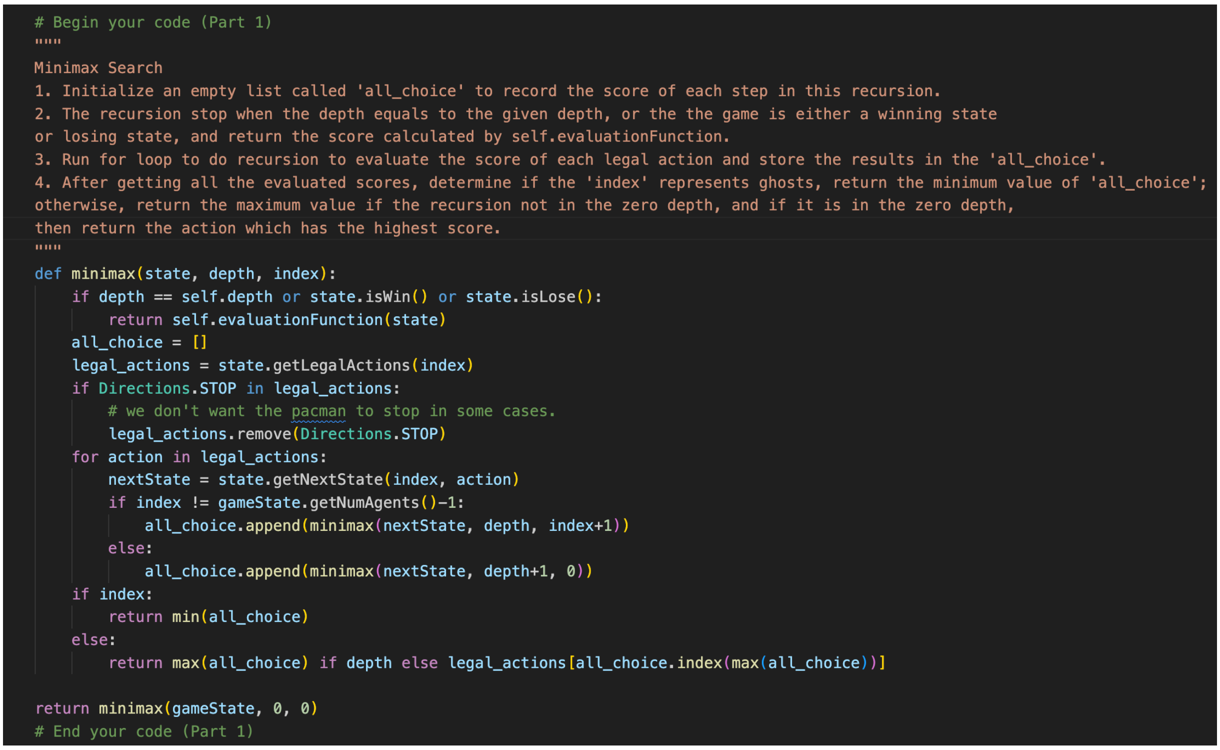
Homework 3: Multi-Agent Search

Part I. Implementation (20%):

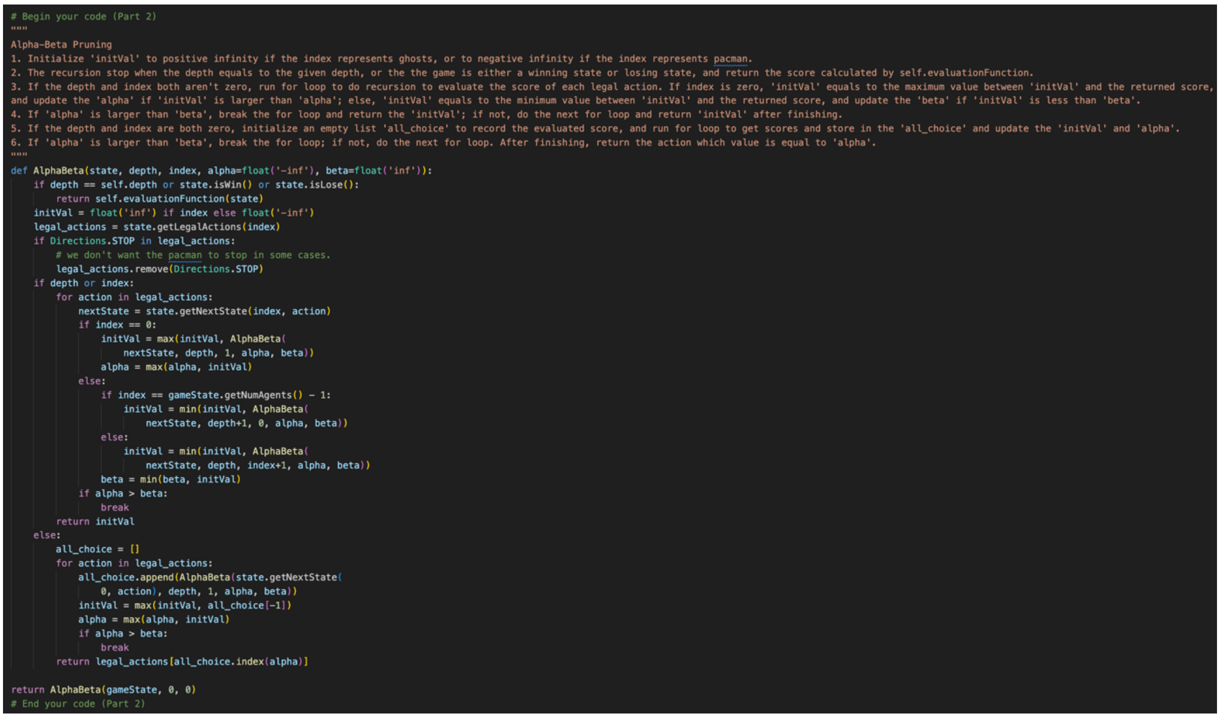
- ### Part 1



```
# Begin your code (Part 1)
"""
Minimax Search
1. Initialize an empty list called 'all_choice' to record the score of each step in this recursion.
2. The recursion stop when the depth equals to the given depth, or the the game is either a winning state
or losing state, and return the score calculated by self.evaluationFunction.
3. Run for loop to do recursion to evaluate the score of each legal action and store the results in the 'all_choice'.
4. After getting all the evaluated scores, determine if the 'index' represents ghosts, return the minimum value of 'all_choice';
otherwise, return the maximum value if the recursion not in the zero depth, and if it is in the zero depth,
then return the action which has the highest score.
"""
def minimax(state, depth, index):
    if depth == self.depth or state.isWin() or state.isLose():
        return self.evaluationFunction(state)
    all_choice = []
    legal_actions = state.getLegalActions(index)
    if Directions.STOP in legal_actions:
