

CPSC 322 Assignment 1

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1 Question 1 (21points): Allocating Developments Problem

(a) Represent this problem as a CSP

(a) **Variables:**

$\{hc, bh, ra, gd\}$

(b) **Domains:**

$\{(0, 0), (0, 1), (0, 2), (1, 0), (1, 1), (1, 2), (2, 0), (2, 1), (2, 2)\}$

(c) **Constraints:**

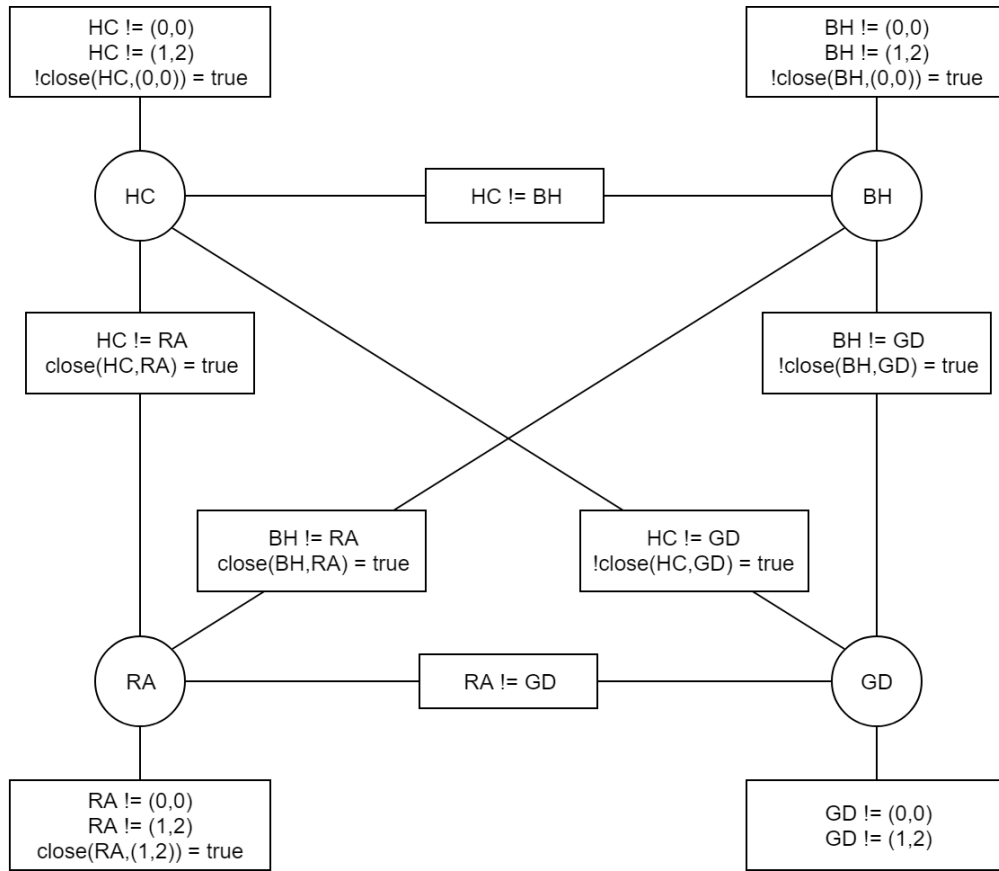
$\{hc \neq ra, hc \neq dg, hc \neq bh, bh \neq ra, bh \neq gd, ra \neq gd,$
 $hc \neq (0, 0), bh \neq (0, 0), ra \neq (0, 0), gd \neq (0, 0),$
 $hc \neq (1, 2), bh \neq (1, 2), ra \neq (1, 2), gd \neq (1, 2),$
 $!Close(hc, (0, 0)), !Close(bh, (0, 0)), !Close(hc, gd), !Close(bh, gd)$
 $Close(ra, (1, 2)), Close(hc, ra), Close(bh, ra)\}$

For our constraint definitions we use the following functions:

Function $Close(A, B)$

// Check if $\|A - B\|_1 == 1$, the Manhattan distance must be 1
return $(|A[0] - B[0]| + |A[1] - B[1]|) == 1$

(b) Draw a constraing graph for this problem



2 CSP - Search

- (a) Show how search can be used to solve this problem, using the variable ordering A, B, C, D, E, F, G, H.

