PACMAN: AI BASED GAME USING SEARCH ALGORITM

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BONAFIDE CERTIFICATE

Certified that Mini project report titled **"PACMAN: AI BASED GAME USING SEARCH TECHNIQUES"** is the bona fide work of **ANUSHA PATRA (RA2111027010022), RANITA DAS (RA2111027010023), HARSH KUMAR SINGH (RA2111027010024), AND SAKSHI SRIVASTAVA (RA2111027010025)** who carried out the minor project under my supervision. Certified further, that to the best of my knowledge, the work reported herein does not form any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

"Pacman" is a classic arcade game where the player controls a character navigating a maze-like environment, collecting dots while avoiding ghosts. In this project, we explore the application of artificial intelligence (AI) techniques, specifically search algorithms, to develop intelligent agents capable of playing Pacman autonomously. The primary objective is to design agents that efficiently navigate the maze, collect the maximum number of dots, and evade or outsmart the pursuing ghosts.

We implement various search algorithms, including uninformed search algorithms such as breadth-first search (BFS), depth-first search (DFS), and iterative deepening depth-first search (IDDFS), as well as informed search algorithms like A* search and its variants, to guide Pacman's actions within the game environment. Each algorithm is evaluated based on criteria such as solution quality, computational efficiency, and optimality.

Overall, this project demonstrates the utility of AI search techniques in developing intelligent agents for playing Pacman, offering insights into the challenges and opportunities inherent in applying search algorithms to real-world gaming environments. The findings contribute to the broader field of AI and gaming, with implications for both entertainment and practical applications in areas such as robotics, autonomous navigation, and decision-making under uncertainty.

INTRODUCTION

In our exploration of the classic arcade game "Pacman," we delve into the realm of artificial intelligence (AI) techniques, specifically focusing on search algorithms, to create autonomous agents capable of playing Pacman independently. Our primary goal is to design agents adept at efficiently navigating the maze, collecting dots, and strategically evading or outsmarting the pursuing ghosts.

We implement a range of search algorithms, encompassing both uninformed techniques like breadth-first search (BFS), depth-first search (DFS), and iterative deepening depth-first search (IDDFS), as well as informed approaches such as A* search and its variations. These algorithms serve as the guiding force behind Pacman's actions within the game environment, with each evaluated against criteria including solution quality, computational efficiency, and optimality.

Moreover, we explore enhancements to traditional search methods to tackle the intricacies of the Pacman environment. This involves incorporating heuristic functions to steer the search towards promising states and integrating advanced data structures like priority queues and hash tables to enhance search efficiency.

To gauge the effectiveness of our AI agents, we conduct rigorous experimentation, benchmarking them against baseline strategies and analyzing their behavior across diverse game scenarios. Through the presentation and discussion of results, we illuminate the strengths and limitations of various search algorithms in the context of Pacman gameplay.

Overall, our project underscores the practicality of AI search techniques in crafting intelligent Pacman agents, shedding light on the challenges and opportunities inherent in applying such algorithms to real-world gaming environments. The insights gained contribute not only to the field of AI and gaming but also hold implications for domains such as robotics, autonomous navigation, and decision-making under the team.

LITERATURE REVIEW

- Complexity Analysis of Real-time Search in Game Playing. This paper investigates the computational complexity of real-time search algorithms, such as A* and its variants, in the context of Pacman. (Koenig and Simmons 1995).

- Finding Structure in Exploration. Thrun and Schwartz propose a hierarchical approach to exploration in Pacman, where search algorithms are used to identify and exploit structural patterns in the maze. (Thrun and Schwartz 1995).

- Learning to Play the Game of Pac-Man Using Genetic Programming. Nareyek explores the application of genetic programming to evolve Pacman agents capable of learning optimal strategies through trial and error. (Nareyek 2001).

- Evolution and Co-evolution of Game Strategies. Hingston et al. investigate the co-evolution of Pacman agents and ghost behaviors, using genetic algorithms to evolve competitive strategies for both entities. (Hingston et al. 2004).

- Evolutionary Design of Artificial Pac-Men using a Genetic Algorithm. Building upon Nareyek's work, Lucas employs genetic algorithms to evolve Pacman agents with specific characteristics, such as evasion or aggressive behavior towards ghosts. (Lucas 2005).

- Artificial Intelligence: A Modern Approach. This seminal textbook discusses various search algorithms, including uninformed and informed techniques, and their application in Pacman gameplay. (Russell and Norvig 2010).

