', 'Virginia': 'Blue', 'Delaware': 'Green', 'NewJersey': 'Red', 'NewYork': 'Green', 'Vermont': 'Red', 'Massachusetts': 'Blue', 'NewHampshire': 'Green', 'Connecticut': 'Red', 'RhodeIsland': 'Green', 'Maine': 'Red', 'Alaska': 'Red', 'Hawaii': 'Red'}
Backtrack---> 0

```

Time taken: 0.0070819854736328125



## 12. Backtracking – USA (with Degree Constraints)

```
source Alabama
Assigned color-> Red
source Georgia
source Georgia
Assigned color-> Green
source Tennessee
source Tennessee
source Tennessee
Assigned color-> Blue
source NorthCarolina
Assigned color-> Red
source SouthCarolina
source SouthCarolina
source SouthCarolina
Assigned color-> Blue
source Florida
source Florida
source Florida
Assigned color-> Blue
source Mississippi
source Mississippi
Assigned color-> Green
source Arkansas
Assigned color-> Red
source Louisiana
source Louisiana
source Louisiana
Assigned color-> Blue
source Missouri
source Missouri
Assigned color-> Green
source Oklahoma
source Oklahoma
source Oklahoma
Assigned color-> Blue
source Kansas
Assigned color-> Red
source Nebraska
source Nebraska
source Nebraska
Assigned color-> Blue
source Colorado
source Colorado
Assigned color-> Green
source NewMexico
Assigned color-> Red
source Arizona
source Arizona
source Arizona
Assigned color-> Blue
source Utah
source Utah
source Utah
source Utah
Assigned color-> Yellow
source Wyoming
```

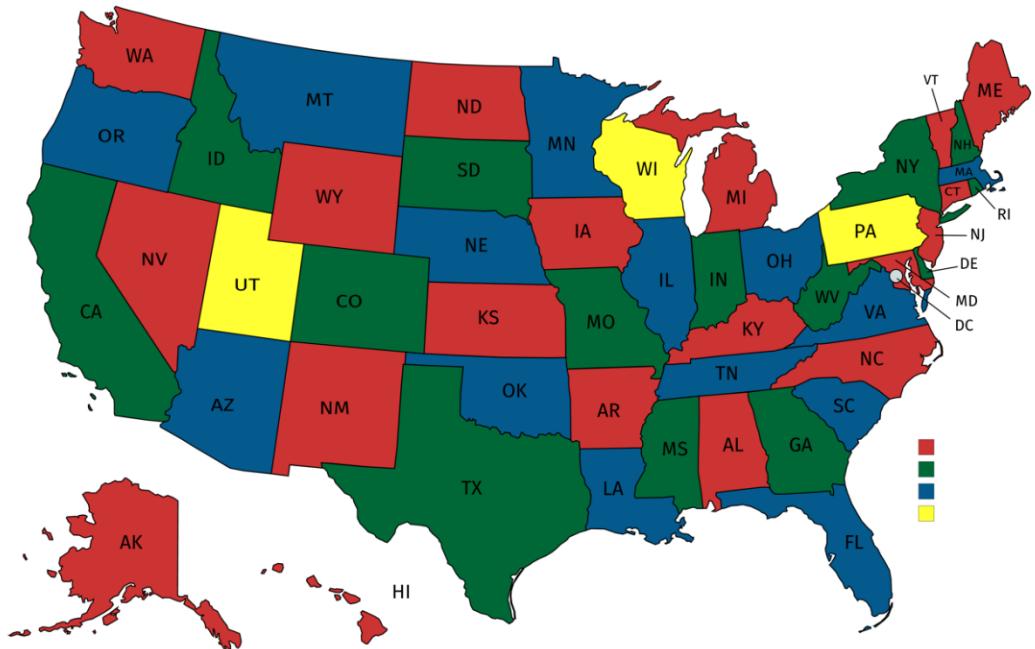
Assigned color-> Red  
source Idaho  
source Idaho  
Assigned color-> Green  
source Nevada  
Assigned color-> Red  
source California  
source California  
Assigned color-> Green  
source Montana  
source Montana  
source Montana  
Assigned color-> Blue  
source SouthDakota  
source SouthDakota  
Assigned color-> Green  
source Oregon  
source Oregon  
source Oregon  
Assigned color-> Blue  
source Iowa  
Assigned color-> Red  
source Minnesota  
source Minnesota  
source Minnesota  
Assigned color-> Blue  
source Illinois  
source Illinois  
source Illinois  
Assigned color-> Blue  
source NorthDakota  
Assigned color-> Red  
source Kentucky  
Assigned color-> Red  
source Indiana  
source Indiana  
Assigned color-> Green  
source Wisconsin  
source Wisconsin  
source Wisconsin  
source Wisconsin  
Assigned color-> Yellow  
source Michigan  
Assigned color-> Red  
source Washington  
Assigned color-> Red  
source Ohio  
source Ohio  
source Ohio  
Assigned color-> Blue  
source WestVirginia  
source WestVirginia  
Assigned color-> Green  
source Maryland  
Assigned color-> Red  
source Pennsylvania  
source Pennsylvania  
source Pennsylvania

