Constraint Satisfaction Problem in AI

Course Name: Artificial Intelligence

Course code: CSE-403 [SECTION - A]

Khandaker Jannatul Ritu, Lecturer Dept. of CSE at BAIUST

Constraint Satisfaction Problem in AI

The goal of AI is to create intelligent machines that can perform tasks that usually require human intelligence, such as reasoning, learning, and problem-solving. One of the key approaches in AI is the use of constraint satisfaction techniques to solve complex problems.

CSP *is a specific type of problem-solving approach that involves identifying constraints that must be satisfied and finding a solution that satisfies all the constraints. CSP has been used in a variety of applications, including scheduling, planning, resource allocation, and automated reasoning.*

There are mainly three basic components in the constraint satisfaction problem:

- **Variables:** The things that need to be determined are variables. Variables in a CSP are the objects that must have values assigned to them in order to satisfy a particular set of constraints. Boolean, integer, and categorical variables are just a few examples of the various types of variables, for instance, could stand in for the many puzzle cells that need to be filled with numbers in a sudoku puzzle.

- **Domains:** The range of potential values that a variable can have is represented by domains. Depending on the issue, a domain may be finite or limitless. For instance, in Sudoku, the set of numbers from 1 to 9 can serve as the domain of a variable representing a problem cell.

- **Constraints:** The guidelines that control how variables relate to one another are known as constraints. Constraints in a CSP define the ranges of possible values for variables. Unary constraints, binary constraints, and higher-order constraints are only a few examples of the various sorts of constraints. For instance, in a sudoku problem, the restrictions might be that each row, column, and 3×3 box can only have one instance of each number from 1 to 9.

Constraint Satisfaction Problem (CSP)

A **Constraint Satisfaction Problem** in artificial intelligence involves a set of variables, each of which has a domain of possible values, and a set of constraints that define the allowable combinations of values for the variables. The goal is to find a value for each variable such that all the constraints are satisfied.
The goal of a CSP is to find an assignment of values to the variables that satisfies all the constraints. This assignment is called a solution to the CSP.

Constraint Satisfaction Problems (CSP) representation:

- The finite set of variables V_1, V_2, V_3 .....V_n.
- Non-empty domain for every single variable D_1, D_2, D_3 .....D_n.
- The finite set of constraints C_1, C_2 ....., Cm.
    - where each constraint C_i restricts the possible values for variables,
        - e.g., $V_1 \neq V_2$
    - Each constraint C_i is a pair <scope, relation>
        - Example: <(V_1, V_2), V_1 not equal to V_2>
    - Scope = set of variables that participate in constraint.
    - Relation = list of valid variable value combinations.
        - There might be a clear list of permitted combinations. Perhaps a relation that is abstract and that allows for membership testing and listing.

➢ Types of Constraints in CSP

1. Unary Constraints:- A unary constraint is a constraint on a single variable. For example, Variable A not equal to “Red”.

2. Binary Constraints:- A binary constraint involves two variables and specifies a constraint on their values. For example, a constraint that two tasks cannot be scheduled at the same time would be a binary constraint.

3. Global Constraints:- Global constraints involve more than two variables and specify complex relationships between them. For example, a constraint that no two tasks can be scheduled at the same time if they require the same resource would be a global constraint.

➢ Real-world Constraint Satisfaction Problems (CSP):

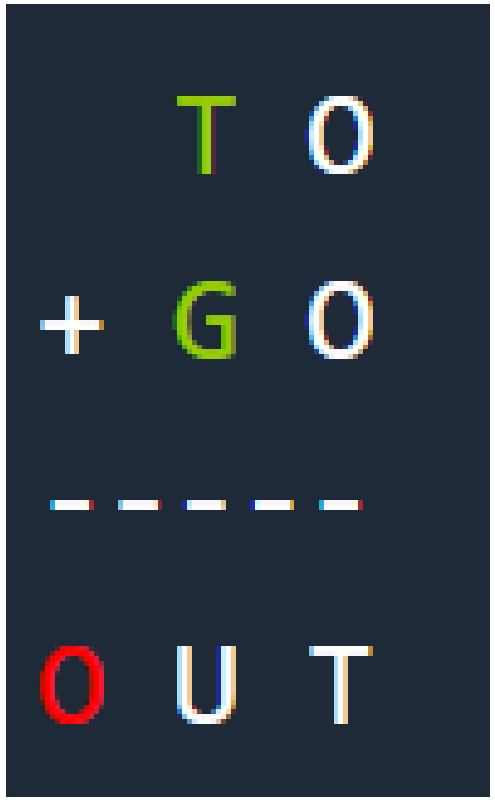
- **Scheduling:** The constraints in this domain specify the availability and capacity of each resource, whereas the variables indicate the time slots or resources.
- **Vehicle routing:** In this domain, the constraints specify each vehicle’s capacity, delivery locations, and time windows, while the variables indicate the routes taken by the vehicles.
- **Assignment:** In this field, the variables stand in for the tasks, while the constraints specify the knowledge, capacity, and workload of each person or machine.
- **Sudoku:** The well-known puzzle game Sudoku can be modelled as a CSP problem, where the variables stand in for the grid’s cells and the constraints specify the game’s rules.
- **Constraint-based image segmentation:** The segmentation of an image into areas with various qualities (such as color, texture, or shape) can be treated as a CSP issue in computer vision.

➢ Constraint Satisfaction Problems (CSP) benefits:

1. conventional representation patterns
2. generic successor and goal functions
3. Standard heuristics (no domain-specific expertise).

Cryptarithmetic problem in AI

Problem-01:



So final values are –
T = 2, O = 1, G = 8, U = 0

```
 2 1
 8 1
------
1 0 2
```

T	2
O	1
G	8
U	0

Problem-02:

```
  HERE
+  SHE
--------
COMES
```

The final values are –
H = 9, E = 4, R = 5, S = 8,
C = 1, O = 0, M = 3

```
  THIS
+   IS
--------
  HERE
```

Final Answer – H = 9, E = 0,
T = 8, S = 5, I = 6, R = 3

```
  YOUR
+   YOU
----------
 HEART
```

```
   9426
+   942
----------
 10368
```

```
   EAT
+THAT
----------
APPLE
```

A = 1,
P = 0,
T = 9,
E = 8,
L = 3,
H = 2

```
 SEND
+MORE
------
MONEY
------
```

S	9
E	5
N	6
D	7
M	1
O	0
R	8
y	2

1.

```
 BASE
+BALL
------
GAMES
------
```


B	7
A	4
S	8
E	3
L	5
G	1
M	9

2.

```
 YOUR
+YOU
------
HEART
------
```


Y	9
O	4
U	2
R	6
H	1
E	0
A	3
T	8

More Cryptarithmetic Problem

```
BLACK      7 9 2 0 8
GREEN      5 3 4 4 6
-----------  ---------------
ORANGE   1 3 2 6 5 4
```

```
CRASH        3 6 8 4 5
HACKER    5 8 3 9 2 6
-----------  ------------------
REBOOT    6 2 0 7 7 1
```

```
CROSS      9 6 2 3 3
ROADS      6 2 5 1 3
-----------  ---------------
DANGER   1 5 8 7 4 6
```

```
  E G G
+ E G G
-------
= P A G E
```

```
  T W O
  T W O +
---------
F O U R
```

E.g., setting F = 1, O = 4, R = 8, T = 7, W = 3,

```
  8 9 9
+ 8 9 9
-------
= 1 7 9 8
```

LOGIC
+LOGIC

_____
PROLOG

so only possible combination is
90452
+90452

_____
180904