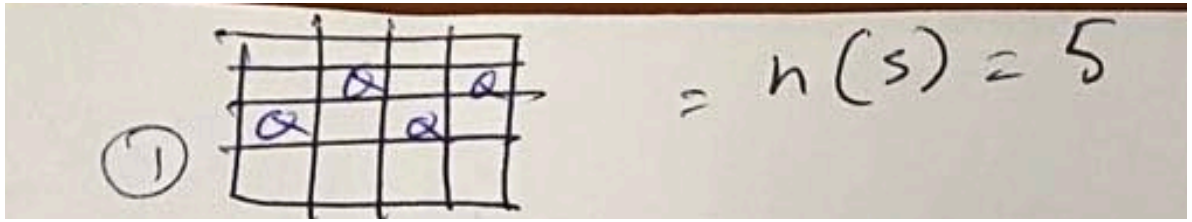
CS143: Artificial Intelligence

Constraint Satisfaction Problem (CSP)

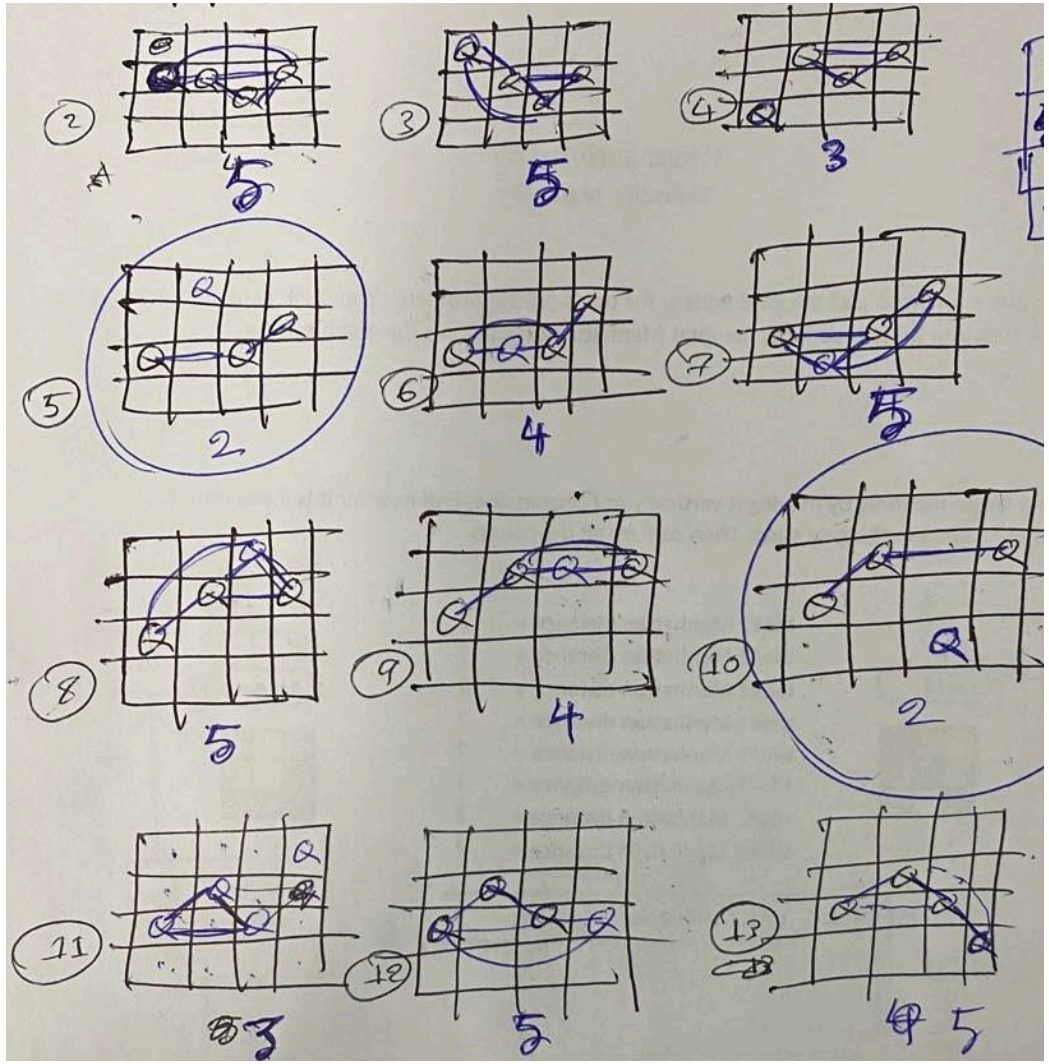
