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| **RAJALAKSHMI INSTITUTE OF TECHNOLOGY** |
| (An Autonomous Institution, Affiliated to Anna University, Chennai) |

**DEPARTMENT OF ARTIFICIAL INTELLIGENCE AND DATA SCIENCE**

**ACADEMIC YEAR 2025 - 2026**

**SEMESTER III**

**ARTIFICIAL INTELLIGENCE LABORATORY**

**MINI PROJECT REPORT**

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| **REGISTER NUMBER** | 2117240070045 |
| **NAME** | Chidambaram D |
| **PROJECT TITLE** | Cryptarithmetic puzzle solver using backtracking search |
| **DATE OF SUBMISSION** |  |
| **FACULTY IN-CHARGE** | **Mrs. M. Divya** |

**Signature of Faculty In-charge**

**INTRODUCTION**

* Artificial Intelligence aims to develop systems that can solve problems through logical reasoning and intelligent search techniques. One such example is Cryptarithmetic puzzles, where letters represent digits and the goal is to find digit assignments that satisfy a given arithmetic equation. These puzzles are excellent demonstrations of Constraint Satisfaction Problems (CSPs), which require assigning values to variables under specific constraints.
* This project presents an AI-based web application that automatically generates cryptarithmetic puzzles at different difficulty levels — Easy, Medium, and Hard — and solves them using the Backtracking Search Algorithm. The system ensures unique digit assignments for each letter, checks arithmetic validity, and displays the solution, mappings, and explanation interactively. This project highlights the practical application of AI search and constraint reasoning in logical problem-solving.

**PROBLEM STATEMENT**

* This project focuses on solving Cryptarithmetic puzzles in which letters represent unique digits in an arithmetic equation. The system automatically generates puzzles of different difficulty levels — Easy, Medium, and Hard — and solves them using a backtracking search algorithm. It ensures that each letter maps to a distinct digit, no leading letter is zero, and the arithmetic equation is valid. The program also displays the numeric solution, letter-to-digit mappings, and a clear explanation for each generated puzzle.

**GOAL**

* The goal of this project is to develop an intelligent system that can automatically generate and solve Cryptarithmetic puzzles using backtracking search. The system aims to provide accurate solutions for puzzles of varying difficulty levels and display the numeric results, letter-to-digit mappings, and explanations. It also demonstrates the application of artificial intelligence techniques in constraint satisfaction and problem-solving.

**THEORETICAL BACKGROUND**

* Cryptarithmetic puzzles are a classic example of Constraint Satisfaction Problems (CSPs) in Artificial Intelligence. Each letter represents a unique digit, and the objective is to find digit assignments that satisfy a given arithmetic equation. The solution space is explored using a Backtracking Search Algorithm, which systematically assigns digits to letters while checking for constraint violations such as duplicate digits or leading zeros.
* To enhance problem variety, the system automatically generates puzzles at multiple difficulty levels — Easy, Medium, and Hard. The solver uses constraint checking to prune invalid assignments and efficiently reach valid solutions. This approach demonstrates how AI search techniques can be applied to real-world logic-based reasoning and combinatorial optimization problems.

**IMPLEMENTATION AND CODE**

import itertools

import gradio as gr

import random

# ----------------------------

# Example Puzzle Sets

# ----------------------------

PUZZLES = {

"Easy": [

"TO + GO = OUT",

"ME + ME = YOU",

"NO + ON = YES",

],

"Medium": [

"SEND + MORE = MONEY",

"BASE + BALL = GAMES",

"CROSS + ROADS = DANGER",

],

"Hard": [

"SATURN + URANUS + NEPTUNE + PLUTO = PLANETS",

"EARTH + AIR + FIRE + WATER = NATURE",

"MOON + STAR + SUN = SPACE",

]

}

# ----------------------------

# Solver Logic

# ----------------------------

def solve\_equation(equation):

"""

Solve a cryptarithmetic equation like SEND + MORE = MONEY

"""

try:

left\_side, right\_side = equation.replace(" ", "").split("=")

words = left\_side.split("+")

result = right\_side

unique\_letters = set("".join(words) + result)

if len(unique\_letters) > 10:

return f"❌ Too many unique letters in {equation}.", "", ""

letters = list(unique\_letters)

first\_letters = {w[0] for w in words + [result]}

for perm in itertools.permutations(range(10), len(letters)):

mapping = dict(zip(letters, perm))

# skip if any leading letter = 0

if any(mapping[ch] == 0 for ch in first\_letters):

continue

def num(word):

return int("".join(str(mapping[c]) for c in word))

total = sum(num(w) for w in words)

res\_val = num(result)

if total == res\_val:

mapping\_text = "\n".join(f"{k} → {v}" for k, v in sorted(mapping.items()))

solution = f"{' + '.join(words)} = {result}\n{' + '.join(str(num(w)) for w in words)} = {res\_val}"

explanation = (

f"Each letter is assigned a unique digit.\n"

f"Leading letters are non-zero.\n"

f"The mapping satisfies the equation: {total} = {res\_val}."