Number of fails: 1278

Number of solutions: 4

Solutions:

| A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|
| 3 | 3 | 4 | 3 | 1 | 2 | 3 | 4 |
| 3 | 1 | 4 | 3 | 1 | 2 | 3 | 4 |
| 2 | 2 | 3 | 4 | 2 | 1 | 2 | 3 |
| 1 | 3 | 2 | 3 | 1 | 4 | 1 | 2 |

See **Appendix A** for the implementation of this CSP.

- (b) Is it possible to generate a smaller tree?

Yes by selecting in different order the variables we assign.

The heuristic we applied to our variable selection, was use first the variables that appear in more constraints. By using this heuristic the tree had only **153** failing branches which is much better than **1278** from the previous approach with alphabetical ordering.

The new order of the variable selection is:

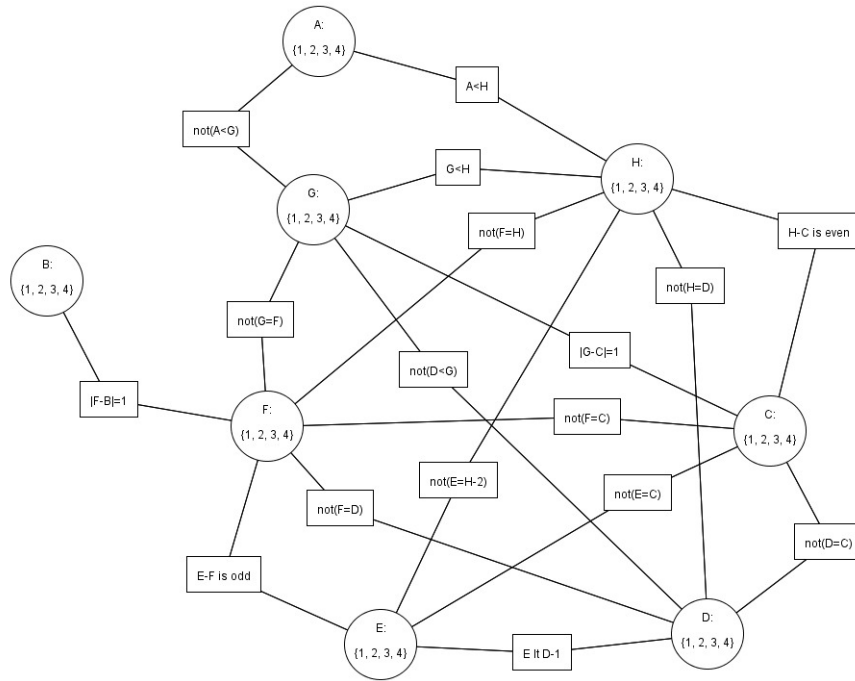
$$\{H, G, F, E, D, C, B, A\}$$

- (c) Explain why you expect the heuristic in part (b) to be good The branches in the search tree stop being searched if they are a failure or a solution, for this problem we know that a solution will always be at the end on the tree, so we need to improve the chance of having failures on shallow branches this will prevent us from doing unnecessary processing and will output a small tree.

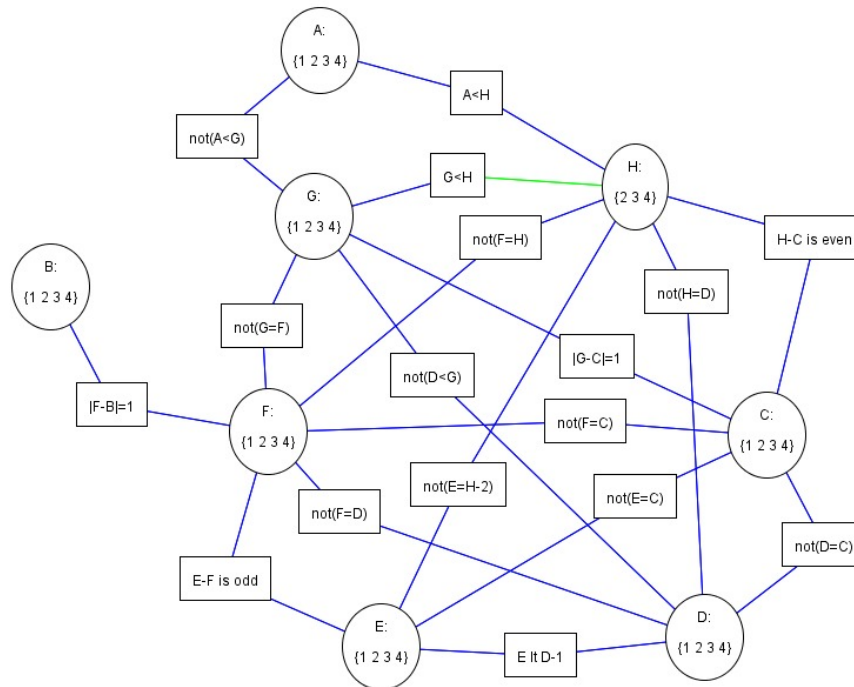
By using the heuristic of assigning a value first to the variables that appear the most in the constraints, we increase the chances for having a failing consistency check.