```

source Pennsylvania
Assigned color-> Yellow
source Texas
source Texas
Assigned color-> Green
source Virginia
source Virginia
source Virginia
Assigned color-> Blue
source Delaware
source Delaware
Assigned color-> Green
source NewJersey
Assigned color-> Red
source NewYork
source NewYork
Assigned color-> Green
source Vermont
Assigned color-> Red
source Massachusetts
source Massachusetts
source Massachusetts
Assigned color-> Blue
source NewHampshire
source NewHampshire
Assigned color-> Green
source Connecticut
Assigned color-> Red
source RhodeIsland
source RhodeIsland
Assigned color-> Green
source Maine
Assigned color-> Red
source Alaska
Assigned color-> Red
source Hawaii
Assigned color-> Red
source empty
Assigned colors: {'Alabama': 'Red', 'Georgia': 'Green', 'Tennessee': 'Blue', 'NorthCarolina': 'Red', 'SouthCarolina': 'Blue', 'Florida': 'Blue', 'Mississippi': 'Green', 'Arkansas': 'Red', 'Louisiana': 'Blue', 'Missouri': 'Green', 'Oklahoma': 'Blue', 'Kansas': 'Red', 'Nebraska': 'Blue', 'Colorado': 'Green', 'NewMexico': 'Red', 'Arizona': 'Blue', 'Utah': 'Yellow', 'Wyoming': 'Red', 'Idaho': 'Green', 'Nevada': 'Red', 'California': 'Green', 'Montana': 'Blue', 'SouthDakota': 'Green', 'Oregon': 'Blue', 'Iowa': 'Red', 'Minnesota': 'Blue', 'Illinois': 'Blue', 'NorthDakota': 'Red', 'Kentucky': 'Red', 'Indiana': 'Green', 'Wisconsin': 'Yellow', 'Michigan': 'Red', 'Washington': 'Red', 'Ohio': 'Blue', 'WestVirginia': 'Green', 'Maryland': 'Red', 'Pennsylvania': 'Yellow', 'Texas': 'Green', 'Virginia': 'Blue', 'Delaware': 'Green', 'NewJersey': 'Red', 'NewYork': 'Green', 'Vermont': 'Red', 'Massachusetts': 'Blue', 'NewHampshire': 'Green', 'Connecticut': 'Red', 'RhodeIsland': 'Green', 'Maine': 'Red', 'Alaska': 'Red', 'Hawaii': 'Red'}
Backtrack---> 0

```

Time taken: 0.0080563467883425678



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### 13. Backtracking – USA (with LCV)

```

source Alabama
Assigned color-> Red
source Georgia
source Georgia
Assigned color-> Green
source Tennessee
source Tennessee
source Tennessee
Assigned color-> Blue
source NorthCarolina
Assigned color-> Red
source SouthCarolina
source SouthCarolina
source SouthCarolina
Assigned color-> Blue
source Florida
source Florida
source Florida
Assigned color-> Blue
source Mississippi
source Mississippi
Assigned color-> Green
source Arkansas
Assigned color-> Red
source Louisiana
source Louisiana
source Louisiana

```

Assigned color-> Blue  
source Missouri  
source Missouri  
Assigned color-> Green  
source Oklahoma  
source Oklahoma  
source Oklahoma  
Assigned color-> Blue  
source Kansas  
Assigned color-> Red  
source Nebraska  
source Nebraska  
source Nebraska  
Assigned color-> Blue  
source Colorado  
source Colorado  
Assigned color-> Green  
source NewMexico  
Assigned color-> Red  
source Arizona  
source Arizona  
source Arizona  
Assigned color-> Blue  
source Utah  
source Utah  
source Utah  
source Utah  
Assigned color-> Yellow  
source Wyoming  
Assigned color-> Red  
source Idaho  
source Idaho  
Assigned color-> Green  
source Nevada  
Assigned color-> Red  
source California  
source California  
Assigned color-> Green  
source Montana  
source Montana  
source Montana  
Assigned color-> Blue  
source SouthDakota  
source SouthDakota  
Assigned color-> Green  
source Oregon  
source Oregon  
source Oregon  
Assigned color-> Blue  
source Iowa  
Assigned color-> Red  
source Minnesota  
source Minnesota  
source Minnesota  
Assigned color-> Blue  
source Illinois  
source Illinois  
source Illinois

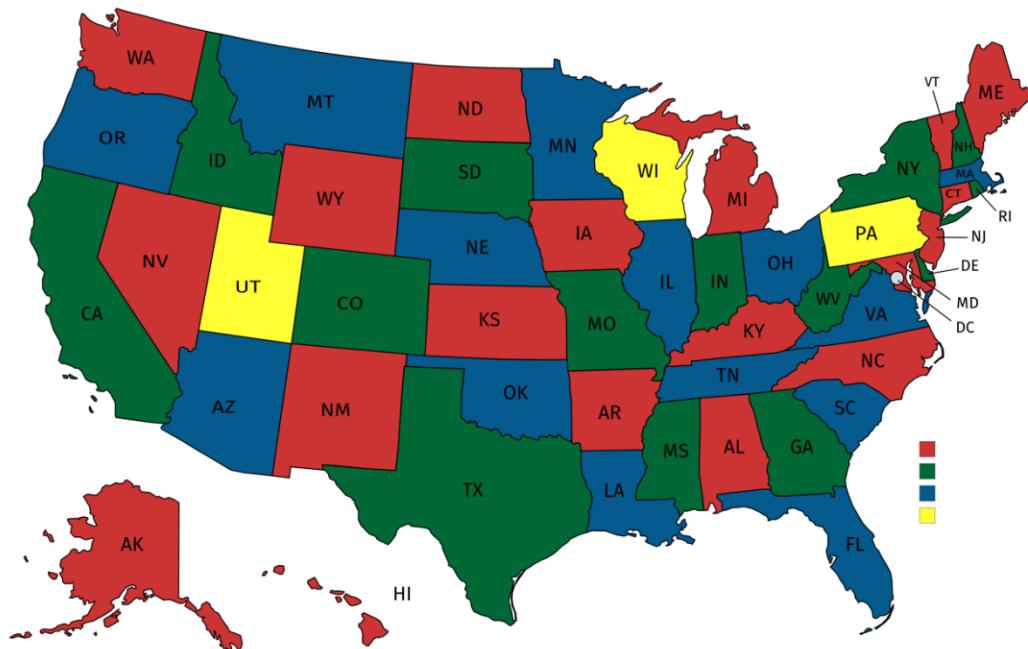
Assigned color-> Blue  
source NorthDakota  
Assigned color-> Red  
source Kentucky  
Assigned color-> Red  
source Indiana  
source Indiana  
Assigned color-> Green  
source Wisconsin  
source Wisconsin  
source Wisconsin  
source Wisconsin  
Assigned color-> Yellow  
source Michigan  
Assigned color-> Red  
source Washington  
Assigned color-> Red  
source Ohio  
source Ohio  
source Ohio  
Assigned color-> Blue  
source WestVirginia  
source WestVirginia  
Assigned color-> Green  
source Maryland  
Assigned color-> Red  
source Pennsylvania  
source Pennsylvania  
source Pennsylvania  
source Pennsylvania  
Assigned color-> Yellow  
source Texas  
source Texas  
Assigned color-> Green  
source Virginia  
source Virginia  
source Virginia  
Assigned color-> Blue  
source Delaware  
source Delaware  
Assigned color-> Green  
source NewJersey  
Assigned color-> Red  
source NewYork  
source NewYork  
Assigned color-> Green  
source Vermont  
Assigned color-> Red  
source Massachusetts  
source Massachusetts  
source Massachusetts  
Assigned color-> Blue  
source NewHampshire  
source NewHampshire  
Assigned color-> Green  
source Connecticut  
Assigned color-> Red  
source RhodeIsland