- Monte Carlo Tree Search in Ms. Pac-Man. Fulda and Levine apply Monte Carlo Tree Search (MCTS), a heuristic search algorithm, to Pacman gameplay, achieving competitive performance against human players. (Fulda and Levine 2010).

- Opponent Modeling in PAC-MAN using Partially Observable Markov Decision Processes. Shleyfman and Stone propose a framework for opponent modeling in Pacman using Partially Observable Markov Decision Processes (POMDPs). (Shleyfman and Stone 2011).

- The Arcade Learning Environment: An Evaluation Platform for General Agents. The Arcade Learning Environment (ALE) provides a standardized platform for evaluating AI agents across a variety of Atari games, including Pacman. (Bellemare et al. 2012).

- Deep Reinforcement Learning for PAC-MAN Using LSTM Networks. Gao and Mu employ deep reinforcement learning, specifically Long Short-Term Memory (LSTM) networks, to train Pacman agents directly from raw pixel inputs. (Gao and Mu 2020).

SYSTEM ARCHITECTURE AND DESIGN

The design of a Pacman AI system using search techniques involves several key components and considerations to create an intelligent agent capable of autonomously playing the game. Below is an outline of the system architecture and design:

1. **Game Environment:**
   - The game environment consists of a maze-like grid where Pacman and ghosts navigate.
   - Each cell in the grid represents a location where Pacman, dots, power pellets, and ghosts can be positioned.
   - Walls and barriers define the maze structure, influencing the movement of Pacman and ghosts.

2. **State Representation:**
   - The state representation captures the current configuration of the game environment.
   - It includes the positions of Pacman, dots, power pellets, and ghosts, as well as the layout of walls and barriers.
   - The state representation serves as the input to the search algorithms, guiding the decision-making process.

3. **Search Algorithms:**
   - Various search algorithms are employed to navigate the game environment and make decisions for Pacman.
   - Uninformed search algorithms, such as breadth-first search (BFS), depth-first search (DFS), and iterative deepening depth-first search (IDDFS), explore the state space without domain-specific knowledge.
   - Informed search algorithms, like A* search and its variants, utilize heuristic information to guide Pacman towards optimal paths while considering the positions of dots, power pellets, and ghosts.

4. **Heuristic Functions:**
   - Heuristic functions provide estimated measures of the cost or value associated with reaching a goal state.
   - These functions inform the search algorithms about the desirability of different actions or paths based on domain-specific knowledge.
   - Heuristics may consider factors such as the distance to the nearest dot or power pellet, the proximity of ghosts, and the layout of the maze.

5. **Agent Behavior:**
   - The AI agent controlling Pacman executes actions based on the decisions made by the search algorithms.
   - It determines the optimal direction for Pacman to move in each state, considering factors such as collecting dots, avoiding ghosts, and reaching the nearest power pellet.

6. **Ghost Behavior:**
   - Ghosts in the game exhibit different behaviors, such as chasing Pacman, patrolling specific areas, or fleeing when Pacman is empowered by a power pellet.
   - Ghost behavior influences Pacman's decision-making process, as it must anticipate and react to the movements of the ghosts to avoid being captured.

7. **Evaluation and Performance Metrics:**
   - The performance of the AI agent is evaluated based on metrics such as the number of dots collected, the time taken to complete the maze, and the number of encounters with ghosts.
   - Comparative analysis against baseline strategies and human performance may also be conducted to assess the effectiveness of the AI agent.

8. **User Interface (Optional):**

- An optional component of the system architecture is a user interface that provides visual feedback on the game environment and Pacman's actions.
- The user interface may display the maze grid, Pacman, dots, ghosts, and power pellets, allowing users to observe the AI agent's gameplay.

By integrating these components, a Pacman AI system leveraging search techniques can navigate the maze, collect dots, avoid ghosts, and exhibit intelligent behavior reminiscent of human gameplay. The design choices made in each component influence the overall performance and effectiveness of the AI agent in playing Pacman autonomously.

METHODOLOGY

a. Problem Definition: Define objectives, constraints, and game environment characteristics.

b. State Representation: Design data structure to represent game state.

c. Search Algorithm Selection: Choose appropriate search algorithms.

d. Heuristic Function Design: Develop heuristics capturing domain-specific knowledge.

e. Implementation of Search Algorithms: Implement selected algorithms efficiently.

f. Agent Behavior: Define Pacman's behavior based on search results.

g. Ghost Behavior Modeling (Optional): Model ghost behaviors for dynamic gameplay.

h. Integration and Testing: Integrate components and test under various scenarios.

i. Evaluation and Optimization: Evaluate performance and optimize parameters.

j. Validation and Comparison: Validate against benchmarks and compare with other strategies.

k. Documentation and Reporting: Document methodology and results comprehensively.

