

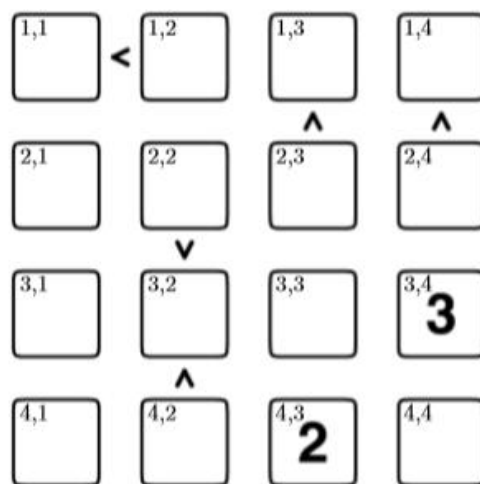
VE 492 Homework5

Due: 23:59, June.30th

Q1. CSP Futoshiki

Futoshiki is a Japanese logic puzzle that is very simple, but can be quite challenging. You are given an $n \times n$ grid, and must place the numbers $1, \dots, n$ in the grid such that every row and column has exactly one of each. Additionally, the assignment must satisfy the inequalities placed between some adjacent squares.

To the right is an instance of this problem, for size $n = 4$. Some of the squares have known values, such that the puzzle has a unique solution. (The letters mean nothing to the puzzle, and will be used only as labels with which to refer to certain squares). Note also that inequalities apply only to the two adjacent squares, and do not directly constrain other squares in the row or column.



Let's formulate this puzzle as a CSP. We will use 4^2 variables, one for each cell, with X_{ij} as the variable for the cell in the i th row and j th column (each cell contains its i, j label in the top left corner). The only unary constraints will be those assigning the known initial values to their respective squares (e.g. $X_{34} = 3$).

- Complete the formulation of the CSP using only binary constraints (in addition to the unary constraints specified above. In particular, describe the domains of the variables, and all binary constraints you think are necessary. You do not need to enumerate them all, just describe them using concise mathematical notation. You are not permitted to use n -ary constraints where $n \geq 3$).
- After enforcing unary constraints, consider the binary constraints involving X_{14} and X_{24} . Enforce arc consistency on just these constraints and state the resulting domains for the two variables.

- e) By inspection of column 2, we find it is necessary that $X_{32} = 1$, despite not having found an assignment to any of the other cells in that column. Would running arc consistency find this requirement? Explain why or why not.

a):

^{1,1} 3	^{1,2} 4	^{1,3} 1	^{1,4} 2
^{2,1} 1	^{2,2} 2	^{2,3} 3	^{2,4} 4
^{3,1} 2	^{3,2} 1	^{3,3} 4	^{3,4} 3
^{4,1} 4	^{4,2} 3	^{4,3} 2	^{4,4} 1

Domain = $\{1, 2, 3, 4\}$

$X_{1,1} < X_{1,2}$

$X_{3,2} < X_{4,2}$

$X_{1,3} < X_{2,3}$

$X_{1,4} < X_{2,4}$

$X_{3,2} < X_{2,2}$

$X_{ij} \neq X_{i,k}$ for $i, j, k \in \{1, 2, 3, 4\}$ and $j \neq k$.

$X_{ij} \neq X_{kj}$ for $i, j, k \in \{1, 2, 3, 4\}$ and $i \neq k$.

$$b) : X_{1,4} < X_{2,4}$$

$$X_{1,4} \neq X_{2,4} \neq 3, \quad X_{4,4} \neq 2$$

Domain of $X_{1,4} = \{1, 2\}$, $X_{2,4} = \{2, 4\}$

c) 4

d) 3

e) No, after running arc consistency we find the following domain of variables.

$$X_{1,2} = \{1, 2, 3\}, X_{2,2} = \{2, 3, 4\}, X_{3,2} = \{1, 2\}$$

$$X_{4,2} = \{3, 4\}.$$

We find that $X_{3,2} = 2$ also satisfy the constraints.

Q2. CSPs: Properties

True a) When enforcing arc consistency in a CSP, the set of values which remain when the algorithm terminates does not depend on the order in which arcs are processed from the queue.

True False

$O(d^n)$ b) In a general CSP with n variables, each taking d possible values, what is the maximum number of times a backtracking search algorithm might have to backtrack (i.e. the number of the times it generates an assignment, partial or complete, that violates the constraints) before finding a solution or concluding that none exists? (circle one)

0 $O(1)$ $O(nd^2)$ $O(n^2d^3)$ $O(d^n)$ ∞

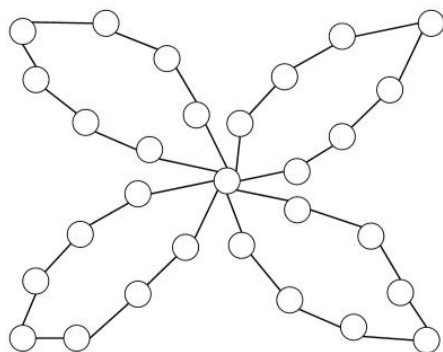
$O(d^n)$ c) What is the maximum number of times a backtracking search algorithm might have to backtrack in a general CSP, if it is running arc consistency and applying the MRV and LCV heuristics? (circle one)

0 $O(1)$ $O(nd^2)$ $O(n^2d^3)$ $O(d^n)$ ∞

0 d) What is the maximum number of times a backtracking search algorithm might have to backtrack in a *tree-structured* CSP, if it is running arc consistency and using an optimal variable ordering? (circle one)

0 $O(1)$ $O(nd^2)$ $O(n^2d^3)$ $O(d^n)$ ∞

e) **Constraint Graph** Consider the following constraint graph:



In two sentences or less, describe a strategy for efficiently solving a CSP with this constraint structure.

Let the central node be the cutset.
Then the four leaves become four tree-structured CSP, which can be efficiently solved.