```

source RhodeIsland
Assigned color-> Green
source Maine
Assigned color-> Red
source Alaska
Assigned color-> Red
source Hawaii
Assigned color-> Red
source empty
Assigned colors: {'Alabama': 'Red', 'Georgia': 'Green', 'Tennessee': 'Blue', 'NorthCarolina': 'Red', 'SouthCarolina': 'Blue', 'Florida': 'Blue', 'Mississippi': 'Green', 'Arkansas': 'Red', 'Louisiana': 'Blue', 'Missouri': 'Green', 'Oklahoma': 'Blue', 'Kansas': 'Red', 'Nebraska': 'Blue', 'Colorado': 'Green', 'NewMexico': 'Red', 'Arizona': 'Blue', 'Utah': 'Yellow', 'Wyoming': 'Red', 'Idaho': 'Green', 'Nevada': 'Red', 'California': 'Green', 'Montana': 'Blue', 'SouthDakota': 'Green', 'Oregon': 'Blue', 'Iowa': 'Red', 'Minnesota': 'Blue', 'Illinois': 'Blue', 'NorthDakota': 'Red', 'Kentucky': 'Red', 'Indiana': 'Green', 'Wisconsin': 'Yellow', 'Michigan': 'Red', 'Washington': 'Red', 'Ohio': 'Blue', 'WestVirginia': 'Green', 'Maryland': 'Red', 'Pennsylvania': 'Yellow', 'Texas': 'Green', 'Virginia': 'Blue', 'Delaware': 'Green', 'NewJersey': 'Red', 'NewYork': 'Green', 'Vermont': 'Red', 'Massachusetts': 'Blue', 'NewHampshire': 'Green', 'Connecticut': 'Red', 'RhodeIsland': 'Green', 'Maine': 'Red', 'Alaska': 'Red', 'Hawaii': 'Red'}
Backtrack---> 0

```

Time taken: 0.006054537009334613

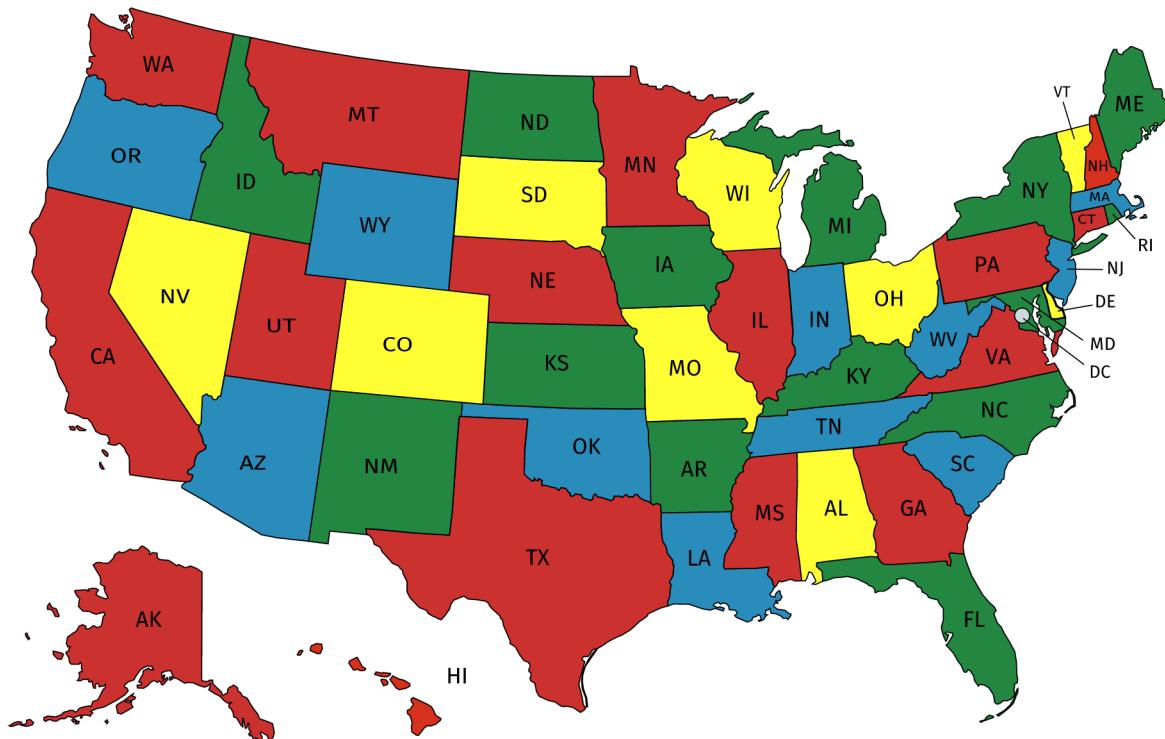


## 14. Backtracking + Forward Checking – USA (with MRV)

