Project 01

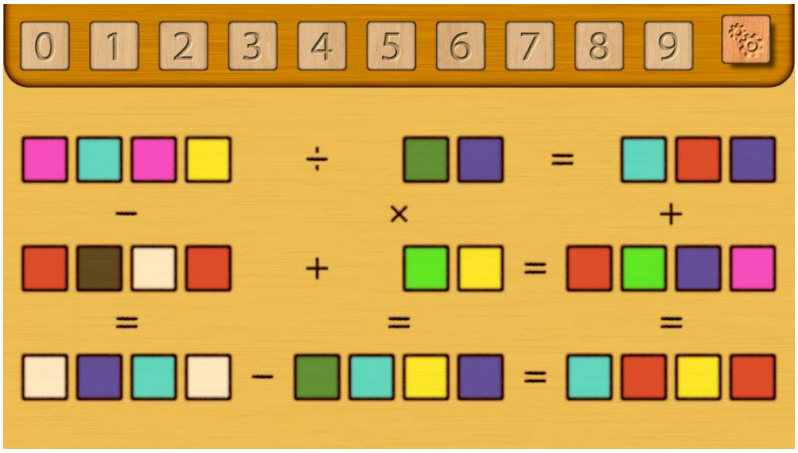
Cryptarithmetic Problem in AI

1. Description

This assignment is created based on an article on tutorialexample.com website. The link is given in the References section. The next paragraphs are extracted from the webpage with some modification.

Cryptarithmetic Problem is a type of constraint satisfaction problem where the game is about digits and its unique replacement either with alphabets or other symbols. In cryptarithmetic problem, the digits (0-9) get substituted by some possible alphabets or symbols. The task in cryptarithmetic problem is to substitute each digit with an alphabet to get the result arithmetically correct.

In Google Play, you can find some game with cryptarithmetic puzzle. The Cryptogram is an example. You can enjoy it for some early experience but not be immersed in it.



We can perform all the arithmetic operations on a given cryptarithmetic problem. The rules or constraints on a cryptarithmetic problem are as follows:

- There should be a unique digit to be replaced with a unique alphabet.
- The result should satisfy the predefined arithmetic rules, i.e., 2+2 =4, nothing else. Digits should be from 0-9 only.
- There should be only one carry forward, while performing the addition operation on a problem.
- The problem can be solved from both sides, i.e., left-hand side (L.H.S), or right-hand side (R.H.S)

Let us understand the cryptarithmetic problem as well its constraints better with the help of an example:

Given a cryptarithmetic problem, i.e., S E N D + M O R E = M O N EY

```
  S E N D
+ M O R E
---------
M O N E Y
```

In this example, add both terms S E N D and M O R E to bring M O N E Y as a result.

Follow the below steps to understand the given problem by breaking it into its subparts:

- Starting from the left hand side (L.H.S) , the terms are S and M. Assign a digit which could give a satisfactory result. Let's assign S->9 and M->1.

```
  S          9
+ M   ⟶    + 1
-----      ----
 MO         10
```

  Hence, we get a satisfactory result by adding up the terms and got an assignment for O as O→0 as well.

- Now, move ahead to the next terms E and O to get N as its output.

```
  E          5
+ O   ⟶    + 0
-----      ----
  N          5
```

  Adding E and O, which means 5+0=0, which is not possible because according to cryptarithmetic constraints, we cannot assign the same digit to two letters. So, we need to think more and assign some other value.

```
  E          5
+ O    →   + 0
-----      -----
  N          6
             -----
             With 1 carry
```

Note: When we will solve further, we will get one carry, so after applying it, the answer will be satisfied.

- Further, adding the next two terms N and R we get,

```
  N          6
+ R    ⇸   + 8
-----      -----
  E          1 4
```

But, we have already assigned E->5. Thus, the above result does not satisfy the values because we are getting a different value for E. So, we need to think more. Again, after solving the whole problem, we will get a carry over on this term, so our answer will be satisfied.

```
  N          6
+ R    →   + 8
-----      -----
  E          1 5
             -----
             With 1 carry
```

where 1 will be carry forward to the above term

- Again, on adding the last two terms, i.e., the rightmost terms D and E, we get Y as its result.

```
  D          7
+ E    →   + 5
-----      -----
  Y          1 2
```

where 1 will be carry forward to the above term.

