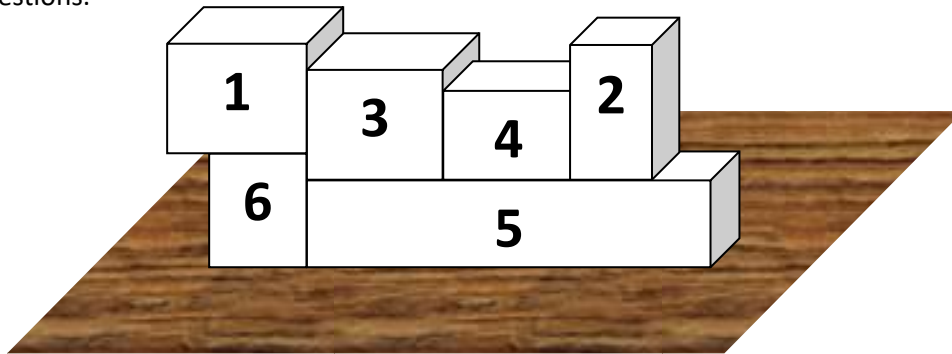# SOLUTION

**1)** In this question, you will be solving a box-coloring problem. In this domain, there are 6 boxes stacking on each others. Each of the boxes must be colored in one color of three possible colors (Gold, Silver, and Bronze). The boxes must be colored in such a way that no adjacent boxes are the same color. Two boxes are considered to be adjacent if they touch along an edge. (Two boxes that touch only at a corner are not adjacent.) Here is the picture that you'll be using for all of the questions:


A) **Backtracking search**

Suppose we decide to use simple backtracking search to find a solution to this constraint satisfaction problem. The variable ordering heuristic we use is simply to instantiate the variables in numbered order. The color value ordering heuristic is to consider the color values in the order Gold, Silver, Bronze. You can use any reasonable shorthand to indicate the instantiations (e.g., "1=G" can mean box 1 is instantiated to the gold color).

(i) Show the complete search tree, circling the solution node, if one is found.
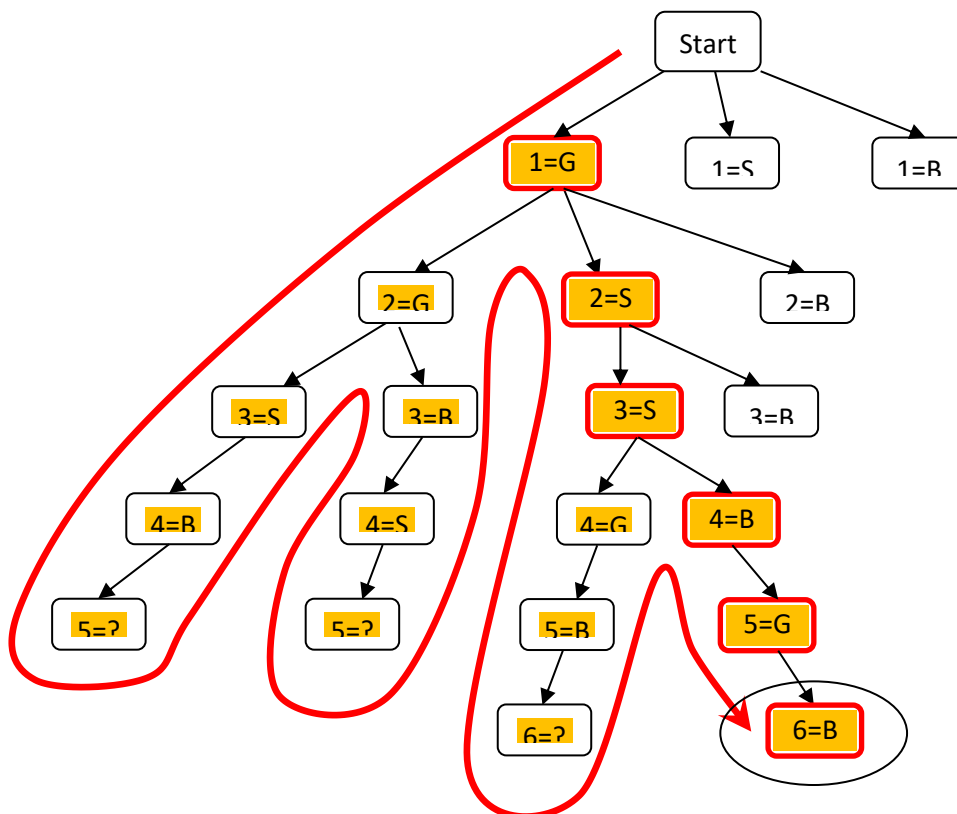
(ii) Show the final coloring, if one is found, on the picture above or on a copy of the picture.
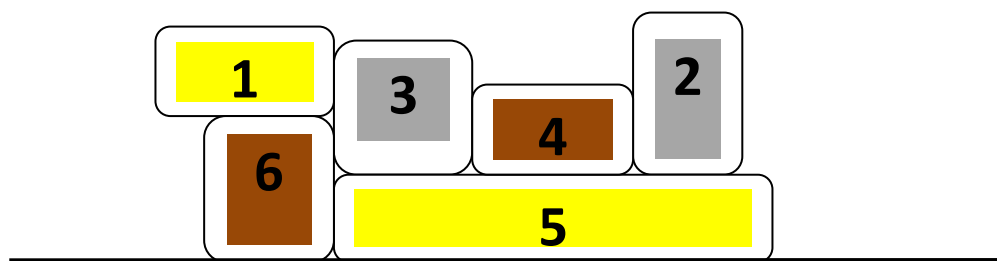
(iii) How many variable instantiations (search steps for both successful and unsuccessful) are tried by this search method?