```
Assigned colors: {'Alaska': 'Red', 'Minnesota': 'Red', 'NorthDakota': 'Green', 'Montana': 'Red', 'Idaho': 'Green', 'Utah': 'Red', 'NewMexico': 'Green', 'Texas': 'Red', 'Oklahoma': 'Blue', 'Missouri': 'Yellow', 'Iowa': 'Green', 'SouthDakota': 'Yellow', 'Wyoming': 'Blue', 'Nebraska': 'Red', 'Kansas': 'Green', 'Colorado': 'Yellow', 'Arizona': 'Blue', 'California': 'Red', 'Oregon': 'Blue', 'Washington': 'Red', 'Nevada': 'Yellow', 'Wisconsin': 'Yellow', 'Indiana': 'Blue', 'Ohio': 'Yellow', 'Maryland': 'Green', 'Virginia': 'Red', 'Kentucky': 'Green', 'Illinois': 'Red', 'Michigan': 'Green', 'Tennessee': 'Blue', 'NorthCarolina': 'Green', 'Georgia': 'Red', 'Florida': 'Green', 'Alabama': 'Yellow', 'Mississippi': 'Red', 'Arkansas': 'Green', 'Louisiana': 'Blue', 'SouthCarolina': 'Blue', 'WestVirginia': 'Blue', 'Pennsylvania': 'Red', 'NewYork': 'Green', 'Connecticut': 'Red', 'Massachusetts': 'Blue', 'RhodeIsland': 'Green', 'NewHampshire': 'Red', 'Maine': 'Green', 'Vermont': 'Yellow', 'NewJersey': 'Blue'}
```

Backtrack---> 0

Time taken: 0.039299726486206055



## 15. Backtracking + Forward Checking – USA (with Degree Constraints)

```
Assigned colors: {'Texas': 'Red', 'Oklahoma': 'Green', 'NewMexico': 'Blue', 'Utah': 'Green', 'Wyoming': 'Red', 'SouthDakota': 'Yellow', 'Minnesota': 'Blue', 'NorthDakota': 'Green', 'Montana': 'Blue', 'Idaho': 'Yellow', 'Washington': 'Blue', 'Oregon': 'Green', 'California': 'Red'}
```

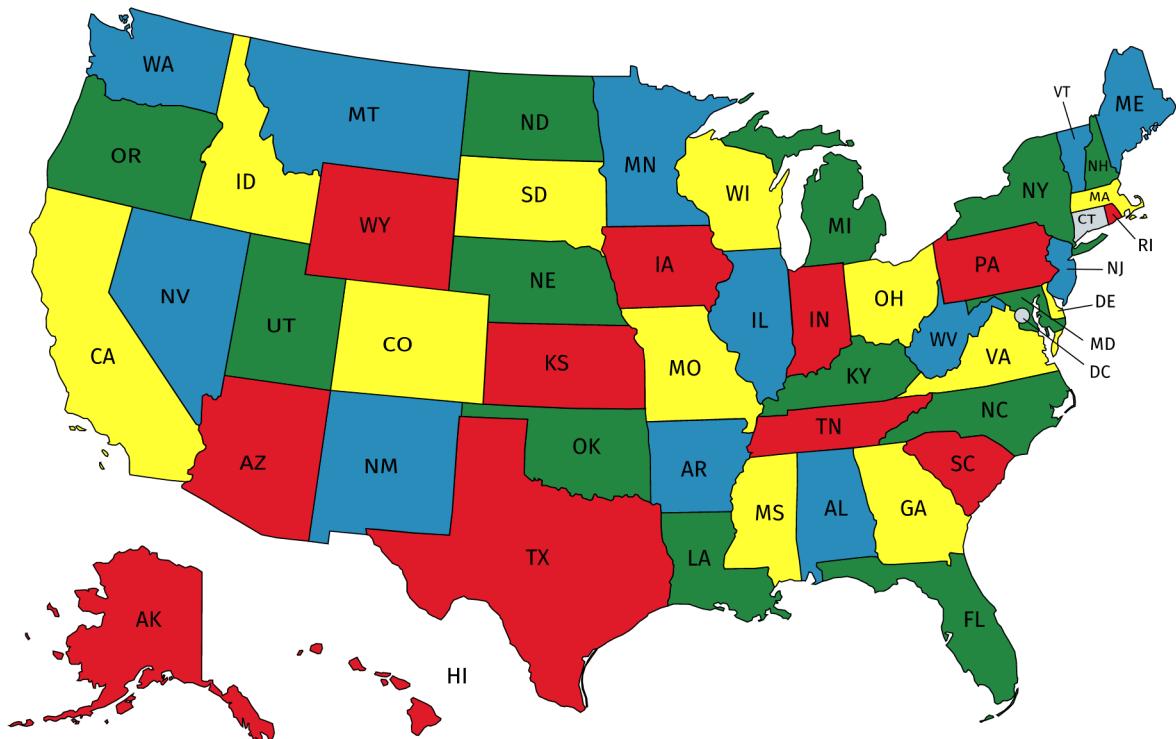
```

: 'Yellow', 'Arizona': 'Red', 'Nevada': 'Blue', 'Colorado': 'Yellow'
, 'Nebraska': 'Green', 'Iowa': 'Red', 'Missouri': 'Yellow', 'Illinoi
s': 'Blue', 'Wisconsin': 'Yellow', 'Indiana': 'Red', 'Ohio': 'Yellow
', 'Maryland': 'Green', 'Virginia': 'Yellow', 'Kentucky': 'Green', 'T
ennessee': 'Red', 'NorthCarolina': 'Green', 'Georgia': 'Yellow', 'F
lorida': 'Green', 'Alabama': 'Blue', 'Mississippi': 'Yellow', 'Arkan
sas': 'Blue', 'Louisiana': 'Green', 'SouthCarolina': 'Red', 'WestVir
ginia': 'Blue', 'Pennsylvania': 'Red', 'NewYork': 'Green', 'Connecti
cut': 'Blue', 'Massachusetts': 'Yellow', 'RhodeIsland': 'Red', 'NewH
ampshire': 'Green', 'Maine': 'Blue', 'Vermont': 'Blue', 'NewJersey':
'Blue', 'Delaware': 'Yellow', 'Michigan': 'Green', 'Kansas': 'Red'}

```

Backtrack---> 0

Time taken: 0.0813901424407959



## 16. Backtracking + Forward Checking – USA (with LCV)

