Solutions to Exercises Week 9
Intelligent Systems Programming (ISP)

Exercise 1

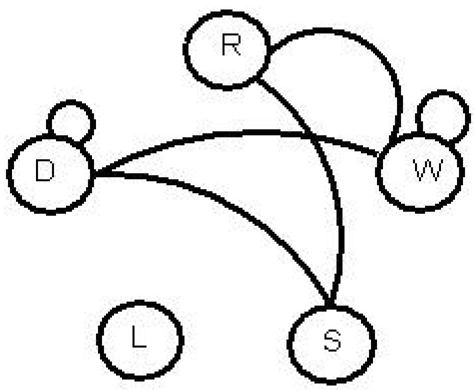
a) CSP model:

Variables: {*R*, *D*, *L*, *S*, *W*}

Domains: {*1*, *2*, *3*} for each variable

Constraints: {$S \neq D$, $S = R$, $D \neq 3$, $D \neq W$, $W = 2$, $W \neq R$}

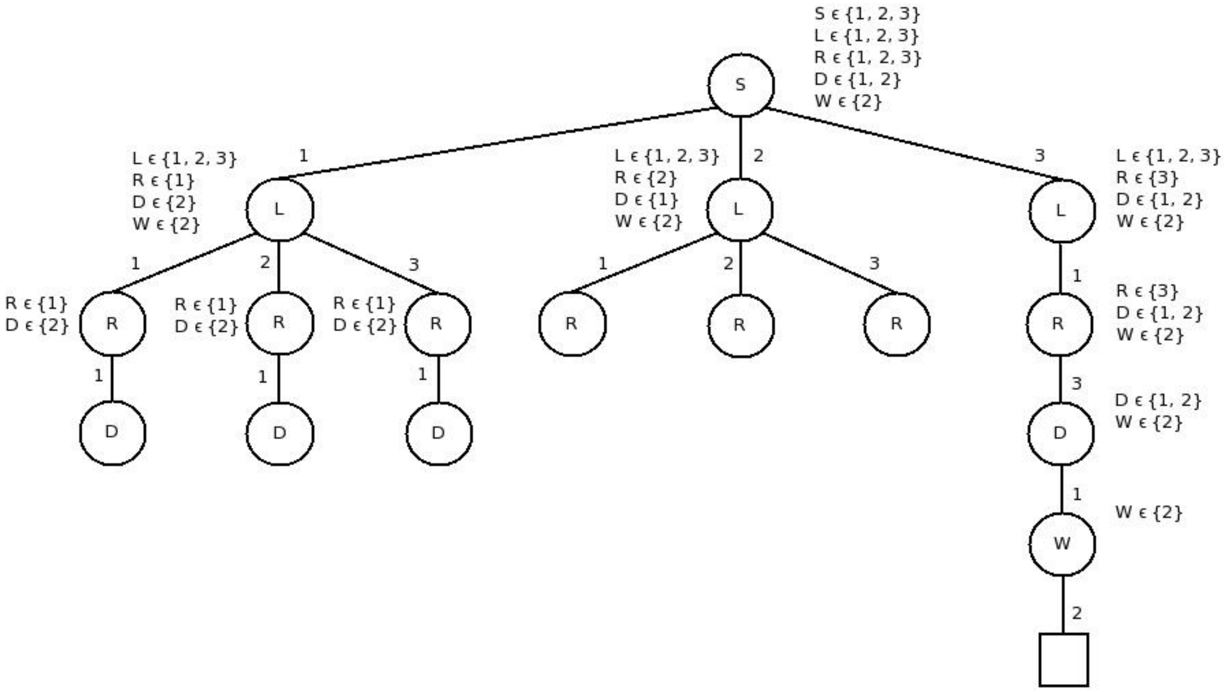
b) CSP graph:



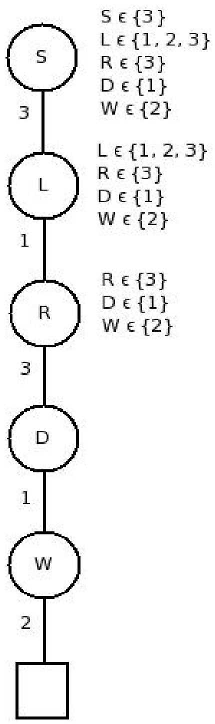
c) Each node has right next to it the domain of the variables after executing FC with the previous variable-value assignment. In the case of the first node the domains shown are the result of executing node consistency on the CSP. The values on the edges of the search tree represent the variable-value assignment represented by the branch. Each **leaf** with a circular shape represents a failed node (not possible variable-value assignment). The **leaf** with a square shape represents a solution.