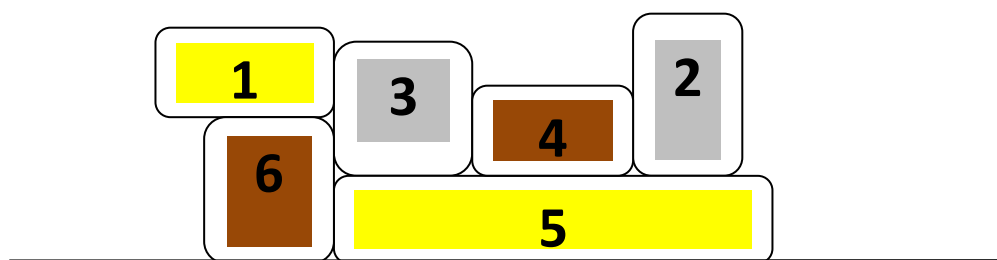   ***16 variable instantiations***

   B) **Forward checking**

Now suppose we use forward checking to eliminate illegal values from the domains of un-instantiated variables. (Recall that in forward checking; only the constraints immediately connected to instantiated variables are checked.) Furthermore, suppose we use a variable ordering heuristic that <u>chooses the variable with the fewest legal instantiations remaining</u> to instantiate next. If more than one such variable exists, the one earlier in the numbered order is selected (for example, choose box 1 before box 3). The same color value ordering heuristic is used as in backtracking search (i.e., consider first gold, then silver, then bronze).

(i) Show the complete search tree for forward checking search. At each node, show the remaining legal values for the un-instantiated variables. For example, at the first node below the root, only box 1 will be colored, so you should indicate the legal values for variables 2, 3, 4, and 5. Continue until your search finds a solution or fails.

Step		Box 1	Box 2	Box 3	Box 4	Box 5	Box 6
Start	*Instantiations*	GSB	GSB	GSB	GSB	GSB	GSB
1	*1=G*	**G**	GSB	SB	GSB	GSB	SB
2	*3=S*	**G**	GSB	**S**	GB	GB	B
3	*6=B*	**G**	GSB	**S**	GB	G	**B**
4	*5=G*	**G**	SB	**S**	B	**G**	**B**
5	*4=B*	**G**	S	**S**	**B**	**G**	**B**
6	*2=S*	**G**	**S**	**S**	**B**	**G**	**B**

(ii) Show the final coloring, if one is found, on a copy of the picture above.

(iii) How many variable instantiations are tried by this search method?

6 variable instantiations

C) **Solution spaces**

(i) How large is the search space for this problem? That is, how many different colorings, legal or illegal, are there for the blank picture shown above?

All possible solutions are 3^6 = 729 cases.

(ii) For this picture, how many different solutions (legal colorings) are there?