Midterm exam discussion

Question 3: BFS, DFS, IDS searches

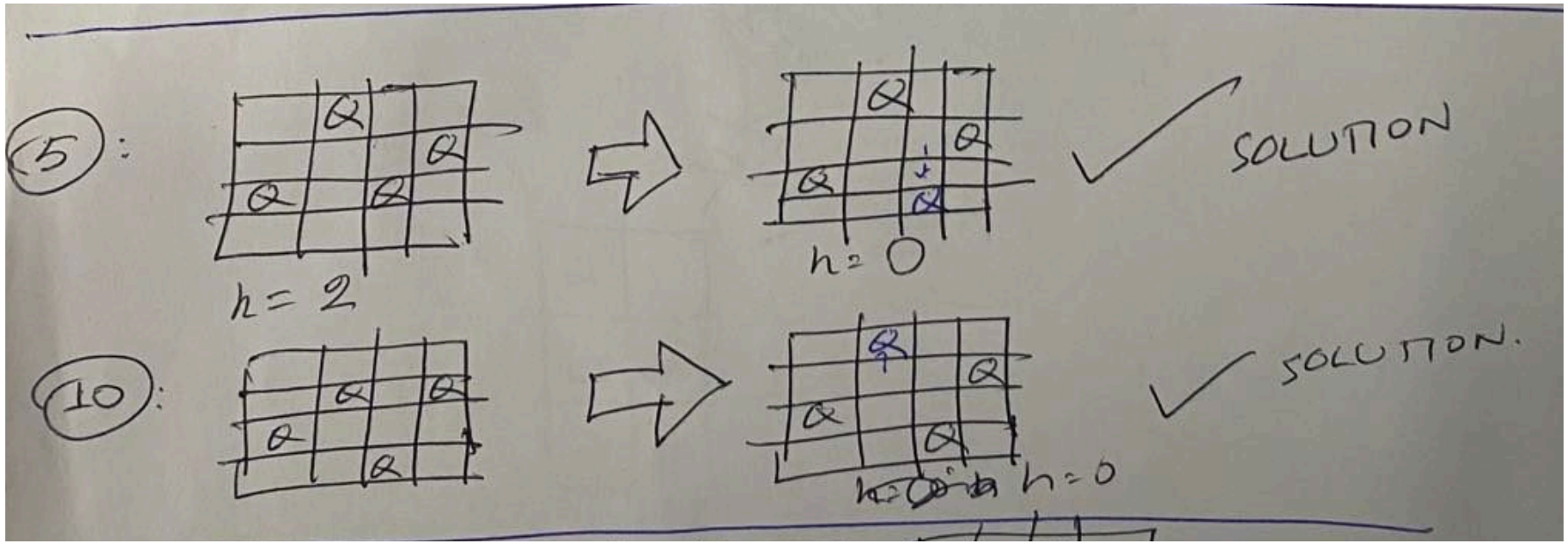
Question 4: Hill climbing search



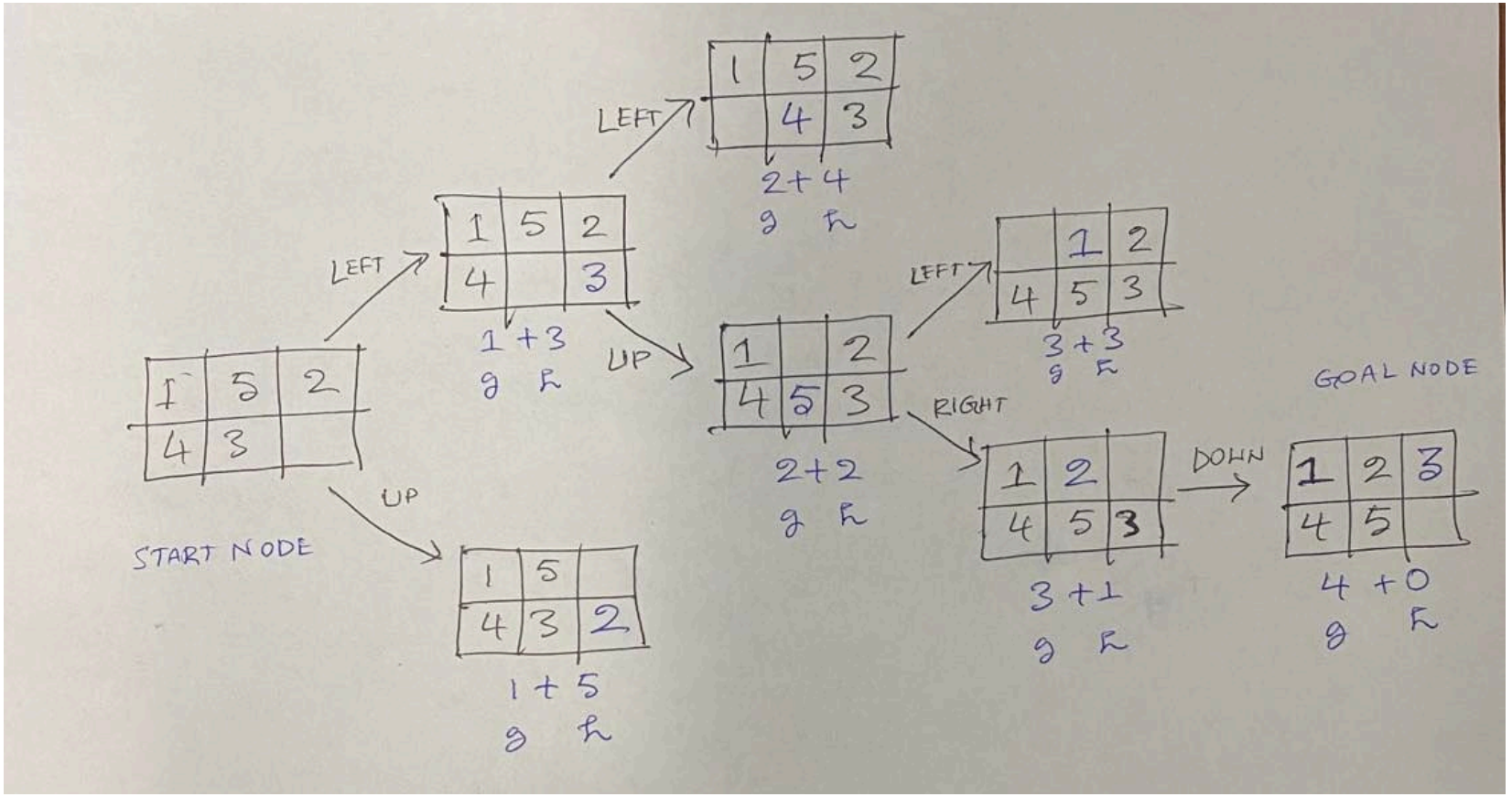