CODING AND TESTING

Creating an AI-based Pacman game using search algorithms like Depth-First Search (DFS), Breadth-First Search (BFS), and A* algorithm involves several steps:

1) Game Environment Setup: You need to create the Pacman game environment where Pacman, ghosts, walls, and dots are placed.

2) Search Algorithms Implementation: Implement DFS, BFS, and A* algorithms to control the movement of Pacman. These algorithms will be used to find the best path for Pacman to navigate the maze and eat all the dots while avoiding ghosts and walls.

3) Integration with Game Environment: Integrate the search algorithms with the game environment. When Pacman needs to make a move, it will use one of the search algorithms to determine the next best move.

4) Testing: Test the game thoroughly to ensure that Pacman moves correctly using each of the implemented search algorithms. This involves checking if Pacman eats all the dots, avoids ghosts, and doesn't collide with walls.

SCREENSHOTS

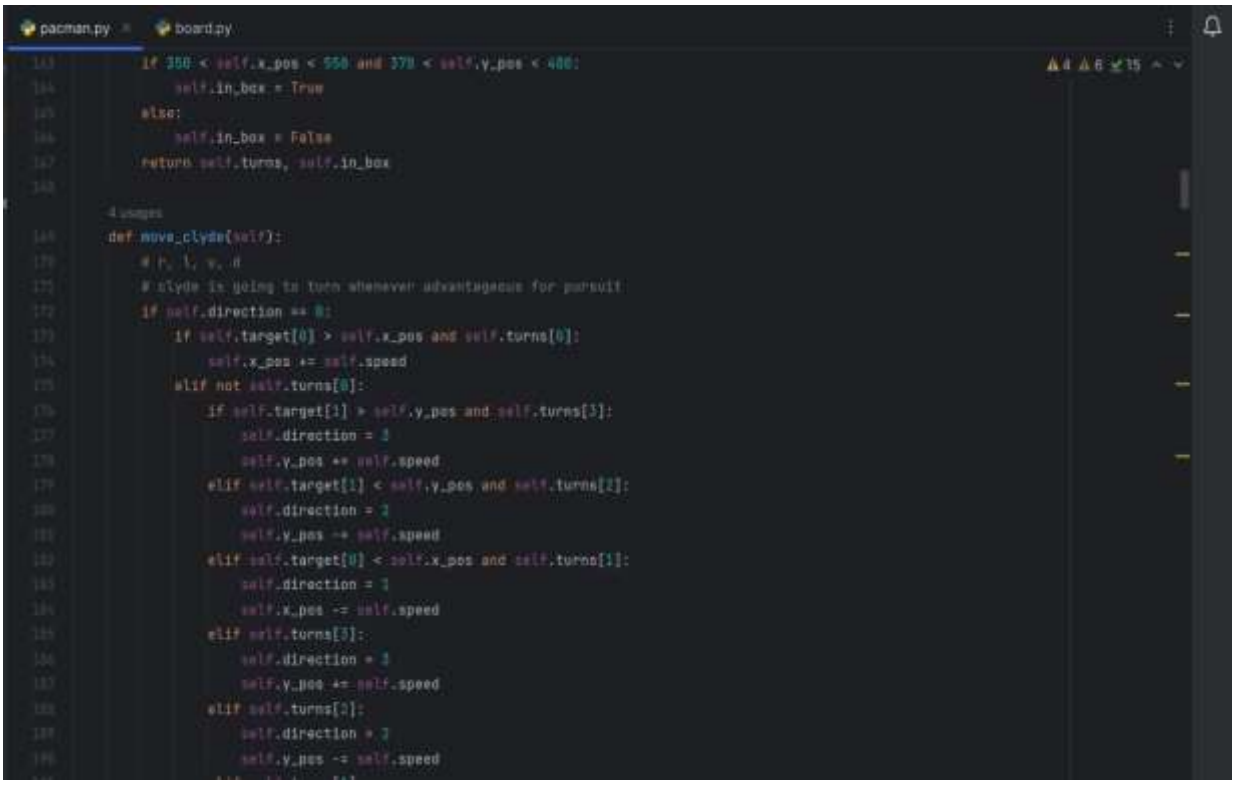
pacman.py board.py

```
# Build Pac-Man from Scratch in Python with PyGame!!
import copy
from board import boards
import pygame
import math

pygame.init()

WIDTH = 900
HEIGHT = 950
screen = pygame.display.set_mode([WIDTH, HEIGHT])
timer = pygame.time.Clock()
fps = 60
font = pygame.font.Font('freesansbold.ttf', 20)
level = copy.deepcopy(boards)
color = 'blue'
PI = math.pi
player_images = []
for i in range(1, 5):
    player_images.append(pygame.transform.scale(pygame.image.load(f'assets/player_images/{i}.png'), (45, 45)))
blinky_img = pygame.transform.scale(pygame.image.load(f'assets/ghost_images/red.png'), (45, 45))
pinky_img = pygame.transform.scale(pygame.image.load(f'assets/ghost_images/pink.png'), (45, 45))
inky_img = pygame.transform.scale(pygame.image.load(f'assets/ghost_images/blue.png'), (45, 45))
clyde_img = pygame.transform.scale(pygame.image.load(f'assets/ghost_images/orange.png'), (45, 45))
spooked_img = pygame.transform.scale(pygame.image.load(f'assets/ghost_images/powerup.png'), (45, 45))
dead_img = pygame.transform.scale(pygame.image.load(f'assets/ghost_images/dead.png'), (45, 45))
player_x = 450
player_y = 663
direction = 0
```