```

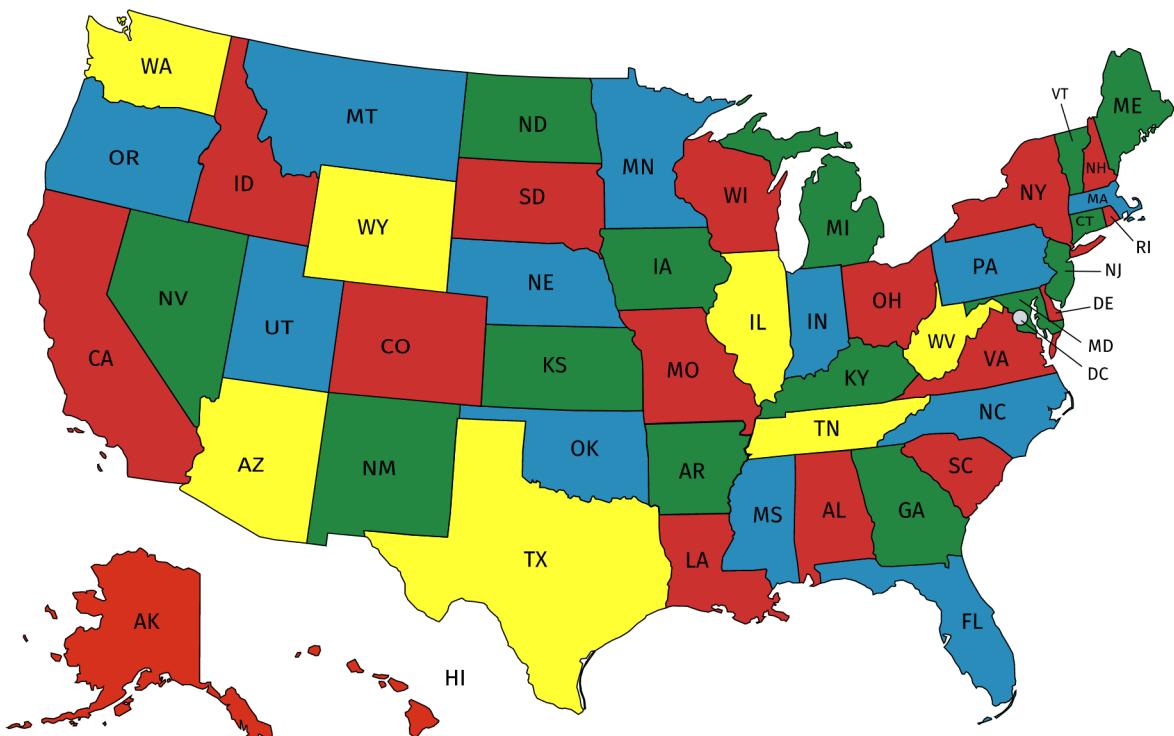
Assigned colors: {'Virginia': 'Red', 'Kentucky': 'Green', 'Ohio': 'R
ed', 'Maryland': 'Green', 'Delaware': 'Red', 'NewJersey': 'Green',
'NewYork': 'Red', 'Connecticut': 'Green', 'Massachusetts': 'Blue',
'RhodeIsland': 'Red', 'NewHampshire': 'Red', 'Maine': 'Green',
'Vermon
t': 'Green', 'Pennsylvania': 'Blue', 'WestVirginia': 'Yellow',
'Indi
ana': 'Blue', 'Wisconsin': 'Red', 'Iowa': 'Green', 'SouthDakota': 'R
ed', 'Minnesota': 'Blue', 'NorthDakota': 'Green', 'Montana': 'Blue',
'Idaho': 'Red', 'Utah': 'Blue', 'NewMexico': 'Green', 'Texas': 'Yell
ow', 'Oklahoma': 'Blue', 'Missouri': 'Red', 'Illinois': 'Yellow',
'Michigan': 'Green', 'Nebraska': 'Blue', 'Wyoming': 'Yellow', 'Colorad
o': 'Red', 'Arizona': 'Yellow', 'California': 'Red', 'Oregon': 'Blue

```

```
', 'Washington': 'Yellow', 'Nevada': 'Green', 'Kansas': 'Green', 'Arkansas': 'Green', 'Louisiana': 'Red', 'Mississippi': 'Blue', 'Alabama': 'Red', 'Georgia': 'Green', 'NorthCarolina': 'Blue', 'Tennessee': 'Yellow', 'SouthCarolina': 'Red', 'Florida': 'Blue'}
```

Backtrack---> 0

Time taken: 0.03386688232421875



## 17. Backtracking + Forward Checking + Singleton propagation – USA (without heuristics)

Time taken: 0.0006031990051269531

## Backtrack Count 0