Question 4: Hill climbing search



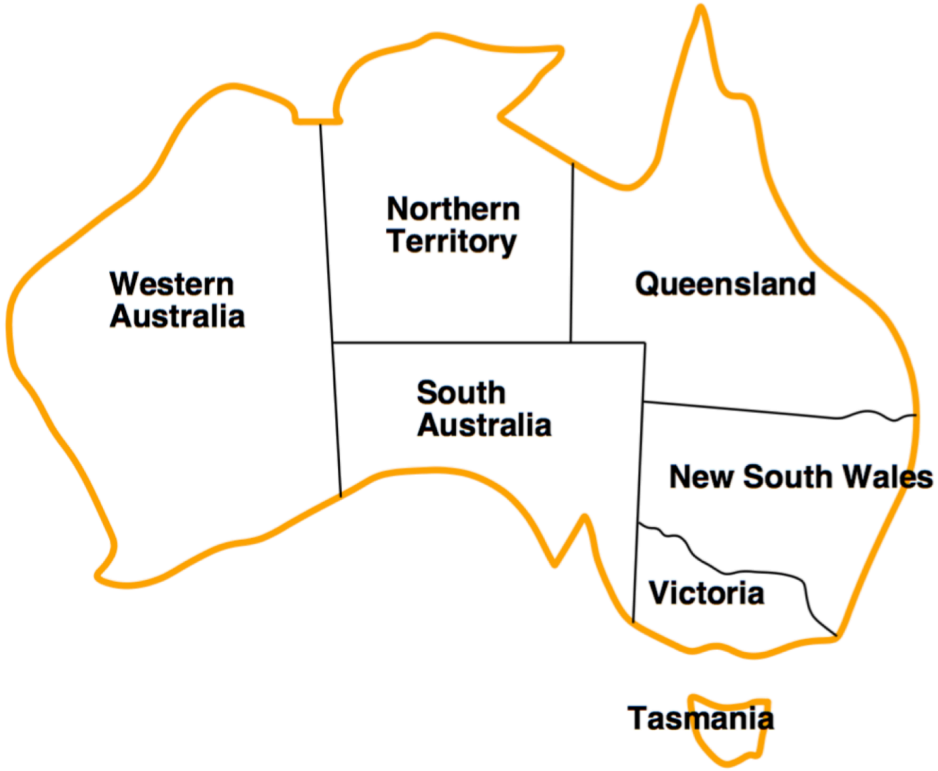
Question 4: Hill climbing search



Question 5: A* search

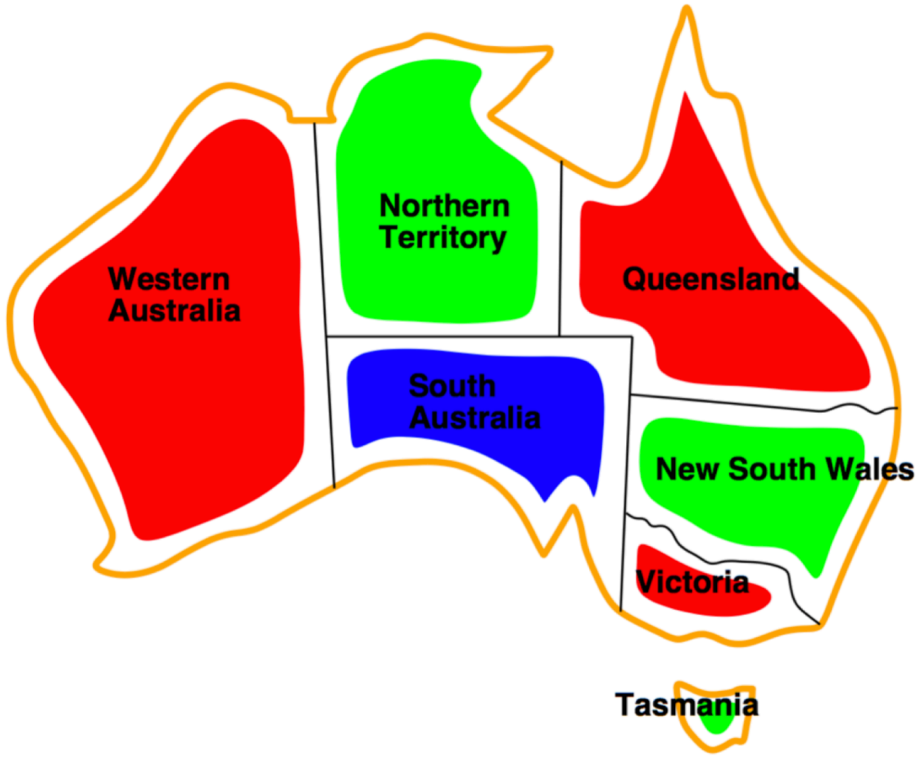


MAP COLORING PROBLEM



- Color each state so that no two adjacent states get the same color. You can use Red, Green, and Blue to color each state.