You can see that box 1, 3 and 6 are connected to each other, so each box have to get a unique color, therefore there are 6 possible solutions here. Because Box 1 has 3 possible colors in which each case there are 2 possible ways to color box 3 & box 6. Therefore, there are 3x2=6 possible solutions for box 1, 3 and 6.

Then, for each possible solution of box 1, 3 and 6, the color of box 2 have to be the same color as box 3, in which will force box 4 and 5 to have only one possible color for each box.

Finally, there are 3x2x1 = 6 possible solutions.

2) **Representing and solving a CSP problem:**

Constraints At The Zoo

Last month, five mothers brought their five kids to the zoo. It was a fun time for the kids. Some of the kids dared to touch animal fur and feed the food for some animals. Moreover, every kid found out that each of them had one kind of animals of their own favorite and one kind of hated animals. Surprisingly, all those animals were only five distinctive kinds of animals. <u>In addition, an animal that a kid loved would be the animal that another kid hated, because each kid liked and disliked different kinds of animals</u>. Additionally, in order to reward the kids who well behaved for the whole day, the mothers bought snacks for the kids—one kind for each kid. More clues are listed as follows…

1. **Julia** chose **candy**. **Mary** did not choose **apple**. Kid whose last name was **Procter** did not like **monkey**.
2. **Alan Small**'s favorite animal was not **seal**. **Beth** is the girl who did not choose **doughnut**.
3. No boys chose **doughnut**. One boy chose **corn-chip**. Another boy liked **monkey**. One who did not like **giraffe** chose **popcorn**.
4. The kid whose last name was **Brown** liked **lion**. **Beth** liked **seal**. **Mary**'s last name was not **Cook**.
5. **Tom**, whose last name was not **Brown** did not choose **apple**. The kid whose last name was **Macgreger** chose **doughnut**.
6. The girl who liked **elephant** did not like **seal**. The kid whose last name was **Cook** liked **monkey**. The animal **Alan** hated was not **giraffe**.

A) Define this problem formally as a CSP problem.

Initials Domain

       First name = {Julia(F), Mary(F), Alan(M), Beth(F),Tom(M)}

Set of Variables

       First name, Last name, Favorite animal, Hated animal, Snack

A domain of possible value

       First name = {Julia(F), Mary(F), Alan(M), Beth(F),Tom(M)}

       Last name = {Procter, Small, Brown, Cook, Macgreger}

       Favorite animal = {Monkey, Giraffe, Lion, Seal, Elephant}

       Hated animal = {Monkey, Giraffe, Lion, Seal, Elephant}

       Snack = {Candy, Caramel apple, Doughnut, Popcorn, Corn chip}

Set of constrains

       Alldiff(First name), Alldiff(Last name), Alldiff(Favorite animal), Alldiff(Hated animal), Alldiff(Snack)

       Favorite animal ≠ Hated animal

       Julia = candy

       Mary ≠ caramel apple

       Procter ≠ monkey

       Alan = Small

       Alan ≠ seal

       Beth ≠doughnut

       Boy ≠ doughnut

       One boy = corn chip

       Another boy = monkey

       One child ≠ giraffe = popcorn

       Brown = lion

       Beth = seal

       Mary ≠ Cook

       Tom ≠ Brown

       Tom ≠ caramel apple

       Macgreger = doughnut

       The girl = elephant ≠ seal

       Cook = monkey

       Alan ≠ giraffe

B) Using the provided information, *your task is to determine each kid's first name and last name, their favorite and hated animals, and snack each kid chose*. Use the MRV heuristic and forward checking. Some of the constraints can be encoded directly in the initial domains. **Show your steps**.

Step 1 Initial

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Candy, Caramel apple, Doughnut, Popcorn, Corn chip	Candy, Caramel apple, Doughnut, Popcorn, Corn chip	Candy, Caramel apple, Doughnut, Popcorn, Corn chip	Candy, Caramel apple, Doughnut, Popcorn, Corn chip	Candy, Caramel apple, Doughnut, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 2

Julia chose candy.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Candy, Caramel apple, Doughnut, Popcorn, Corn chip	Candy, Caramel apple, Doughnut, Popcorn, Corn chip	Candy	Candy, Caramel apple, Doughnut, Popcorn, Corn chip	Candy, Caramel apple, Doughnut, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 3