3 CSP - Arc Consistency

(a) Show how arc consistency can be used to solve the scheduling problem in Question 2

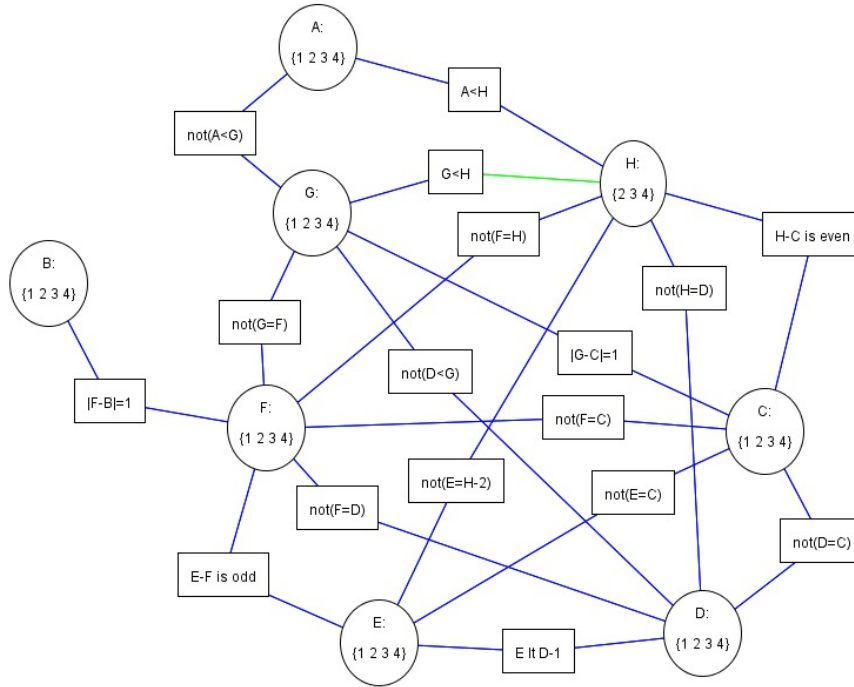


Initial state

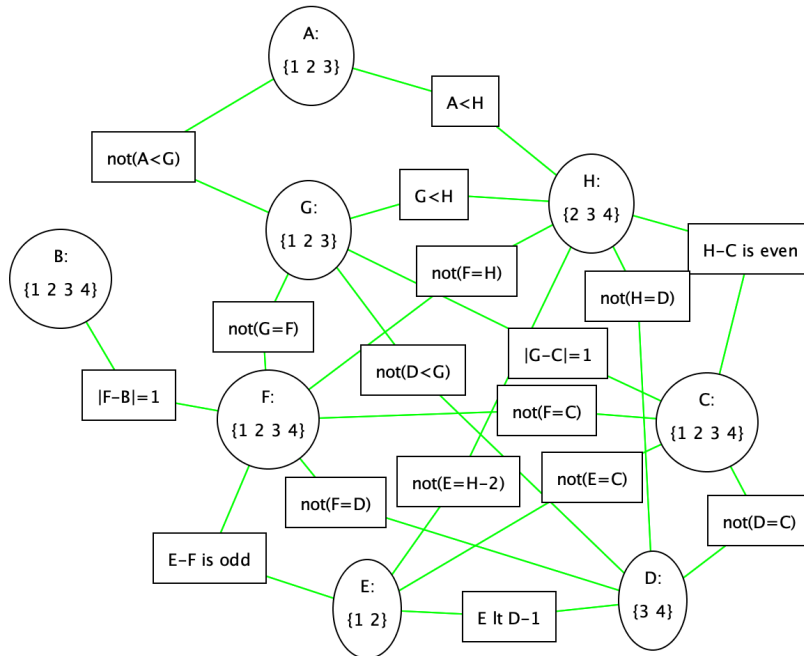


Step 1: arc (H, G) was selected, 1 was removed from the domain of H.