The solution found by FC was {$S = 3$, $L = 1$, $R = 3$, $D = 1$, $W = 2$}

FC search tree:



d) MAC search tree:



The solution found by the MAC algorithm was {$S = 3$, $L = 1$, $R = 3$, $D = 1$, $W = 2$}, the same found by the FC algorithm.

Exercise 2

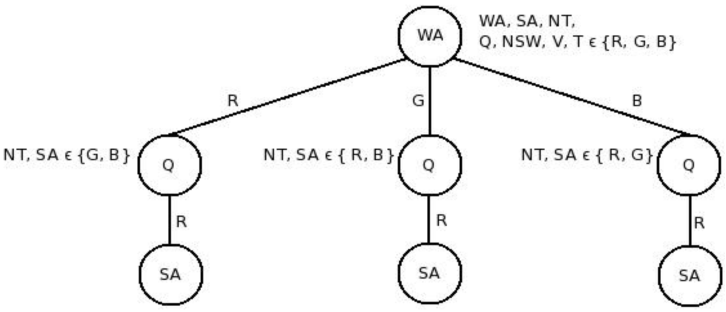
a) CSP definition:

X = {WA, NT, SA, Q, NSW, V, T}, one variable for each territory

D = {R, G, B} for all variables

C = {$WA{\neq}NT$, $WA{\neq}SA$, $NT{\neq}SA$, $NT{\neq}Q$, $SA{\neq}Q$, $SA{\neq}NSW$, $SA{\neq}V$, $Q{\neq}NSW$, $NSW{\neq}V$, $Q{\neq}V$}

b) MAC search tree:



The value on each branch represents the variable-value assignment for the variable in the previous node. The domains next to the nodes are the result of executing AC-3. Only the variables whose domains have changed are shown. Each **leaf** with a circular share represents a failure node. Notice that in the left node for Q, the domain of Q is still {R,G,B} that only R leads to a child is due to the fact that trying G and B lead to failure of AC-3!

We can see that after adding the constraint $Q{\neq}V$, the CSP doesn't have a solution anymore.

c) We define a new our new set of constraints C´, where we include the symmetry-breaking constraints.

$C´= C \cup \{WA>NT, WA > SA, NT > SA\}$

Then we proceed to solve the CSP with the new set of constraints by using the MAC algorithm. After including the symmetry-breaking constraint, the AC-3 algorithm at the pre-processing step finds out that it is not possible to have valid assignments for all the variables of the CSP, therefore avoiding any further search. The search tree is reduced to zero nodes.

Exercise 3

a) We proceed here to define a CSP model for this problem. In order to do so we need to define our set of variables, the domain of those variables, and the constraints over the variables. Since we are interested in determining the price of the items that the kid bought at the store, it makes sense that the variables in our CSP model represent the cost of each item. The domain of the variables is then the price each of the products can take. Since the only information we have is that the price of all products together (the sum and the product) is \$7.11, we define as domain of each variable all number from 0 to 7.11 (we do not include in the domain of the variables all real numbers between 0 and 7.11, but instead we define our level of granularity to be based on cents). Two constraints are defined in our CSP model, where the first one represents the fact that the sum of all items is equal to \$7.11 and the second one that the product of all items is \$7.11.

Summarizing we have:

Variables: $\{V_1, V_2, V_3, V_4\}$

Domains: $\{0,\ldots,7.11\}$ for all variables

Constraints: $V_1 + V_2 + V_3 + V_4 = 7.11$, $V_1 * V_2 * V_3 * V_4 = 7.11$

b) The set of integer and real numbers are said to be commutative over the addition and multiplication. This means that in a sum or a product, it does not matter in which order we sum or multiply the terms of the operation, the result will be always the same. Due to this property, we can freely swap the values we assign to the variables and generate equivalent solutions. In order to overcome this situation we add an ordering constraint to our problem: $V_1 \leq V_2 \leq V_3 \leq V_4$.