        # we don't want the pacman to stop in some cases.
        legal_actions.remove(Directions.STOP)
    for action in legal_actions:
        nextState = state.getNextState(index, action)
        if index != gameState.getNumAgents()-1:
            all_choice.append(minimax(nextState, depth, index+1))
        else:
            all_choice.append(minimax(nextState, depth+1, 0))
    if index:
        return min(all_choice)
    else:
        return max(all_choice) if depth else legal_actions[all_choice.index(max(all_choice))]

return minimax(gameState, 0, 0)
# End your code (Part 1)
```

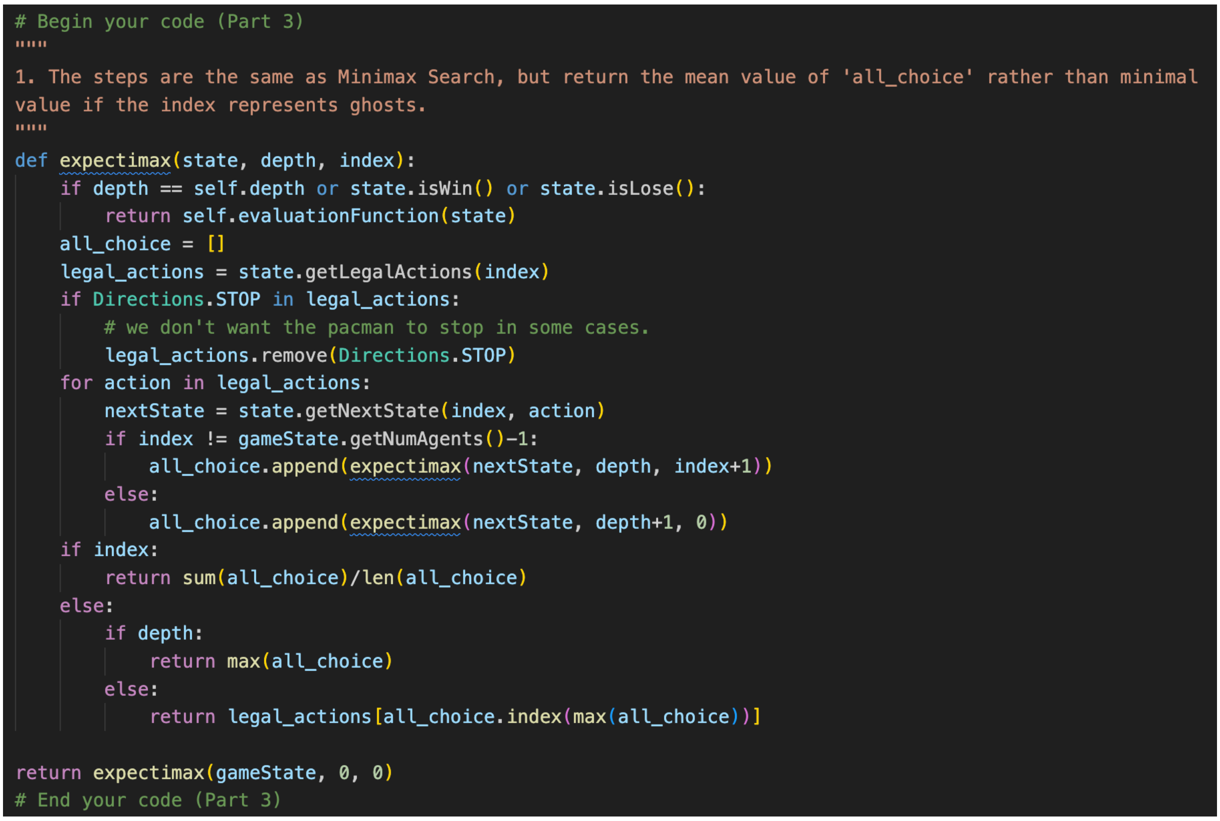
- ### Part 2



```
# Begin your code (Part 2)
"""
Alpha-Beta Pruning
1. Initialize 'initVal' to positive infinity if the index represents ghosts, or to negative infinity if the index represents pacman.
2. The recursion stop when the depth equals to the given depth, or the the game is either a winning state or losing state, and return the score calculated by self.evaluationFunction.
3. If the depth and index both aren't zero, run for loop to do recursion to evaluate the score of each legal action. If index is zero, 'initVal' equals to the maximum value between 'initVal' and the returned score,
and update the 'alpha' if 'initVal' is larger than 'alpha'; else, 'initVal' equals to the minimum value between 'initVal' and the returned score, and update the 'beta' if 'initVal' is less than 'beta'.
4. If 'alpha' is larger than 'beta', break the for loop and return the 'initVal'; if not, do the next for loop and return 'initVal' after finishing.
5. If the depth and index are both zero, initialize an empty list 'all_choice' to record the evaluated score, and run for loop to get scores and store in the 'all_choice' and update the 'initVal' and 'alpha'.