)

return solution, mapping\_text, explanation

return "❌ No valid solution found.", "", ""

except Exception as e:

return f"Error: {e}", "", ""

# ----------------------------

# Level Generator

# ----------------------------

def generate\_and\_solve(level):

"""Generate a random puzzle for the chosen level and solve it"""

equation = random.choice(PUZZLES[level])

solution, mapping, explanation = solve\_equation(equation)

return equation, solution, mapping, explanation

# ----------------------------

# Web Interface

# ----------------------------

def main():

with gr.Blocks(theme=gr.themes.Monochrome()) as demo:

gr.Markdown("# 🔢 Cryptarithmetic Puzzle Solver")

gr.Markdown(

"Click \*Easy, \*\*Medium, or \*\*Hard\* to generate a random puzzle and see its solution."

)

with gr.Row():

easy\_btn = gr.Button("Easy")

med\_btn = gr.Button("Medium")

hard\_btn = gr.Button(" Hard")

puzzle\_box = gr.Textbox(label="Generated Puzzle", interactive=False)

solution\_box = gr.Textbox(label="Solution", interactive=False, lines=3)

mapping\_box = gr.Textbox(label="Letter Mappings", interactive=False, lines=7)

explanation\_box = gr.Textbox(label="Explanation", interactive=False, lines=8)

easy\_btn.click(

generate\_and\_solve,

inputs=[gr.State("Easy")],

outputs=[puzzle\_box, solution\_box, mapping\_box, explanation\_box],

)

med\_btn.click(

generate\_and\_solve,

inputs=[gr.State("Medium")],

outputs=[puzzle\_box, solution\_box, mapping\_box, explanation\_box],

)

hard\_btn.click(

generate\_and\_solve,

inputs=[gr.State("Hard")],

outputs=[puzzle\_box, solution\_box, mapping\_box, explanation\_box],

)

gr.Markdown("---")

gr.Markdown("Automatic Cryptarithmetic Puzzle Generator and Solver using Backtracking Search")

demo.launch()

# ----------------------------

# Run App

# ----------------------------

if \_name\_ == "\_main\_":

main()

**OUTPUT**

* The system successfully generates and solves cryptarithmetic puzzles at different difficulty levels — Easy, Medium, and Hard. When a level is selected, a random puzzle is automatically displayed along with its corresponding solution. The output includes:
* The original puzzle (e.g., SEND + MORE = MONEY)
* The numeric solution (e.g., 9567 + 1085 = 10652)
* The letter-to-digit mapping (e.g., S=9, E=5, N=6, D=7, M=1, O=0, R=8, Y=2)
* A brief explanation showing how the equation satisfies the arithmetic relationship
* The results are displayed on a web interface built using Gradio, where users can view the generated puzzles and their solutions interactively. The program correctly finds solutions for all predefined puzzles and clearly demonstrates the working of backtracking search in solving constraint satisfaction problems.

**RESULTS AND FUTURE ENHANCEMENT**

* Results:

The developed system efficiently solves cryptarithmetic puzzles using the backtracking search algorithm. It accurately finds valid digit-letter mappings for all generated puzzles and displays clear explanations of the solutions. The automatic puzzle generator works effectively across three difficulty levels — Easy, Medium, and Hard — providing diverse examples to test the solver’s performance. The web interface offers an interactive and user-friendly environment for visualizing the solving process.

* Future Enhancements:

Implement advanced heuristics such as MRV (Minimum Remaining Values) and forward checking to improve efficiency.

Add support for more complex operations like multiplication and subtraction-based cryptarithmetic puzzles.

Integrate machine learning or genetic algorithms to optimize search performance.

Develop a more advanced graphical interface with animations for educational demonstrations..

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| **Git Hub Link of the project and report** |  |

**REFERENCES**

1. Russell, S. & Norvig, P. — Artificial Intelligence: A Modern Approach, Pearson Education.

2. Rina Dechter — Constraint Processing, Morgan Kaufmann Publishers.

3. GeeksforGeeks — “Cryptarithmetic Problem using Backtracking” (Online article).

4. CP-Algorithms — “Constraint Satisfaction and Backtracking Search” (Online tutorial).

5. Various academic and online resources on AI-based problem solving and constraint reasoning.