```
Visited Node {'Mississippi', 'Texas', 'Ohio', 'Alabama', 'Oklahoma', 'Maryland', 'Idaho', 'Nebraska',  
'NewYork', 'Georgia', 'Pennsylvania', 'RhodelsIsland', 'Arkansas', 'NewHampshire', 'Indiana',  
'Nevada', 'Kansas', 'Missouri', 'Iowa', 'NorthCarolina', 'Illinois', 'NewJersey', 'Arizona',  
'NorthDakota', 'Maine', 'Louisiana', 'SouthCarolina', 'Kentucky', 'Massachusetts', 'Minnesota',  
'Delaware', 'Florida', 'California', 'Tennessee', 'Virginia', 'Oregon', 'Montana', 'Michigan',  
'Colorado', 'Hawaii', 'Wisconsin', 'Vermont', 'Utah', 'SouthDakota', 'Washington', 'Alaska',  
'Connecticut', 'WestVirginia', 'Wyoming', 'NewMexico'}
```

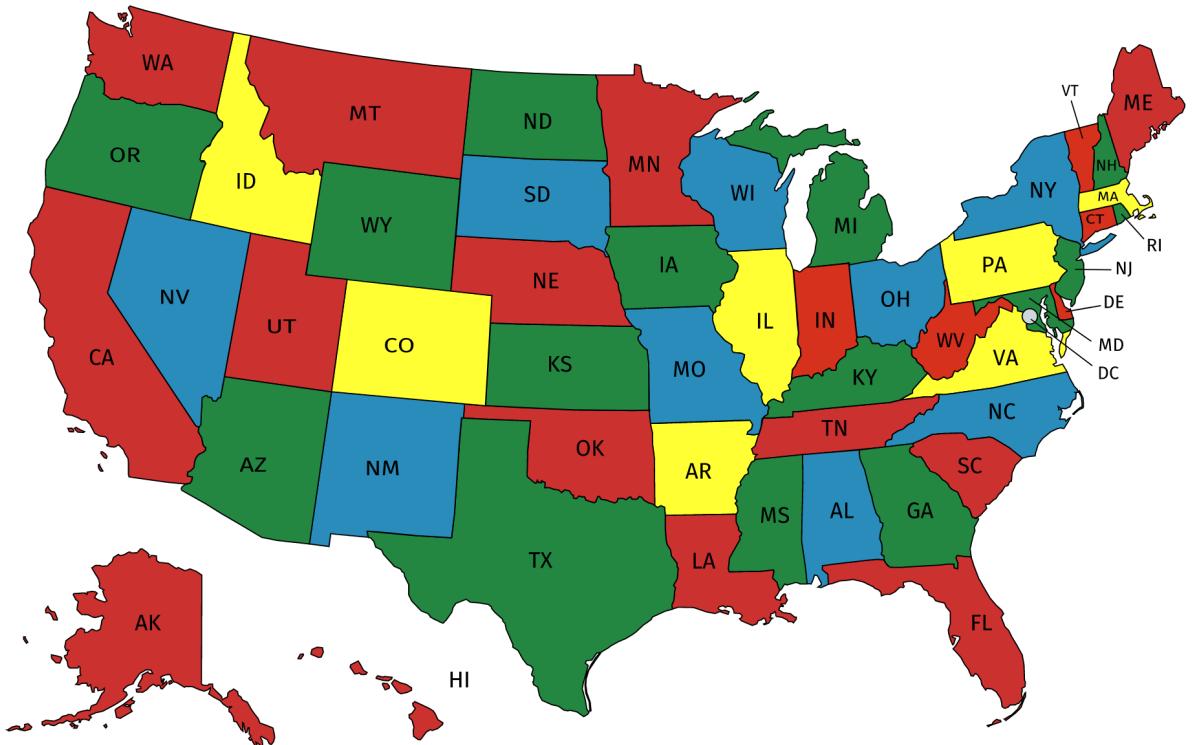
Assigned Color to state Nebraska -> ['Red']

Assigned Color to state Kansas -> ['Green']

Assigned Color to state Oklahoma -> ['Red']

Assigned Color to state Texas -> ['Green']

Assigned Color to state Minnesota -> ['Red']  
Assigned Color to state Iowa -> ['Green']  
Assigned Color to state Missouri -> ['Blue']  
Assigned Color to state Arkansas -> ['Yellow']  
Assigned Color to state Louisiana -> ['Red']  
Assigned Color to state Washington -> ['Red']  
Assigned Color to state Oregon -> ['Green']  
Assigned Color to state NewMexico -> ['Blue']  
Assigned Color to state Colorado -> ['Yellow']  
Assigned Color to state NorthDakota -> ['Green']  
Assigned Color to state SouthDakota -> ['Blue']  
Assigned Color to state Mississippi -> ['Green']  
Assigned Color to state Alabama -> ['Blue']  
Assigned Color to state Florida -> ['Red']  
Assigned Color to state California -> ['Red']  
Assigned Color to state Nevada -> ['Blue']  
Assigned Color to state Idaho -> ['Yellow']  
Assigned Color to state Montana -> ['Red']  
Assigned Color to state Wyoming -> ['Green']  
Assigned Color to state Utah -> ['Red']  
Assigned Color to state Arizona -> ['Green']  
Assigned Color to state Georgia -> ['Green']  
Assigned Color to state SouthCarolina -> ['Red']  
Assigned Color to state NorthCarolina -> ['Blue']  
Assigned Color to state Tennessee -> ['Red']  
Assigned Color to state Kentucky -> ['Green']  
Assigned Color to state Virginia -> ['Yellow']  
Assigned Color to state Delaware -> ['Red']  
Assigned Color to state Maryland -> ['Green']  
Assigned Color to state WestVirginia -> ['Red']  
Assigned Color to state Ohio -> ['Blue']  
Assigned Color to state Indiana -> ['Red']  
Assigned Color to state Illinois -> ['Yellow']  
Assigned Color to state Wisconsin -> ['Blue']  
Assigned Color to state Michigan -> ['Green']  
Assigned Color to state Pennsylvania -> ['Yellow']  
Assigned Color to state NewJersey -> ['Green']  
Assigned Color to state Connecticut -> ['Red']  
Assigned Color to state RhodeIsland -> ['Green']  
Assigned Color to state NewYork -> ['Blue']  
Assigned Color to state Vermont -> ['Red']  
Assigned Color to state NewHampshire -> ['Green']  
Assigned Color to state Massachusetts -> ['Yellow']  
Assigned Color to state Maine -> ['Red']  
Assigned Color to state Alaska -> ['Red']  
Assigned Color to state Hawaii -> ['Red']



### 18. Backtracking + Forward Checking + Singleton propagation – USA (with MRV)

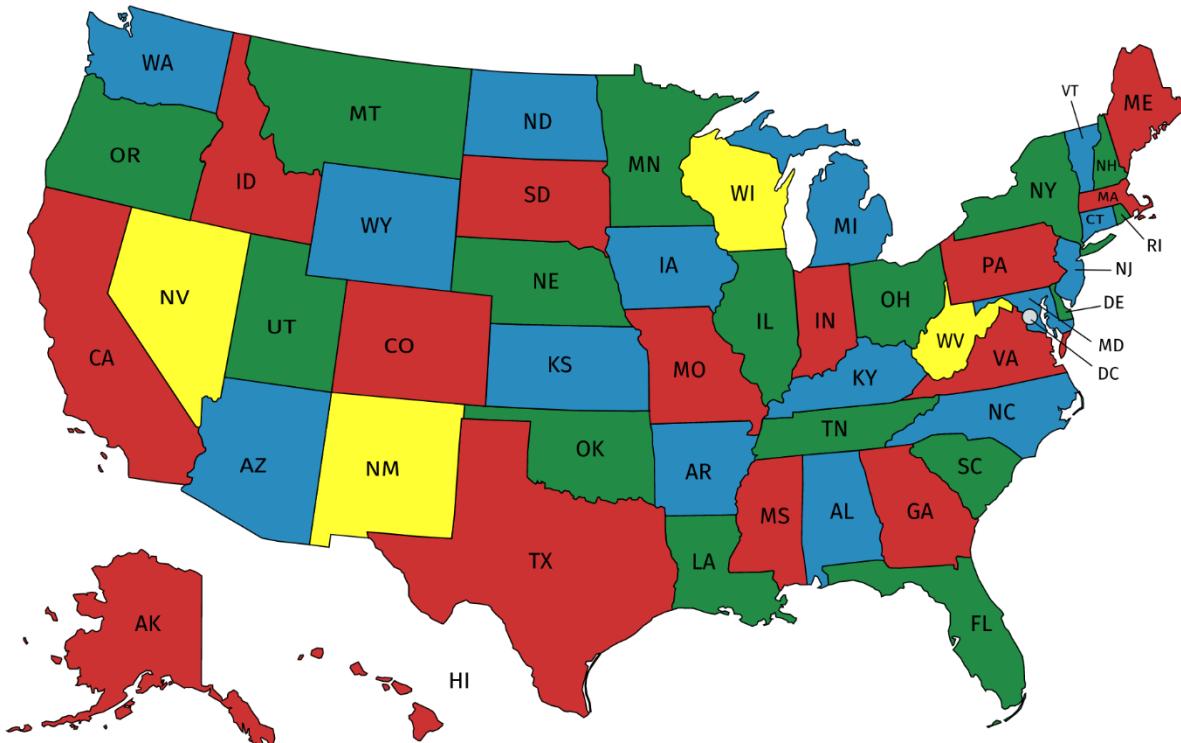