6. If 'alpha' is larger than 'beta', break the for loop; if not, do the next for loop. After finishing, return the action which value is equal to 'alpha'.
"""
def AlphaBeta(state, depth, index, alpha=float('-inf'), beta=float('inf')):
    if depth == self.depth or state.isWin() or state.isLose():
        return self.evaluationFunction(state)
    initVal = float('inf') if index else float('-inf')
    legal_actions = state.getLegalActions(index)
    if Directions.STOP in legal_actions:
        # we don't want the pacman to stop in some cases.
        legal_actions.remove(Directions.STOP)
    if depth or index:
        for action in legal_actions:
            nextState = state.getNextState(index, action)
            if index == 0:
                initVal = max(initVal, AlphaBeta(
                    nextState, depth, 1, alpha, beta))
                alpha = max(alpha, initVal)
            else:
                if index == gameState.getNumAgents() - 1:
                    initVal = min(initVal, AlphaBeta(
                        nextState, depth+1, 0, alpha, beta))
                else:
                    initVal = min(initVal, AlphaBeta(
                        nextState, depth, index+1, alpha, beta))
                beta = min(beta, initVal)
            if alpha > beta:
                break
        return initVal
    else:
        all_choice = []
        for action in legal_actions:
            all_choice.append(AlphaBeta(state.getNextState(
                0, action), depth, 1, alpha, beta))
            initVal = max(initVal, all_choice[-1])
