Fall Semester, 2015 **B.Y. Choueiry**

CSCE 421/821: Foundations of Constraint Processing

Homework 4

Assigned: Wednesday, Oct 9, 2015

Due: Wednesday, Oct 23, 2015 (Wednesday, Oct 16, 2015 progress report due)

Total value: 100 points. Penalty of 15 points for lack of clarity.

Notes: This homework must be done individually. *If you receive help from anyone, you must clearly acknowledge it.* Always acknowledge sources of information (URL, book, class notes, etc.). Please inform instructor quickly about typos or other errors.

Contents

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1 Configuration and Design: Lot development (Total 10 points)

From Nadel (1989) via Dechter

The map in Figure 1 shows eight lots available Five developments are to be located on these lots: a recreation area, an apartment complex, a cluster of 50 single-family houses, a large cemetery, and a dump site. Assume the following information and conditions:

- The recreation area must be near the lake.

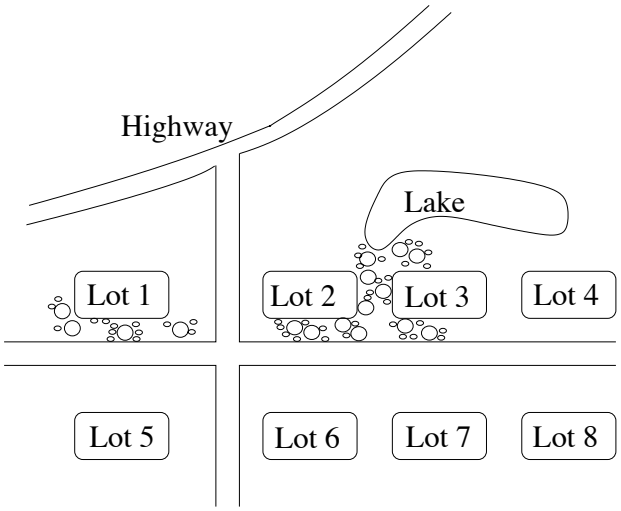

Figure 1: *Development map.*

- Steep slopes must be avoided for all but the recreation area.
- Poor soil must be avoided for developments that involve construction, namely, the apartments and the houses.
- Because it is noisy, the highway must not be near the apartments, the houses or the recreation area.
- The dump site must not be visible from the apartments, the houses, or the lake.
- Lots 3 and 4 have poor soil.
- Lots 3, 4, 7, and 8 are on steep slopes.
- Lots 2, 3, and 4 are near the lake.
- Lots 1 and 2, are near the highway.

Formulate this problem as a CSP. Define the variables, their domains, the constraints and the query. Clearly state any assumptions you make that are not listed above, otherwise

2 Reduction of 3SAT into a CSP (Total 10 points)

1. Formulate 3SAT as a CSP. (5 points)
   Indications: Your formulation should be as general as possible and should represent each of the elements of the 3SAT and its question in the terminology of a CSP. Consider X, the set of Boolean variables of a 3SAT instance. What are the values that a variable can take? Use this to define the variables of the CSP and their values. A clause is a disjunction of literals. How

to represent a clause in the CSP formalism? A 3SAT sentence is a conjunction of clauses. How is the sentence represented in the CSP formalism? Finally, state how the question of 3SAT is reduced as a question to the CSP and prove that a solution to 3SAT exists if and only if a solution to the corresponding CSP exists.

2. What is the arity of the constraints of the resulting CSP? (1 points)

3. As a direct application of your reduction, transform the following 3SAT problem into a CSP. Specify the variables, their domains, define the constraint in extension, and draw the corresponding constraint network: (2 points)

$$(c_1 \vee c_2 \vee c_3) \wedge (c_2 \vee c_3 \vee c_4) \wedge (\neg c_1 \vee c_5) \wedge (c_1 \vee c_4 \vee c_5)$$

4. Knowing how a 3SAT clause (which is a disjunction of at most 3 literals) is represented in the CSP, how do you propose to represent a clause of SAT (which has an arbitrary number of literals in the clause)? (2 points)

3 Conflict-Directed Backjumping (CBJ)

The goal of this exercise is to implement and test CBJ.

- Implement CBJ for finding a single solution. 20 points
- Implement CBJ for finding all solutions (see lecture slides pages 26, 27, and 28). 20 points
- Report the results obtained on the examples of Homework 3 for finding both 1 solution and all solutions. 5 points
- Report the results for finding a *single* solution on the wiki by filling out the Excel sheet. The results should be reported for the four ordering heuristics. 10 points
- Report the results for finding *all* solution obtained on the wiki by filling out the Excel sheet. The results should be reported for the four ordering heuristics. 10 points
- Your impressions on the results of BT and CBJ. 5 points
- *Progress report* (**Due Wednesday, Oct 16, 2015**): Submit a progress report documenting how far along you are and submit some version of your code. 10 points

3.1 General indications

- *Please make sure that you keep your code and protect your files.* Your name, date, and course number must appear in each file of code that you submit.

- All programs must be compiled, run, and tested on `cse.unl.edu`. Programs that do not run correctly in this environment will not be accepted unless prior approval is obtained. You must include a Makefile with your program so that your code can be compiled by issuing 'make' while on `cse.unl.edu`. You also must include a script called 'runProgram.sh' that contains the command to run your program.
- You must submit a README file with precise steps on how to compile, run and test your code. Failure to do so may result in no points for the homework.
- To facilitate debugging and the expectations of the homework assignment, web grader is set up to quickly evaluate the correctness of your program: `https://cse.unl.edu/~cse421/grade/`. After you have files submitted through webhandin, you will be able to run the web grader.

3.2 Implementation Notes

Please carefully consider the following requirements in your implementation.

3.2.1 Administrative

Implement the mechanism for reducing the backtracking effort 'conflict-directed backjumping' (CBJ). Your procedure should take the parameters specifying the ordering heuristic: LD, degree, or ddr. You are responsible for the static ordering of the variables.

Specify the search algorithm BT or CBJ by passing parameters to the program. You are required to implement the following flags to specify the algorithm and the ordering heuristic:

- **-s BT** for backtrack search
- **-s CBJ** for conflict-directed backjump search
- **-u LX** for lexicographical ordering heuristic
- **-u LD** for least domain ordering heuristic
- **-u DEG** for degree domain ordering heuristic
- **-u DD** for domain degree domain ordering heuristic
- **-f** <**filename**> for the file of the CSP problem

Notice that exactly one **-s**, one **-u** and one **-f** flags are passed to the program. Failure to follow the specification of the flags above may results in deduction of substantial amount of points.

Your output should be the same as in Homework 3. The output format that web grader will check is in the following:

```
Instance name: XXX
Search: BT|CBJ
variable-order-heuristic: LX|LD|DEG|DD
var-static-dynamic: static
value-ordering-heuristic: LX
val-static-dynamic: static
cc: XXX
nv: XXX
bt: XXX
cpu: XXX
First solution: <sequence of values for the variables in order to pass to the SolutionChecker>
all-sol cc: XXX
all-sol nv: XXX
all-sol bt: XXX
all-sol cpu: XXX
Number of solutions: XXX
```

where the XXX should be replaced with the corresponding values.

3.2.2 Datastructures

The additional information required for CBJ may be stored in an array, linked-list, hashtable, etc. Irrespective of the programing language or the libraries of datastructures you are using, for acceptable performance implement operations on the datastructures that take constant time whenever possible. That is, every time you add or remove an element, the cost should be constant whenever possible. Avoid traversing the list for addition or removal of items unless the cost is negligible.