Time taken: 0.0017328262329101562

Backtrack Count 0

Visited Node {'Mississippi', 'Texas', 'Ohio', 'Alabama', 'Oklahoma', 'Maryland', 'Idaho', 'Nebraska', 'NewYork', 'Georgia', 'Pennsylvania', 'RhodesIsland', 'Arkansas', 'NewHampshire', 'Indiana', 'Nevada', 'NorthCarolina', 'Missouri', 'Iowa', 'NewJersey', 'Illinois', 'Kansas', 'Arizona', 'NorthDakota', 'Maine', 'Louisiana', 'SouthCarolina', 'Kentucky', 'Massachusetts', 'Minnesota', 'Delaware', 'California', 'Florida', 'Tennessee', 'Virginia', 'Oregon', 'Michigan', 'Montana', 'Colorado', 'Hawaii', 'Wisconsin', 'Vermont', 'Utah', 'SouthDakota', 'Washington', 'Alaska', 'Connecticut', 'WestVirginia', 'Wyoming', 'NewMexico'}

Assigned Color to state Missouri -> ['Red']  
 Assigned Color to state Tennessee -> ['Green']  
 Assigned Color to state Kentucky -> ['Blue']  
 Assigned Color to state Arkansas -> ['Blue']  
 Assigned Color to state Illinois -> ['Green']  
 Assigned Color to state Iowa -> ['Blue']  
 Assigned Color to state Nebraska -> ['Green']  
 Assigned Color to state Oklahoma -> ['Green']  
 Assigned Color to state SouthDakota -> ['Red']  
 Assigned Color to state Wyoming -> ['Blue']  
 Assigned Color to state Colorado -> ['Red']  
 Assigned Color to state Utah -> ['Green']  
 Assigned Color to state Idaho -> ['Red']  
 Assigned Color to state Arizona -> ['Blue']

Assigned Color to state Nevada -> ['Yellow']  
Assigned Color to state NewMexico -> ['Yellow']  
Assigned Color to state Texas -> ['Red']  
Assigned Color to state Indiana -> ['Red']  
Assigned Color to state Wisconsin -> ['Yellow']  
Assigned Color to state Michigan -> ['Blue']  
Assigned Color to state Minnesota -> ['Green']  
Assigned Color to state Ohio -> ['Green']  
Assigned Color to state Virginia -> ['Red']  
Assigned Color to state WestVirginia -> ['Yellow']  
Assigned Color to state Maryland -> ['Blue']  
Assigned Color to state Pennsylvania -> ['Red']  
Assigned Color to state Mississippi -> ['Red']  
Assigned Color to state Alabama -> ['Blue']  
Assigned Color to state Georgia -> ['Red']  
Assigned Color to state Oregon -> ['Green']  
Assigned Color to state California -> ['Red']  
Assigned Color to state Delaware -> ['Green']  
Assigned Color to state Montana -> ['Green']  
Assigned Color to state NewJersey -> ['Blue']  
Assigned Color to state NewYork -> ['Green']  
Assigned Color to state NorthCarolina -> ['Blue']  
Assigned Color to state Florida -> ['Green']  
Assigned Color to state Kansas -> ['Blue']  
Assigned Color to state Louisiana -> ['Green']  
Assigned Color to state NorthDakota -> ['Blue']  
Assigned Color to state SouthCarolina -> ['Green']  
Assigned Color to state Washington -> ['Blue']  
Assigned Color to state Massachusetts -> ['Red']  
Assigned Color to state Connecticut -> ['Blue']  
Assigned Color to state Vermont -> ['Blue']  
Assigned Color to state NewHampshire -> ['Green']  
Assigned Color to state Rhodelsland -> ['Green']  
Assigned Color to state Maine -> ['Red']  
Assigned Color to state Alaska -> ['Red']  
Assigned Color to state Hawaii -> ['Red']



**19. Backtracking + Forward Checking + Singleton propagation – USA (with Degree Constraints)**

**20. Backtracking + Forward Checking + Singleton propagation – USA (with LCV)**

Time taken: 0.0008182525634765625

