Artificial Intelligence (CS 452/552)
Assignment 02 (80–100 points)

Due before class, Friday, 13 October 2017

[**1**] (*75 points*) This exercise involves coding, and writing a few paragraphs about the final result. I prefer that you code the solution in Java, but if you wish to use another language, let me know first. Your program needs to run from the command line, using the command `java Solve`, and take **two strings** as input. The strings will be the names of two text files. This first file will describe a crossword puzzle grid; the second will contain a list of words. Your program will use CSP techniques to attempt to find a combination of words from the dictionary that will fill in the crossword grid, where a complete solution satisfies the conditions:

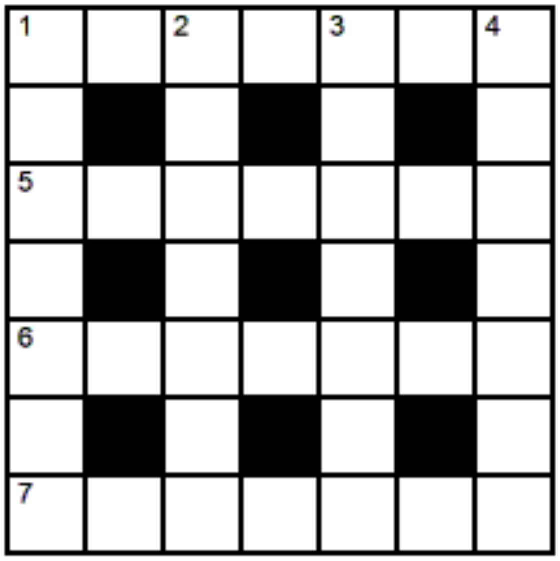
a. Words begin at numbered squares, and fill up all blanks leading across or down from that number until encountering the edge of the puzzle or a black square.

b. Across words always have a puzzle edge or a black square to the **left of their number**; down words always have a puzzle edge or a black square **above their number**.

c. If two words intersect at a given blank square, their letters must match.

A puzzle specification file will begin with two integers `ROW` and `COL`, specifying the number of rows and columns in the puzzle. It will then have a corresponding grid of numbers, mixed with symbols for blank squares (the underscore, _) and black squares (the ampersand, &). For example, the puzzle file `xword00.txt` and the puzzle grid it represents look like:

```
7 7
1 _ 2 _ 3 _ 4
_ & _ & _ & _
5 _ _ _ _ _ _
_ & _ & _ & _
6 _ _ _ _ _ _
_ & _ & _ & _
7 _ _ _ _ _ _
```



When run, your program will perform **backtracking CSP search** to solve the problem. It will:

a. Read in the puzzle file and dictionary file.

b. Based on the puzzle file, it will compute the number of variables (blank words going across or down) in the problem, and print out this value.

c. It will compute the set of constraints on the variables—there will be one constraint for every position in the grid at which two words intersect.

d. For each word-variable, it will compute the possible domain of values (words of the right length) from the dictionary file. Initially, each variable will be assigned no value from its domain. The program will print out a list of the variables (given in the form m-`across` or n-`down` for appropriate values of m, n), along with the size of that variable's domain.

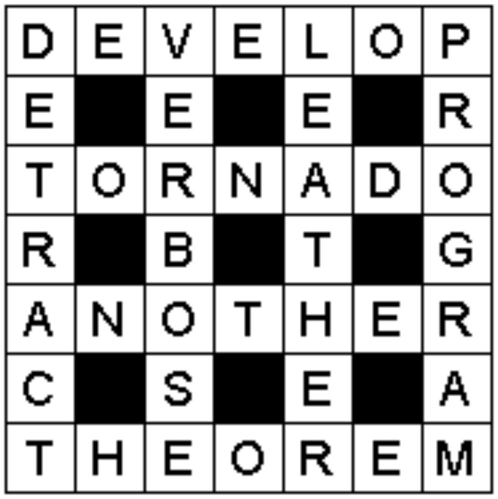
e. It will employ recursive backtracking search, as explained in lecture and the textbook.