- Keeping all the constraints in mind, the final resultant is as follows:

S	9
E	5
N	6
D	7

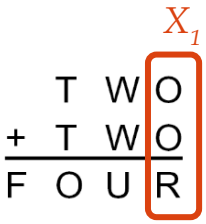
M	1
O	0
R	8
Y	2

Some other example:

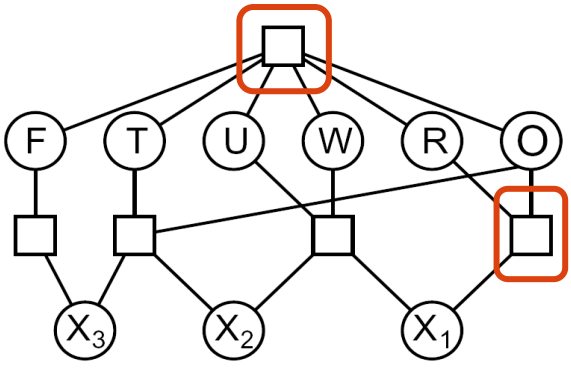
```
   T W O
+  T W O
-------
F O U R
```

Results: O=7, R=4, W=6, U=2, T=8, F=1; 867 + 867 = 1734

We describe the problem as constraint solving problem (CSP):



- Variables: F, T, U, W, R, O, X_1, X_2, X_3
- Domain: {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}
- Constraints:
  - alldiff(F, T, U, W, R, O)
  - O + O = R + 10 * X_1
  - ...



2. Goals

You are required to solve the cryptarithmetic problem with algorithms in AI course. You are not allowed to use Brute Force method. If not, you will have a 0 grade for this assignment.

To solve the problem from simple to advance, I build up the 4 different levels:

- Level 1: Solve the addition equation or subtraction equation with 2 operands.
- Level 2: Solve any kind of equation with multiple operands and single operator (+ -).

  For example:

  SO+MANY+MORE+MEN+SEEM+TO+SAY+THAT+

  THEY+MAY+SOON+TRY+TO+STAY+AT+HOME+

  SO+AS+TO+SEE+OR+HEAR+THE+SAME+ONE+

  MAN+TRY+TO+MEET+THE+TEAM+ON+THE+

  MOON+AS+HE+HAS+AT+THE+OTHER+TEN =TESTS

  The answer is that TRANHYSMOE=9876543210.
- Level 3: Solve any kind of equation with multiple operands and operators (+ -). We use the parentheses () are used to specify the order of operations.

  SEND+(MORE+MONEY)-OR+DIE=NUOYI

  The answers are SENDMORYIU=1369547082, 1658432970…
- Level 4: Solve level 3 with the multiplication equation (*).

Note that, some equation will have no result or many results. For no solution case, you must print out **NO SOLUTION** for these equations. For many solutions case, you print out one solution of them.

All equation will be presented in valid format and we do not write leading zeros in numbers.

3. Specifications

- **Input:** is a text file including a single line describing the equation. The valid letters are:
  - Uppercase characters A-Z.
  - Operators: +, -, *
  - The parentheses ( )
  - The equal sign =

For example:

SEND+MORE=MONEY

- **Output**: is a text file with lines that shows the decoded values for letters. The order of values follows the order of the letters in alphabetical order. There is no space between the digits. Each line is a solution.

For example, with SEND+MORE=MONEY, the result is DEMNORSY = 75160891. The output will be:

```
75160891
```

4. Requirements

No.	Criteria	Scores
1	Finish level 1 successfully.	15%
2	Finish level 2 successfully.	15%
3	Finish level 3 successfully.	15%
4	Finish level 4 successfully.	10%
5	Generate at least 5 test cases for each level with different attributes such as size, time to solve, output type. Describe them in the experiment section of your report.	15%
6	Report your algorithms, experiments with some reflection or comments.	30%
Total		100%

5. Notices

- This is a **GROUP** assignment. Each group has a maximum of 3 members.
- Duration: about 3 or 4 weeks.
- Your group can use any programming language to do.
- Beside the above requirements, the report must also give the following information:
  - Your detailed information (Student Id, Full Name)
  - Assignment Plan
  - Environment to compile and run your program.
  - Estimating the degree of completion level for each requirement.

- References (if any)

- Any plagiarism, any tricks, or any lie will have a 0 point for the COURSE grade.

6. References

[1] Tutorial And Example. 2021. Cryptarithmetic Problem in AI - Tutorial And Example. [online] Available at: <https://www.tutorialandexample.com/cryptarithmetic-problem/#:~:text=Cryptarithmetic%20Problem%20is%20a%20type,some%20possible%20alphabets%20or%20symbols.> [Accessed 1 March 2021].