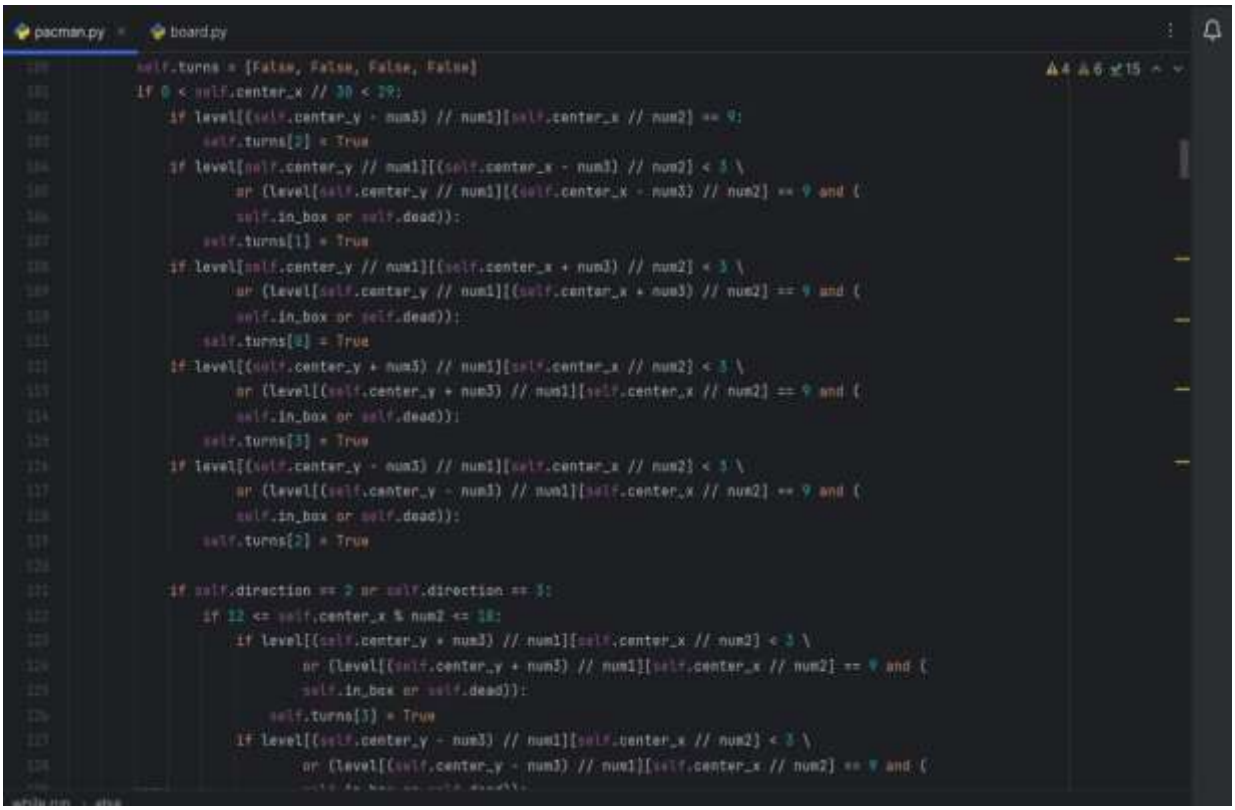
pacman.py board.py

```
inky_y = 388
inky_direction = 2
pinky_x = 440
pinky_y = 438
pinky_direction = 2
clyde_x = 440
clyde_y = 438
clyde_direction = 2
counter = 0
flicker = False
# R, L, U, D
turns_allowed = [False, False, False, False]
direction_command = 0
player_speed = 2
score = 0
powerup = False
power_counter = 0
eaten_ghost = [False, False, False, False]
targets = [(player_x, player_y), (player_x, player_y), (player_x, player_y), (player_x, player_y)]
blinky_dead = False
inky_dead = False
clyde_dead = False
pinky_dead = False
blinky_box = False
inky_box = False
clyde_box = False
pinky_box = False
moving = False
ghost_speeds = [2, 2, 2, 2]
```