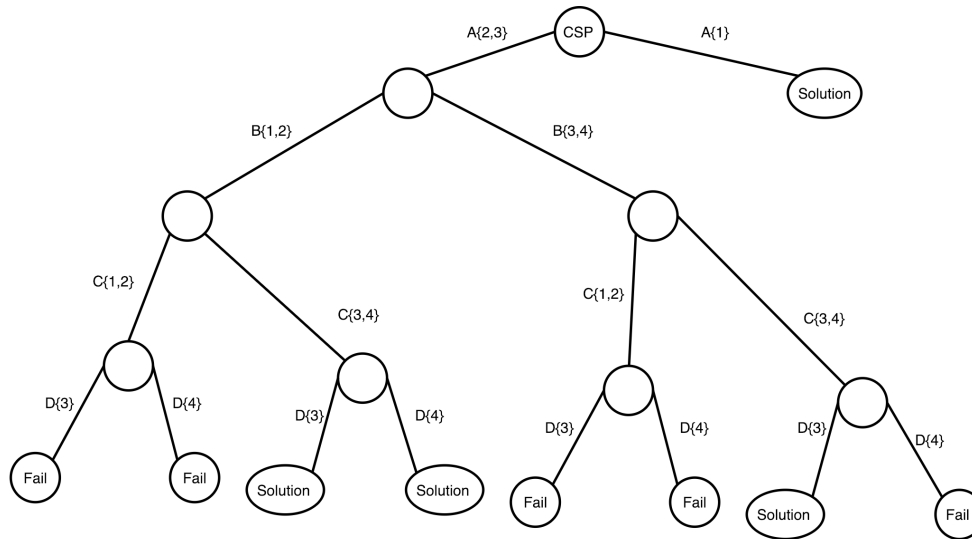


Step 4: arc (G, $-G-C=1$) was selectec, nothing was removed.



Final state

(b) Use domain splitting to solve this problem



Domain splitting graph

- (c) Constraint satisfaction problems can become extremely large and complex. Given the choice between DFS with pruning and arc consistency with domain splitting, what (qualitatively) is the tradeoff between the two methods in terms of time/space complexity?

DFS with pruning is gonna have less space complexity than arc consistency with domain splitting, because on DFS at worst you keep track of the value assigned to all eight variables, whereas with arc consistency with domain splitting we have to track the domain of every variable separately.

On the other hand the domain splitting method works faster and arrive to a solution in fewer steps rather than using DFS. We can recall that in the subsection 2.a, the implementation of dfs with pruning had to do **1278** failing branches to get all the solutions, even by using a heuristic for selecting the variable ordering in subsection 2.b got **153** failing branches. The domain splitting method only had **5** failing branches as we can see on the image above.

4 CSP - Stochastic Local Search

- (a) For one particular run, make SLS select any variable that is involved in an unsatisfied constraint, and select a value that results in the minimum number of unsatisfied constraints. Report the initialized values. At each step, report which variable is changed, its new value, and the resulting number of unsatisfied arcs. (You only need to do this for 5 steps).
- (b) Using batch runs, compare and explain the result of the following settings:
 - (i) Select a variable involved in the maximum number of unsatisfied constraints, and the best value.
 - (ii) Select any variable that is involved in unsatisfied constraints, and the best value.
 - (iii) Select a variable at random, and the best value.
 - (iv) A probabilistic mix of i. and ii. Try a few probabilities and report on the best one you find
- (c) Pick one of the methods(ii)-(iv) from part (b) and run it repeatedly (5 runs should be enough, but you may do more runs if you wish). State which method you chose. Give a screenshot of the results; then think about, describe and explain what you observe.
- (d) How important is it to choose the value that results in the fewest unsatisfied constraints as opposed to choosing a value at random? Justify your answer with evidence.
- (e) For the best variable/best value method from part(b), allow random resets (for example, after 50 steps). Give a screenshot comparing the results to what happens if random resets are not allowed, and explain how this affects the performance of the algorithm, and why.