MAP COLORING IS A CONSTRAINT SATISFACTION PROBLEM (CSP)



- Here is a solution for the map of Australia

CSP

- Given a domain
  - possible values for each state in a problem
  - $D = \{D_1, D_2, D_3 \ldots D_n\}$
- Define a "State" by a set of variables X_i
  - $X = \{X_1, X_2, X_3 \ldots X_n\}$
  - Each variable X_i can be one of the values from the Domain
  - Each Domain D_i consists of a set of allowable values
- Define a set of constraints that must be true
  - Goal test is a set of *constraints* specifying *allowable* combinations of values
    - An "Assignment"

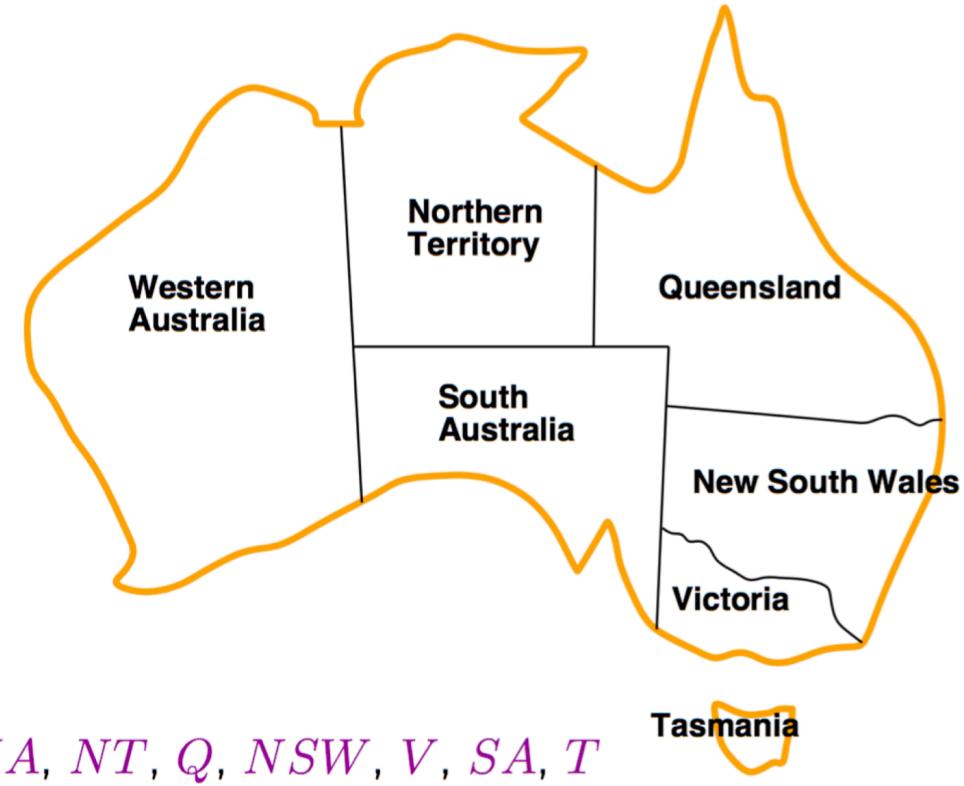
CSP

- If we put a problem into the format of having
  - X: a set of variables
  - D: a set of domains
  - C: a set of constraints that specify allowable combinations of values
- Allows useful *general-purpose* algorithms with more power than standard search algorithms

SOLVING A CSP

- Solving a constraint value problem involves:
  - An **assignment**: Each variable X_i is given a value.
  - An assignment that does not violate any constraints in C is called a **consistent/legal** assignment.
  - A **partial assignment** only assigns values to some of the variables.
  - A **complete** assignment has values assigned to each variable.
  - A **solution** is a *complete and consistent* assignment.