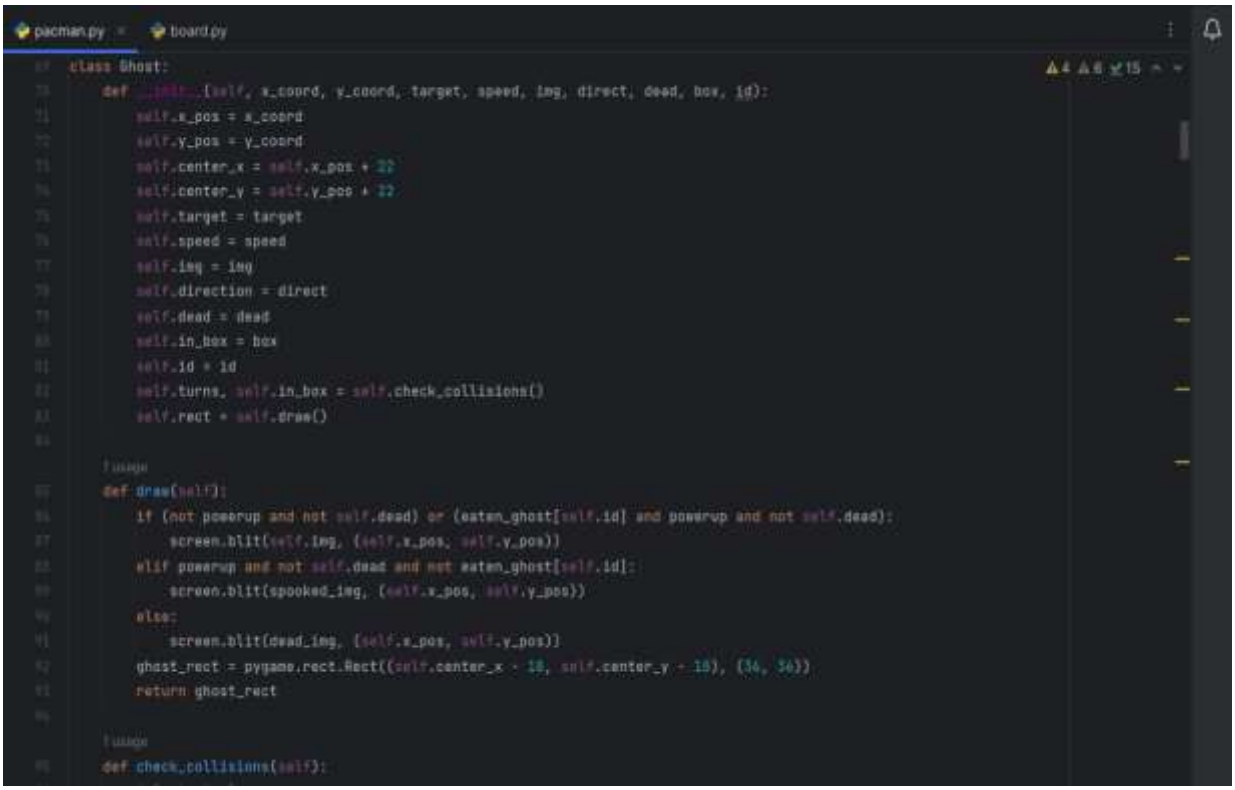
while run else



```
pacman.py  board.py
        if 350 < self.x_pos < 550 and 370 < self.y_pos < 480:
            self.in_box = True
        else:
            self.in_box = False
        return self.turns, self.in_box

    4 usages
    def move_clyde(self):
        # r, l, u, d
        # clyde is going to turn whenever advantageous for pursuit
        if self.direction == 0:
            if self.target[0] > self.x_pos and self.turns[0]:
                self.x_pos += self.speed
            elif not self.turns[0]:
                if self.target[1] > self.y_pos and self.turns[3]:
                    self.direction = 3
                    self.y_pos += self.speed
                elif self.target[1] < self.y_pos and self.turns[2]:
                    self.direction = 2
                    self.y_pos -= self.speed
                elif self.target[0] < self.x_pos and self.turns[1]:
                    self.direction = 1
                    self.x_pos -= self.speed
                elif self.turns[3]:
                    self.direction = 3
                    self.y_pos += self.speed
                elif self.turns[2]:
                    self.direction = 2
                    self.y_pos -= self.speed
```