Mary did not choose caramel apple.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Doughnut, Popcorn, Corn chip	Caramel apple, Doughnut, Popcorn, Corn chip	Candy	Caramel apple, Doughnut, Popcorn, Corn chip	Caramel apple, Doughnut, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 4

Alan Small's favorite animal was not seal.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger	Procter, Small, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Doughnut, Popcorn, Corn chip	Caramel apple, Doughnut, Popcorn, Corn chip	Candy	Doughnut, Popcorn, Corn chip	Caramel apple, Doughnut, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 5

Beth did not choose doughnut.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Doughnut, Popcorn, Corn chip	Caramel apple, Doughnut, Popcorn, Corn chip	Candy	Doughnut, Popcorn, Corn chip	Caramel apple, Doughnut, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 6

No boys chose doughnut.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Doughnut, Popcorn, Corn chip	Caramel apple, Doughnut, Popcorn, Corn chip	Candy	Doughnut, Popcorn, Corn chip	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 7

Mary's last name was not Cook.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Popcorn, Corn chip	Caramel apple, Popcorn, Corn chip	Candy	Doughnut, Popcorn, Corn chip	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 8

The kid whose last name was Macgreger chose doughnut.

Only Mary has doughnut in table. So Mary's last name is Macgreger.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Brown, Cook, Macgreger	Procter, Brown, Cook, Macgreger	Procter, Brown, Macgreger	Procter, Brown, Cook, Macgreger
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Popcorn, Corn chip	Popcorn, Corn chip	Candy	Doughnut, Popcorn, Corn chip	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 9

Beth liked seal.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Brown, Cook	Procter, Brown, Cook	Macgreger	Procter, Brown, Cook
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Hated animal	Monkey, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Popcorn, Corn chip	Popcorn, Corn chip	Candy	Doughnut	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 10

Tom, whose last name was not Brown did not choose caramel apple.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Brown, Cook	Procter, Brown, Cook	Macgreger	Procter, Brown, Cook
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Seal
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Popcorn, Corn chip	Caramel apple, Popcorn, Corn chip	Candy	Doughnut,	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 11

The animal Alan hated was not giraffe.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Cook	Procter, Brown, Cook	Macgreger	Procter, Brown, Cook
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Seal
Hated animal	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Popcorn, Corn chip	Popcorn, Corn chip	Candy	Doughnut,	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 12

The kid whose last name was Brown liked lion. (We already know that Beth liked seal.)

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Procter, Cook	Procter, Brown, Cook	Macgreger	Procter, Brown, Cook
Favorite animal	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Monkey, Giraffe, Lion, Elephant	Seal
Hated animal	Monkey, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Popcorn, Corn chip	Popcorn, Corn chip	Candy	Doughnut,	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 13

The kid whose last name was Cook liked monkey. (We already know that Beth liked seal.)

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	<u>Procter</u>, Cook	Brown	Macgreger	Procter, <u>Cook</u>
Favorite animal	<u>Monkey</u>, Giraffe, Elephant	Monkey, <u>Giraffe</u>, <u>Elephant</u>	Lion	<u>Monkey</u>, Giraffe, Elephant	Seal
Hated animal	Monkey, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	Caramel apple, Popcorn, Corn chip	Popcorn, Corn chip	Candy	Doughnut,	Caramel apple, Popcorn, Corn chip
Sex	Male	Male	Female	Female	Female

Step 14

One boy chose corn chip. Another boy liked monkey. (We already know that Tom liked monkey.)

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Cook	Brown	Macgreger	Procter
Favorite animal	Giraffe, Elephant	Monkey	Lion	Giraffe, Elephant	Seal
Hated animal	Monkey, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant	Monkey, Giraffe, Lion, Seal, Elephant
Snack	<u>Caramel apple</u>, <u>Popcorn</u>, Corn chip	Popcorn, <u>Corn chip</u>	Candy	Doughnut,	Caramel apple, <u>Popcorn</u>, <u>Corn chip</u>
Sex	Male	Male	Female	Female	Female