- When choosing a variable (SELECT-UNASSIGNED-VARIABLE), use the ***Most-Constrained Variable*** heuristic; break ties using the ***Most Constraining Variable*** heuristic, as described in lecture 09, slides 5–6. Values of variables can be iterated over in any order.
- The INFERENCE step will be left out of the algorithm, making it a little simpler.

f. Search will terminate when either a variable assignment is found that satisfies all constraints or no such solution is found, and search fails.

- When search fails, the program will indicate that no solution was found, and print out the number of distinct calls to the recursive search method were made.
- If search is successful, then it will also print out how many recursive calls were required, and then print out the final solution (using spaces for black squares in the grid).

For example, if we ran the CSP solver on the `xword00.txt` file given above, along with the file `dictionary_small.txt`, a possible solution to the problem is:



In generating the solution just given, our program output will look something like:

```
%java Solve xword00.txt dictionary_small.txt

8 words
16 constraints

Initial assignment and domain sizes:
1-across = NO_VALUE (8 values possible)
1-down = NO_VALUE (8 values possible)
2-down = NO_VALUE (8 values possible)
3-down = NO_VALUE (8 values possible)
4-down = NO_VALUE (8 values possible)
5-across = NO_VALUE (8 values possible)
6-across = NO_VALUE (8 values possible)
7-across = NO_VALUE (8 values possible)

SUCCESS! Solution found after 648 recursive calls to search.

DEVELOP
E E E R
TORNADO
R B T G
ANOTHER
C S E A
THEOREM
```

When you have finished encoding the solution, your code should be able to solve the smallest puzzles in most cases; run tests of this as follows:

a. Test the simplest puzzle grid (`xword00`) against all three of the dictionaries. A proper implementation will solve the puzzle in all three cases very quickly.

b. Test the second-simplest puzzle grid (`xword01`) against the `small` and `medium` dictionaries. A proper implementation will solve the puzzle in the `small` case very quickly, while the `medium` case may take several seconds.

Optional: Test this puzzle grid against the `large` dictionary. This can be solved, but it may take a few minutes.

c. Test the more complex puzzle grid (`xword02`) against the `small` dictionary. The algorithm should very quickly determine that the problem can't be solved, as the dictionaries lack the words necessary to fill the grid. (Trying to solve this puzzle on either of the larger dictionaries is unlikely to succeed in under an hour or so.)

[**2**] (*20 points*) ***Required of anyone taking the 552 course; optional for those in 452.***

As described in the text and in class, we can use the method of **arc-consistency** as a pre-processor for solving a CSP, to reduce the number of actual values allowed for the variables in the problem. You will implement the `AC-3` algorithm given in the text, and run it on the CSP problem (after step **d**, page 2) before doing search.

When you do so, you will amend your code so that it can run both the version without pre-processing (as before) and a version where pre-processing is performed. The code should run from the command line as before, and the first two arguments will be the same file-names. If a third argument is provided, of any sort, then pre-processing should be done; that is, ***any*** of the following commands will invoke the pre-processor:

```
java Solve xword01.txt dictionary_small.txt true
java Solve xword01.txt dictionary_small.txt 1
java Solve xword01.txt dictionary_small.txt bananagram
```

In addition, if the pre-processing option is chosen, then the code should print out the size of each variable's domain both ***before and after*** running the arc-consistency check, and then proceed to do the search on the reduced domain.

If properly implemented, the search should then proceed very quickly to a solution or failure state, for any combination of puzzle and dictionary files. Test this.

You will hand in source-code for the program. The instructor will compile it and test it by giving it different input files. All sample files are provided, and you can create your own for testing, but you need to use the same format as given above. Your code should be adequately commented, and function properly. If special instructions are needed for any step (compile or run), especially if you have used some language other than Java (with the instructor's permission), then you must provide those instructions.

Submit the work by uploading a compressed folder containing all of your source to D2L by the due-date and time (before class on the date given at the start of the assignment).