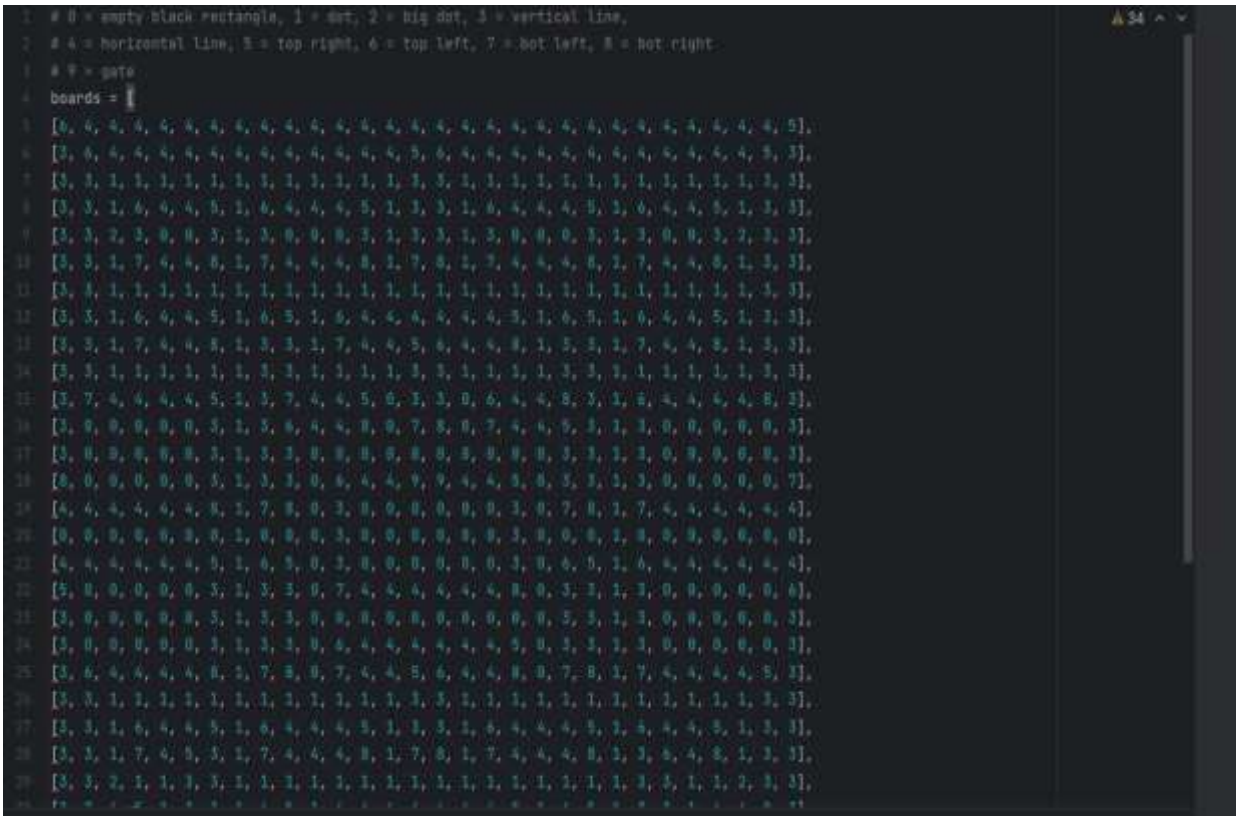


```
pacman.py  board.py
        self.turns = [False, False, False, False]
        if 0 < self.center_x // 30 < 29:
            if level[(self.center_y - num3) // num1][self.center_x // num2] == 9:
                self.turns[2] = True
            if level[self.center_y // num1][(self.center_x - num3) // num2] < 3 \
                    or (level[self.center_y // num1][(self.center_x - num3) // num2] == 9 and (
                    self.in_box or self.dead)):
                self.turns[1] = True
            if level[self.center_y // num1][(self.center_x + num3) // num2] < 3 \
                    or (level[self.center_y // num1][(self.center_x + num3) // num2] == 9 and (
                    self.in_box or self.dead)):
                self.turns[0] = True
            if level[(self.center_y + num3) // num1][self.center_x // num2] < 3 \
                    or (level[(self.center_y + num3) // num1][self.center_x // num2] == 9 and (
                    self.in_box or self.dead)):
                self.turns[3] = True
            if level[(self.center_y - num3) // num1][self.center_x // num2] < 3 \
                    or (level[(self.center_y - num3) // num1][self.center_x // num2] == 9 and (
                    self.in_box or self.dead)):
                self.turns[2] = True

            if self.direction == 2 or self.direction == 3:
                if 12 <= self.center_x % num2 <= 18:
                    if level[(self.center_y + num3) // num1][self.center_x // num2] < 3 \
                            or (level[(self.center_y + num3) // num1][self.center_x // num2] == 9 and (
                            self.in_box or self.dead)):
                        self.turns[3] = True
                    if level[(self.center_y - num3) // num1][self.center_x // num2] < 3 \
                            or (level[(self.center_y - num3) // num1][self.center_x // num2] == 9 and (
```