Step 15

Procter did not like monkey.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Cook	Brown	Macgreger	Procter
Favorite animal	Giraffe, Elephant	Monkey	Lion	Giraffe, Elephant	Seal
Hated animal	<u>Monkey</u>, Lion, Seal, Elephant	<u>Monkey</u>, Giraffe, Lion, Seal, Elephant	<u>Monkey</u>, Giraffe, Lion, Seal, Elephant	<u>Monkey</u>, Giraffe, Lion, Seal, Elephant	Monkey, <u>Giraffe</u>, <u>Lion</u>, <u>Seal</u>, <u>Elephant</u>
Snack	Corn chip	Popcorn	Candy	Doughnut,	Caramel apple
Sex	Male	Male	Female	Female	Female

Step 16

One who did not like giraffe chose popcorn.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Cook	Brown	Macgreger	Procter
Favorite animal	Giraffe, Elephant	Monkey	Lion	Giraffe, Elephant	Seal
Hated animal	Lion, Seal, Elephant	Giraffe, <u>Lion</u>, <u>Seal</u>, <u>Elephant</u>	<u>Giraffe</u>, Lion, Seal, Elephant	<u>Giraffe</u>, Lion, Seal, Elephant	Monkey
Snack	Corn chip	Popcorn	Candy	Doughnut,	Caramel apple
Sex	Male	Male	Female	Female	Female

Step 17

Favorite animal must be different with Hated animal.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Cook	Brown	Macgreger	Procter
Favorite animal	Giraffe, Elephant	Monkey	Lion	Giraffe, Elephant	Seal
Hated animal	Lion, Seal, Elephant	Giraffe	<u>Lion</u>, Seal, Elephant	Lion, Seal, Elephant	Monkey
Snack	Corn chip	Popcorn	Candy	Doughnut,	Caramel apple
Sex	Male	Male	Female	Female	Female

Step 18

The girl who liked elephant did not like seal.

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	Alan	Tom	Julia	Mary	Beth
Last name	Small	Cook	Brown	Macgreger	Procter
Favorite animal	Giraffe, Elephant	Monkey	Lion	Giraffe, Elephant	Seal
Hated animal	Lion, Seal, Elephant	Giraffe	Seal, Elephant	Lion, Seal, Elephant	Monkey
Snack	Corn chip	Popcorn	Candy	Doughnut,	Caramel apple
Sex	Male	Male	Female	Female	Female

Step 19

Solution

	Person 1	Person 2	Person 3	Person 4	Person 5
First name	**Alan**	**Tom**	**Julia**	**Mary**	**Beth**
Last name	**Small**	**Cook**	**Brown**	**Macgreger**	**Procter**
Favorite animal	**Giraffe**	**Monkey**	**Lion**	**Elephant**	**Seal**
Hated animal	**Lion**	**Giraffe**	**Elephant**	**Seal**	**Monkey**
Snack	**Corn chip**	**Popcorn**	**Candy**	**Doughnut,**	**Caramel apple**
Sex	**Male**	**Male**	**Female**	**Female**	**Female**

3) Consider the game of Sudoku 4x4 below:

		2	
	4		
		4	
	3		

The objective of this game is to fill a 4×4 grid with digits so that each column, each row, and each of the four 2×2 sub-grids that compose a big box containing all of the digits from 1 to 4. The puzzle initially provides a partially completed grid, which typically has a unique solution.

➢ **Find a possible solution**. Please use any technique of CSP to solve it. Be sure to define this problem formally as a CSP problem and show all your works.

Define this problem formally as a CSP problem.

Set of Variables

DigitAtPos[1…4, 1…4]

A domain of possible value

{1, 2, 3, 4}

Set of constrains

Alldiff(DigitAtPos[1,1], DigitAtPos[1,2], DigitAtPos[1,3], DigitAtPos[1,4])

Alldiff(DigitAtPos[2,1], DigitAtPos[2,2], DigitAtPos[2,3], DigitAtPos[2,4])

Alldiff(DigitAtPos[3,1], DigitAtPos[3,2], DigitAtPos[3,3], DigitAtPos[3,4])

Alldiff(DigitAtPos[4,1], DigitAtPos[4,2], DigitAtPos[4,3], DigitAtPos[4,4])

Alldiff(DigitAtPos[1,1], DigitAtPos[2,1], DigitAtPos[3,1], DigitAtPos[4,1])

Alldiff(DigitAtPos[1,2], DigitAtPos[2,2], DigitAtPos[3,2], DigitAtPos[4,2])

Alldiff(DigitAtPos[1,3], DigitAtPos[2,3], DigitAtPos[3,3], DigitAtPos[4,3])