            alpha = max(alpha, initVal)
            if alpha > beta:
                break
        return legal_actions[all_choice.index(alpha)]

return AlphaBeta(gameState, 0, 0)
# End your code (Part 2)
```

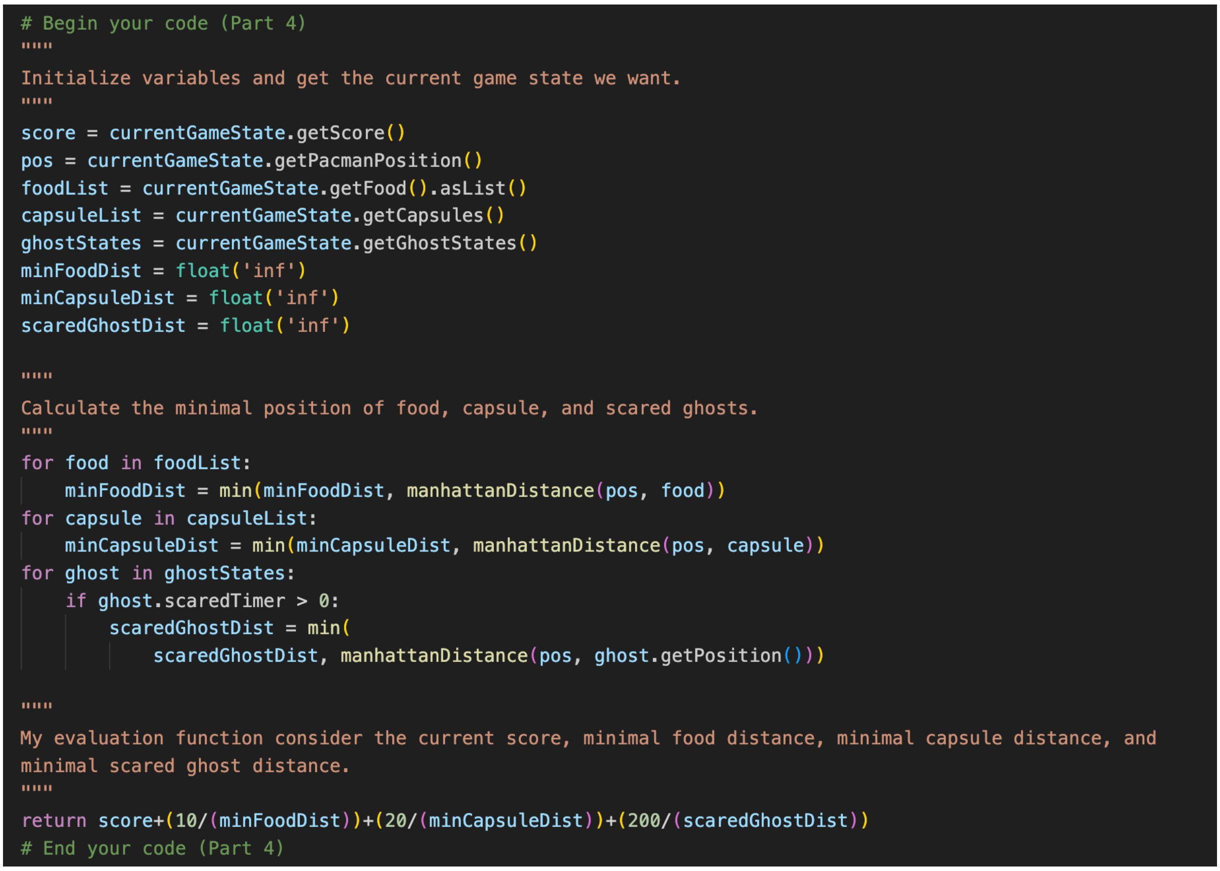
- **Part 3**



```
# Begin your code (Part 3)
"""
1. The steps are the same as Minimax Search, but return the mean value of 'all_choice' rather than minimal
value if the index represents ghosts.
"""
def expectimax(state, depth, index):
    if depth == self.depth or state.isWin() or state.isLose():
        return self.evaluationFunction(state)
    all_choice = []
    legal_actions = state.getLegalActions(index)
    if Directions.STOP in legal_actions:
        # we don't want the pacman to stop in some cases.
        legal_actions.remove(Directions.STOP)
    for action in legal_actions:
        nextState = state.getNextState(index, action)
        if index != gameState.getNumAgents()-1:
            all_choice.append(expectimax(nextState, depth, index+1))
        else:
            all_choice.append(expectimax(nextState, depth+1, 0))
    if index:
        return sum(all_choice)/len(all_choice)
    else:
        if depth:
            return max(all_choice)
        else:
            return legal_actions[all_choice.index(max(all_choice))]

return expectimax(gameState, 0, 0)
# End your code (Part 3)
```

- **Part 4**



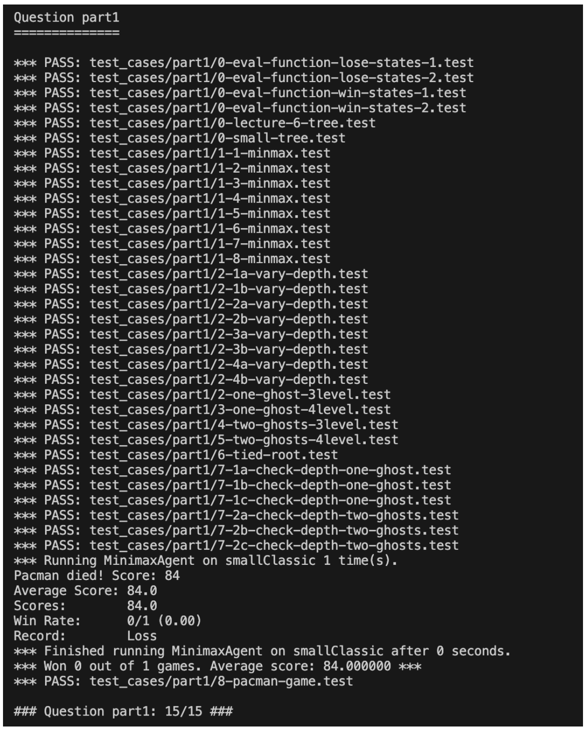
```
# Begin your code (Part 4)
"""
Initialize variables and get the current game state we want.