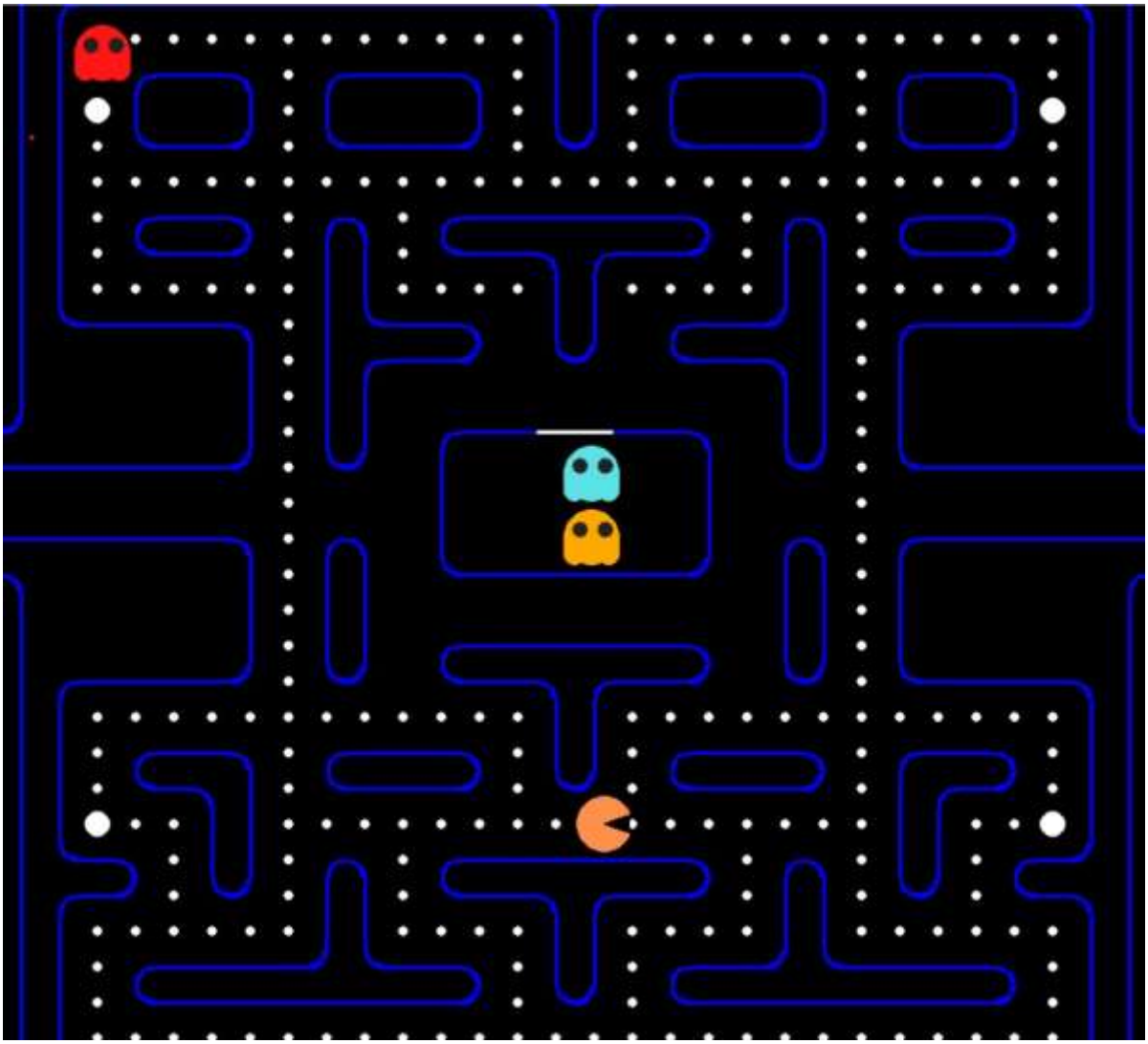


```
pacman.py × board.py
class Ghost:
    def __init__(self, x_coord, y_coord, target, speed, img, direct, dead, box, id):
        self.x_pos = x_coord
        self.y_pos = y_coord
        self.center_x = self.x_pos + 22
        self.center_y = self.y_pos + 22
        self.target = target
        self.speed = speed
        self.img = img
        self.direction = direct
        self.dead = dead
        self.in_box = box
        self.id = id
        self.turns, self.in_box = self.check_collisions()
        self.rect = self.draw()

    1 usage
    def draw(self):
        if (not powerup and not self.dead) or (eaten_ghost[self.id] and powerup and not self.dead):
            screen.blit(self.img, (self.x_pos, self.y_pos))
        elif powerup and not self.dead and not eaten_ghost[self.id]:
            screen.blit(spooked_img, (self.x_pos, self.y_pos))
        else:
            screen.blit(dead_img, (self.x_pos, self.y_pos))
        ghost_rect = pygame.rect.Rect((self.center_x - 18, self.center_y - 18), (36, 36))
        return ghost_rect

    1 usage
    def check_collisions(self):
```

```
pacman.py × board.py
    def move_blinky(self):
        # r, l, u, d
        # blinky is going to turn whenever colliding with walls, otherwise continue straight
        if self.direction == 0:
            if self.target[0] > self.x_pos and self.turns[0]:
                self.x_pos += self.speed
            elif not self.turns[0]:
                if self.target[1] > self.y_pos and self.turns[3]:
                    self.direction = 3
                    self.y_pos += self.speed
                elif self.target[1] < self.y_pos and self.turns[2]:
                    self.direction = 2
                    self.y_pos -= self.speed
                elif self.target[0] < self.x_pos and self.turns[1]:
                    self.direction = 1
                    self.x_pos -= self.speed
                elif self.turns[3]:
                    self.direction = 3
                    self.y_pos += self.speed
                elif self.turns[2]:
                    self.direction = 2
                    self.y_pos -= self.speed
                elif self.turns[1]:
                    self.direction = 1
                    self.x_pos -= self.speed
            elif self.turns[0]:
                self.x_pos += self.speed
        elif self.direction == 1:
            if self.target[0] < self.x_pos and self.turns[1]:
                self.x_pos -= self.speed
```