Alldiff(DigitAtPos[1,4], DigitAtPos[2,4], DigitAtPos[3,4], DigitAtPos[4,4])

Alldiff(DigitAtPos[1,1], DigitAtPos[1,2], DigitAtPos[2,1], DigitAtPos[2,2])

Alldiff(DigitAtPos[1,3], DigitAtPos[1,4], DigitAtPos[2,3], DigitAtPos[2,4])

Alldiff(DigitAtPos[3,1], DigitAtPos[3,2], DigitAtPos[4,1], DigitAtPos[4,2])

Alldiff(DigitAtPos[3,3], DigitAtPos[3,4], DigitAtPos[4,3], DigitAtPos[4,4])

DigitAtPos[3, 1] = {2}

DigitAtPos[2, 2] = {4}

DigitAtPos[3, 3] = {4}

DigitAtPos[2, 4] = {3}

Use the <u>MRV heuristic</u> and <u>forward checking</u>

	D[1,1]	D[2,1]	D[3,1]	D[4,1]	D[1,2]	D[2,2]	D[3,2]	D[4,2]	D[1,3]	D[2,3]	D[3,3]	D[4,3]	D[1,4]	D[2,4]	D[3,4]	D[4,4]
1	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4
2	1,3,4	1,3,4	**2**	1,3,4	1,2,3,4	1,2,3,4	1,3,4	1,3,4	1,2,3,4	1,2,3,4	1,3,4	1,2,3,4	1,2,3,4	1,2,3,4	1,3,4	1,2,3,4
3	1,3	1,3	**2**	1,3,4	1,2,3	**4**	1,3	1,3	1,2,3,4	1,2,3	1,3,4	1,2,3,4	1,2,3,4	1,2,3	1,3,4	1,2,3,4
4	1,3	1,3	**2**	1,3,4	1,2,3	**4**	1,3	1,3	1,2,3	1,2,3	**4**	1,2,3	1,2,3,4	1,2,3	1,3	1,2,3
5	1,3	1	**2**	1,3,4	1,2,3	**4**	1,3	1,3	1,2,3	1,2	**4**	1,2,3	1,2,4	**3**	1	1,2
6	3	**1**	**2**	3,4	2,3	**4**	1,3	1,3	1,2,3	2	**4**	1,2,3	1,2,4	**3**	1	1,2
7	**3**	**1**	**2**	4	2	**4**	1,3	1,3	1,2	2	**4**	1,2,3	1,2,4	**3**	1	1,2
8	**3**	**1**	**2**	**4**	2	**4**	1,3	1,3	1,2	2	**4**	1,2,3	1,2,4	**3**	1	1,2
9	**3**	**1**	**2**	**4**	**2**	**4**	1,3	1,3	1	2	**4**	1,2,3	1,4	**3**	1	1,2
10	**3**	**1**	**2**	**4**	**2**	**4**	1,3	1,3	**1**	2	**4**	2,3	4	**3**	1	1,2
11	**3**	**1**	**2**	**4**	**2**	**4**	1,3	1,3	**1**	**2**	**4**	3	4	**3**	1	1,2
12	**3**	**1**	**2**	**4**	**2**	**4**	1,3	1	**1**	**2**	**4**	**3**	4	**3**	1	1,2
13	**3**	**1**	**2**	**4**	**2**	**4**	3	**1**	**1**	**2**	**4**	3	4	**3**	1	2
14	**3**	**1**	**2**	**4**	**2**	**4**	**3**	**1**	**1**	**2**	**4**	3	4	**3**	1	2
15	**3**	**1**	**2**	**4**	**2**	**4**	**3**	**1**	**1**	**2**	**4**	3	**4**	**3**	1	2
16	**3**	**1**	**2**	**4**	**2**	**4**	**3**	**1**	**1**	**2**	**4**	3	4	**3**	**1**	2
17	**3**	**1**	**2**	**4**	**2**	**4**	**3**	**1**	**1**	**2**	**4**	3	4	**3**	1	**2**
	3	**1**	**2**	**4**	**2**	**4**	**3**	**1**	**1**	**2**	**4**	**3**	**4**	**3**	**1**	**2**

Solution is …

3	1	2	4
2	4	3	1
1	2	4	3
4	3	1	2