AUSTRALIA EXAMPLE



Variables WA, NT, Q, NSW, V, SA, T

Domains $D_i = \{red, green, blue\}$

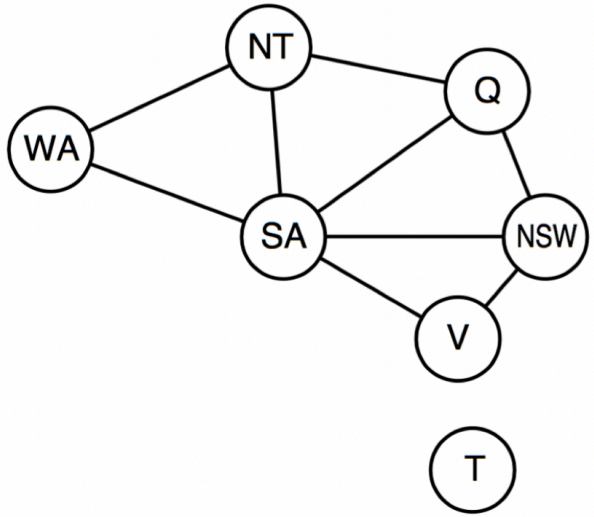
Constraints: adjacent regions must have different colors

e.g., $WA \neq NT$ (if the language allows this), or

$(WA, NT) \in \{(red, green), (red, blue), (green, red), (green, blue), \ldots\}$

CONSTRAINT GRAPHS

- Constraint graph: nodes are variables, arcs show constraints



- General-purpose CSP algorithms use the graph structure to speed up search.
    - Tasmania is an independent subproblem.

```python
class CSP:

    def __init__(self, variables, domains):
        # a list of variables
        # a dictionary of domains: a mapping of variables to a list of possible values
        self.variables = variables
        self.domains = domains
        self.constraints = {}
        for v in variables:
            self.constraints[v] = []
```

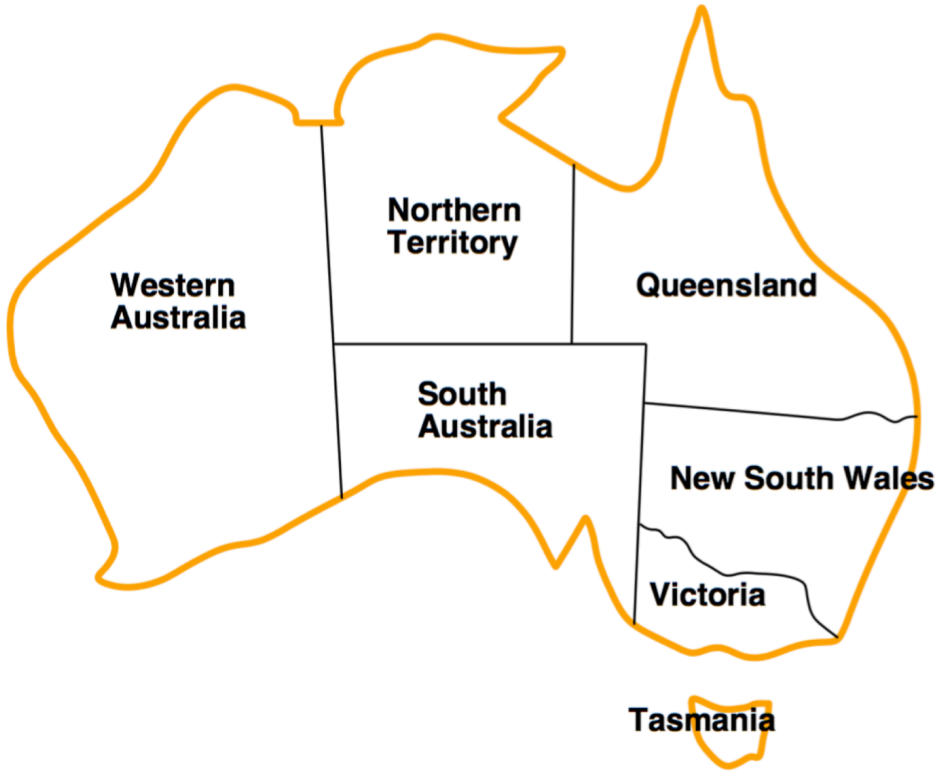
```python
variables = ["Northern Territory", "Queensland", "New South Wales", "Victoria"]
domains = {}
for variable in variables:
    domains[variable] = ["red", "green", "blue"]

myCSP = CSP(variables, domains)
```