A Appendix: CSP as Search implementation

```
import sys
# Helper class to represent a variable assignment
class Node:
    def __init__(self, name, value=None, depth = 0, values = []):
        self.adjacents = []
        self.name = name
        self.value = value
        self.depth = depth
        self.values = values.copy()
        if depth > 0:
            self.values[depth-1] = value
    # Returns the name and value of the node, i.e., A = 1
    def description(self):
        if self.depth == 0:
            return ""
        return "{}={}".format(self.name, self.value)
    # Links node to another one
    def link(self, node):
        self.adjacents.append(node)

"""
Solve the CSP
"""
def solveCSP(useHeuristic = False, file = None):
    # Problem configuration
    Domain = [1,2,3,4]
    varNames = ['A', 'B', 'C', 'D', 'E', 'F', 'G', 'H']
    constraints = {
        'AG': lambda A, G : A >= G,
        'AH': lambda A, H : A < H,
        'FB': lambda F, B : abs(F-B) == 1,
        'GH': lambda G, H : G < H,
        'GC': lambda G, C : abs(G-C) == 1,
        'HC': lambda H, C : abs(H-C) % 2 == 0,
        'HD': lambda H, D : H != D,
        'DG': lambda D, G : D >= G,
        'DC': lambda D, C : D != C,
        'EC': lambda E, C : E != C,
        'ED': lambda E, D : E < D-1,
        'EH': lambda E, H : E != H-2,
        'GF': lambda G, F : G != F,
        'HF': lambda H, F : H != F,
        'CF': lambda C, F : C != F,
        'DF': lambda D, F : D != F,
        'EF': lambda E, F : abs(E-F) % 2 == 1,
    }
    mapVarNames = {'A':0, 'B':1, 'C':2, 'D':3, 'E':4, 'F':5, 'G':6, 'H':7}
    varN = len(varNames)

    # Helper that check if constraints are valid for the provided values
    def checkConstraints(values):
        for key, constraint in constraints.items():
            X = values[mapVarNames[key[0]]]
            Y = values[mapVarNames[key[1]]]
```

```

        if X == None:
            continue
        if Y == None:
            continue
        if not constraint(X,Y):
            return False
    return True

# Helper that generates a new order for the variables to assign
def varNamesByHeuristic():
    heuristics = {}
    newNames = []
    mapNewNames = {}
    for i in range(varN):
        varName = varNames[i]
        heuristics.update({varName:0})
        for key, constraint in constraints.items():
            if varName in key:
                heuristics[varName] += 1
    i = 0
    for key in sorted(heuristics.keys(), reverse=True):
        mapNewNames.update({key: i})
        newNames.append(key)
        i += 1

    return newNames, mapNewNames

# CSP Solve setup
root = Node("Root", values=[None]*varN)
frontier = [root]
solutions = []
fails = 0
# For formatting correctly the tree structure
newLine = False
# If heuristic is needed, generate new ordering for the variables
if useHeuristic:
    varNames, mapVarNames = varNamesByHeuristic()
# If [file] is provided, the tree description will be written on a file with the name [file]
f = None
if file != None:
    f = open(file, "w+")

while(len(frontier)>0):
    n = frontier.pop()
    # Format the node description (Variable=Value)
    nTabs = 1
    if newLine:
        nTabs = n.depth
        newLine = False
    description = "{}{}".format("\t"*nTabs, n.description())
    # Write to terminal or the file
    if file != None:
        f.write(description)
    else:
        print(description, end="")

```

```

# Check if the current assigned variables are valid with constraints
if not checkConstraints(n.values):
    # Write to terminal or the file
    if file != None:
        f.write("failure\n")
    else:
        print("failure")
    fails += 1
    newLine = True
    continue

# Check if we hit a solution
if n.depth == varN:
    # Write to terminal or the file
    if file != None:
        f.write("solution\n")
    else:
        print("solution")
    solutions.append(n.values)
    newLine = True
    continue

# Add to frontier the next variable, assigning every possible domain value
for i in range(len(Domain)):
    new = Node(varNames[n.depth], Domain[i], n.depth+1, n.values)
    n.link(new)
    frontier.append(new)
f.close()
return varNames, solutions, fails

if __name__ == "__main__":
    if len(sys.argv)>1:
        # Use the heuristic for variable selection
        variables, solutions, fails = solveCSP(True, "../data/q2_tree_h.txt")
    else:
        # Use alphabetical ordering for variable selection
        variables, solutions, fails = solveCSP(False, "../data/q2_tree.txt")
    varN = len(variables)

    print("\nNumber of fails: {}".format(fails))
    print("\nNumber of Solutions: {}".format(len(solutions)))
    # Print the solutions
    print("\nSolutions:\n")
    for i in range(varN):
        print("\t{}".format(variables[i]),end="")
    print()
    for i in range(len(solutions)):
        for j in range(varN):
            print("\t{}".format(solutions[i][j]),end="")
        print()

```