34
# 0 = empty black rectangle, 1 = dot, 2 = big dot, 3 = vertical line,
# 4 = horizontal line, 5 = top right, 6 = top left, 7 = bot left, 8 = bot right
# 9 = gate
boards = [

OUTPUT



CONCLUSION

Implementing a Pacman game utilizing search algorithms like Depth-First Search (DFS), Breadth-First Search (BFS), and A* would provide a comprehensive exploration of pathfinding strategies. DFS, though simplistic, would embody Pacman's exploratory nature, traversing deep into the maze's branches. BFS, ensuring optimal paths, would enable Pacman to efficiently navigate towards pellets or evade ghosts, albeit at the cost of increased memory usage. A* would offer the best of both worlds, leveraging heuristics to guide Pacman towards the shortest path while considering various factors such as distance to targets and ghost avoidance. By comparing these algorithms' performances in terms of path length, execution time, and memory consumption, one could draw insights into their effectiveness in enhancing Pacman's gameplay experience and strategize accordingly.

FUTURE ENHANCEMENTS

1. Additional Search Algorithms: Implement more advanced search algorithms such as Dijkstra's algorithm, Best-First Search, or Iterative Deepening Depth-First Search (IDDFS). Provide an option for players to select the search algorithm they want to use.

2. Advanced Maze Generation: Introduce maze generation algorithms such as Prim's algorithm, Kruskal's algorithm, or Recursive Division. Allow players to design and share custom mazes

3. Enhanced Graphics and Visuals: Improve the game's visual appeal with enhanced graphics, animations, and visual effects. Add more themes and customizable options for Pacman and the maze.

4. Multiplayer Mode: Implement a multiplayer mode where players can compete against each other. Introduce cooperative or competitive multiplayer modes.

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