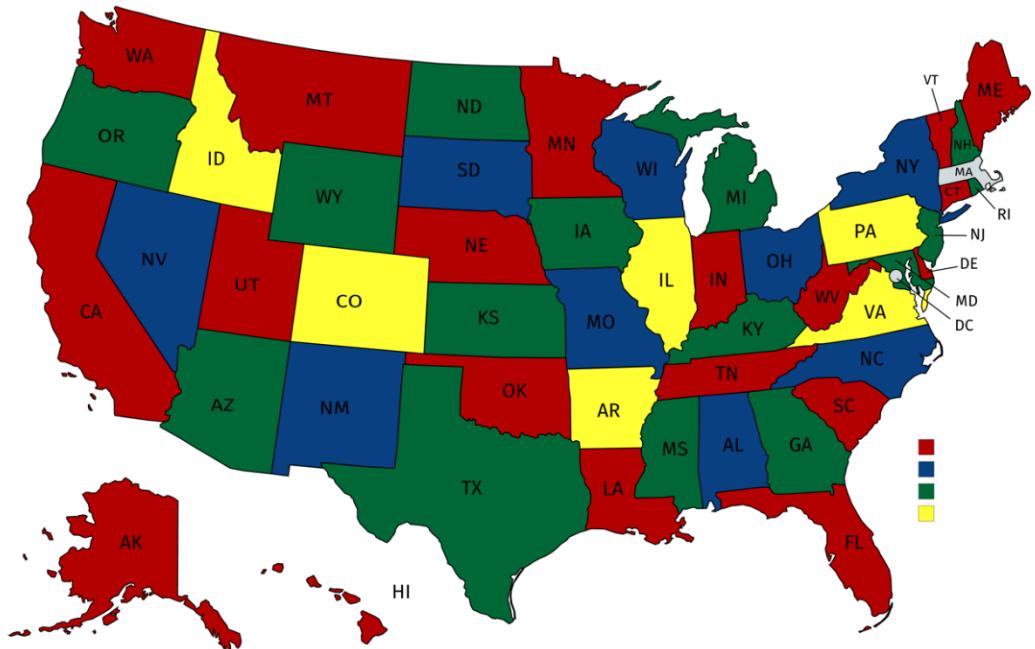
Backtrack Count 0

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Visited Node {'Mississippi', 'Texas', 'Ohio', 'Alabama', 'Oklahoma',
'Maryland', 'Idaho', 'Nebraska', 'NewYork', 'Georgia', 'Pennsylvania',
'RhodeIsland', 'Arkansas', 'NewHampshire', 'Indiana', 'Nevada',
'Kansas', 'Missouri', 'Iowa', 'NorthCarolina', 'Illinois', 'NewJersey',
'Arizona', 'NorthDakota', 'Maine', 'Louisiana', 'SouthCarolina',
'Kentucky', 'Massachusetts', 'Minnesota', 'Delaware', 'California',
'Florida', 'Tennessee', 'Virginia', 'Oregon', 'Montana', 'Michigan',
'Colorado', 'Hawaii', 'Wisconsin', 'Vermont', 'Utah', 'SouthDakota',
'Washington', 'Alaska', 'Connecticut', 'WestVirginia', 'Wyoming',
'NewMexico'}
```

```
Assigned Color to state Washington -> ['Red']
Assigned Color to state Oregon -> ['Green']
Assigned Color to state California -> ['Red']
Assigned Color to state Nevada -> ['Blue']
Assigned Color to state Idaho -> ['Yellow']
Assigned Color to state Montana -> ['Red']
Assigned Color to state Wyoming -> ['Green']
Assigned Color to state Utah -> ['Red']
Assigned Color to state Arizona -> ['Green']
Assigned Color to state NewMexico -> ['Blue']
Assigned Color to state Colorado -> ['Yellow']
```

```
Assigned Color to state NorthDakota -> ['Green']
Assigned Color to state SouthDakota -> ['Blue']
Assigned Color to state Nebraska -> ['Red']
Assigned Color to state Kansas -> ['Green']
Assigned Color to state Oklahoma -> ['Red']
Assigned Color to state Texas -> ['Green']
Assigned Color to state Minnesota -> ['Red']
Assigned Color to state Iowa -> ['Green']
Assigned Color to state Missouri -> ['Blue']
Assigned Color to state Arkansas -> ['Yellow']
Assigned Color to state Louisiana -> ['Red']
Assigned Color to state Mississippi -> ['Green']
Assigned Color to state Alabama -> ['Blue']
Assigned Color to state Florida -> ['Red']
Assigned Color to state Georgia -> ['Green']
Assigned Color to state SouthCarolina -> ['Red']
Assigned Color to state NorthCarolina -> ['Blue']
Assigned Color to state Tennessee -> ['Red']
Assigned Color to state Kentucky -> ['Green']
Assigned Color to state Virginia -> ['Yellow']
Assigned Color to state Delaware -> ['Red']
Assigned Color to state Maryland -> ['Green']
Assigned Color to state WestVirginia -> ['Red']
Assigned Color to state Ohio -> ['Blue']
Assigned Color to state Indiana -> ['Red']
Assigned Color to state Illinois -> ['Yellow']
Assigned Color to state Wisconsin -> ['Blue']
Assigned Color to state Michigan -> ['Green']
Assigned Color to state Pennsylvania -> ['Yellow']
Assigned Color to state NewJersey -> ['Green']
Assigned Color to state Connecticut -> ['Red']
Assigned Color to state RhodeIsland -> ['Green']
Assigned Color to state NewYork -> ['Blue']
Assigned Color to state Vermont -> ['Red']
Assigned Color to state NewHampshire -> ['Green']
Assigned Color to state Massachusetts -> ['Yellow']
Assigned Color to state Maine -> ['Red']
Assigned Color to state Alaska -> ['Red']
Assigned Color to state Hawaii -> ['Red']

statecount: 50
```



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