Constraint Satisfaction Problem - Step 1

- Come up with a list of variables and possible values (domains) they can have

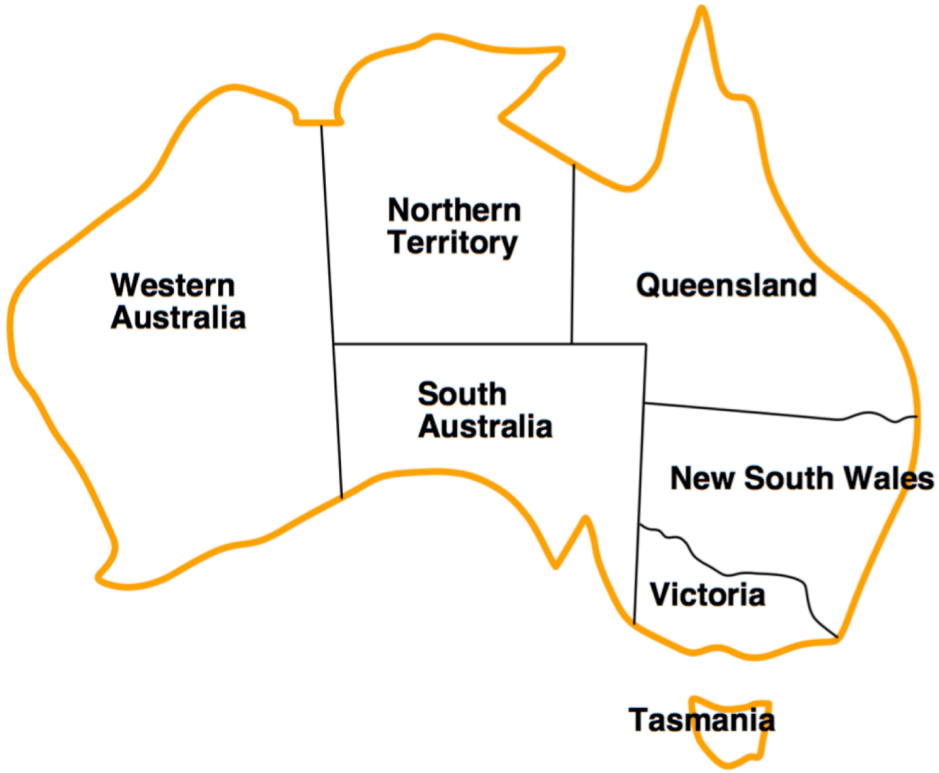
- WA: red, green, blue
- NT: red, green, blue
- SA: red, green, blue
- Q: red, green, blue
- NSW: red, green, blue
- V: red, green, blue
- T: red, green, blue



Constraint Satisfaction Problem - Step 2

- Come up with a list of constraints on the values (variables)

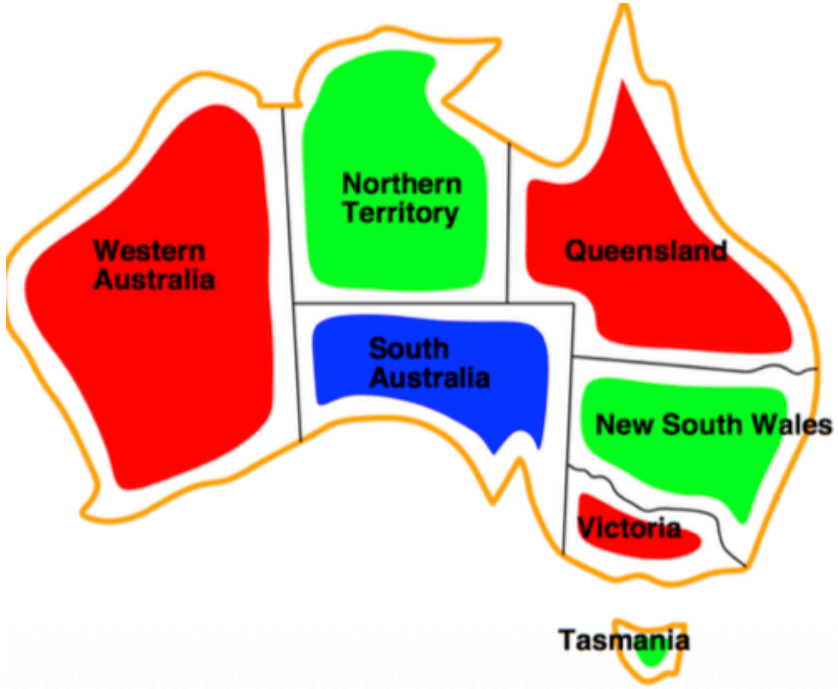
- WA ≠ NT
- WA ≠ SA
- NT ≠ SA
- NT ≠ Q
- SA ≠ Q
- SA ≠ NSW
- SA ≠ V
- Q ≠ NSW
- NSW ≠ V



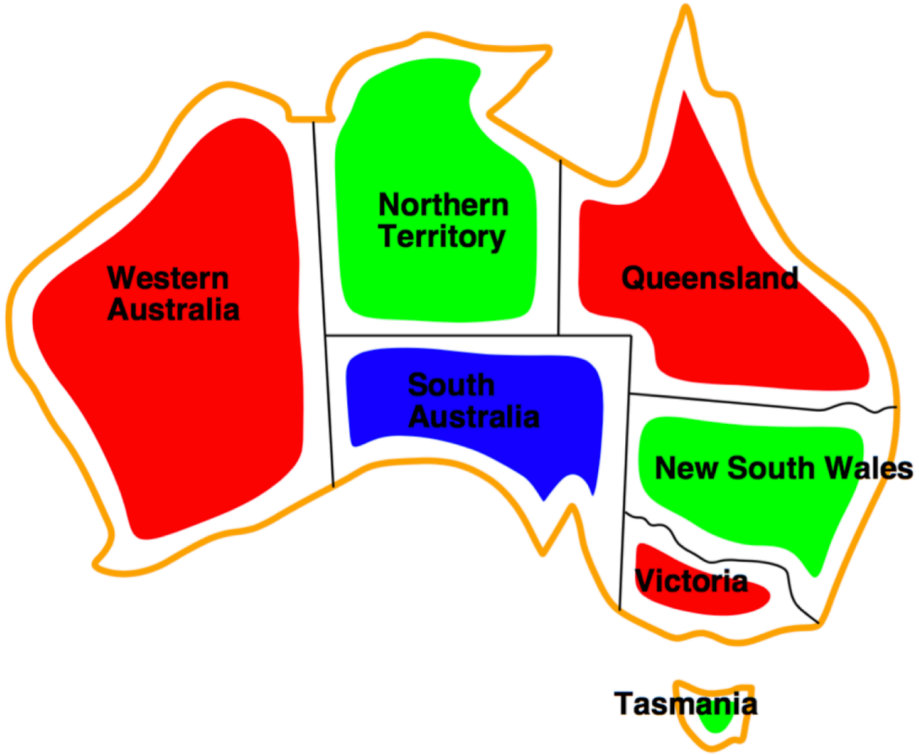
Constraint Satisfaction Problem - Step 3

- Input variables and constraints into a CSP solving algorithm
- There may be multiple solutions
- A solution is an assignment of values to variables

- WA = red
- NT = green
- SA = blue
- Q = red
- NSW = green
- V = red
- T = green



EXAMPLE: SOLUTION TO CSP



Solutions are assignments satisfying all constraints, e.g.,

$\{WA = red, NT = green, Q = red, NSW = green, V = red, SA = blue, T = green\}$

THE EXERCISE

- You are in charge of scheduling for computer science classes. There are 5 classes and 3 professors who will be teaching these classes. You are constrained by the fact that each professor can only teach one class at a time.

- The classes are:
  - **Class 1** - Intro to Programming: meets from **8:00-9:00am**
  - **Class 2** - Intro to Artificial Intelligence: meets from **8:30-9:30am**
  - **Class 3** - Natural Language Processing: meets from **9:00-10:00am**
  - **Class 4** - Computer Vision: meets from **9:00-10:00am**
  - **Class 5** - Machine Learning: meets from **9:30-10:30am**

- The professors are:
  - **Professor A**, who is available to teach Classes 3 and 4.
  - **Professor B**, who is available to teach Classes 2, 3, 4, and 5.
  - **Professor C**, who is available to teach Classes 1, 2, 3, 4, 5.

- **Exercise:** What are the variables and their domains? What are the constraints?