"""
score = currentGameState.getScore()
pos = currentGameState.getPacmanPosition()
foodList = currentGameState.getFood().asList()
capsuleList = currentGameState.getCapsules()
ghostStates = currentGameState.getGhostStates()
minFoodDist = float('inf')
minCapsuleDist = float('inf')
scaredGhostDist = float('inf')

"""
Calculate the minimal position of food, capsule, and scared ghosts.
"""
for food in foodList:
    minFoodDist = min(minFoodDist, manhattanDistance(pos, food))
for capsule in capsuleList:
    minCapsuleDist = min(minCapsuleDist, manhattanDistance(pos, capsule))
for ghost in ghostStates:
    if ghost.scaredTimer > 0:
        scaredGhostDist = min(
            scaredGhostDist, manhattanDistance(pos, ghost.getPosition()))

"""
My evaluation function consider the current score, minimal food distance, minimal capsule distance, and
minimal scared ghost distance.
"""
return score+(10/(minFoodDist))+(20/(minCapsuleDist))+(200/(scaredGhostDist))
# End your code (Part 4)
```

Part II. Results & Analysis (10%):

- ## Part 1



```
Question part1
==============

*** PASS: test_cases/part1/0-eval-function-lose-states-1.test
*** PASS: test_cases/part1/0-eval-function-lose-states-2.test
*** PASS: test_cases/part1/0-eval-function-win-states-1.test
*** PASS: test_cases/part1/0-eval-function-win-states-2.test
*** PASS: test_cases/part1/0-lecture-6-tree.test
*** PASS: test_cases/part1/0-small-tree.test
*** PASS: test_cases/part1/1-1-minmax.test
*** PASS: test_cases/part1/1-2-minmax.test
*** PASS: test_cases/part1/1-3-minmax.test
*** PASS: test_cases/part1/1-4-minmax.test
*** PASS: test_cases/part1/1-5-minmax.test
*** PASS: test_cases/part1/1-6-minmax.test
*** PASS: test_cases/part1/1-7-minmax.test
*** PASS: test_cases/part1/1-8-minmax.test
*** PASS: test_cases/part1/2-1a-vary-depth.test
*** PASS: test_cases/part1/2-1b-vary-depth.test
*** PASS: test_cases/part1/2-2a-vary-depth.test
*** PASS: test_cases/part1/2-2b-vary-depth.test
*** PASS: test_cases/part1/2-3a-vary-depth.test
*** PASS: test_cases/part1/2-3b-vary-depth.test
*** PASS: test_cases/part1/2-4a-vary-depth.test
*** PASS: test_cases/part1/2-4b-vary-depth.test
*** PASS: test_cases/part1/2-one-ghost-3level.test
*** PASS: test_cases/part1/3-one-ghost-4level.test
*** PASS: test_cases/part1/4-two-ghosts-3level.test
*** PASS: test_cases/part1/5-two-ghosts-4level.test
*** PASS: test_cases/part1/6-tied-root.test
*** PASS: test_cases/part1/7-1a-check-depth-one-ghost.test
*** PASS: test_cases/part1/7-1b-check-depth-one-ghost.test
*** PASS: test_cases/part1/7-1c-check-depth-one-ghost.test
*** PASS: test_cases/part1/7-2a-check-depth-two-ghosts.test
*** PASS: test_cases/part1/7-2b-check-depth-two-ghosts.test
*** PASS: test_cases/part1/7-2c-check-depth-two-ghosts.test
*** Running MinimaxAgent on smallClassic 1 time(s).
Pacman died! Score: 84
Average Score: 84.0
Scores:        84.0
Win Rate:      0/1 (0.00)
Record:        Loss
*** Finished running MinimaxAgent on smallClassic after 0 seconds.
*** Won 0 out of 1 games. Average score: 84.000000 ***
*** PASS: test_cases/part1/8-pacman-game.test

### Question part1: 15/15 ###
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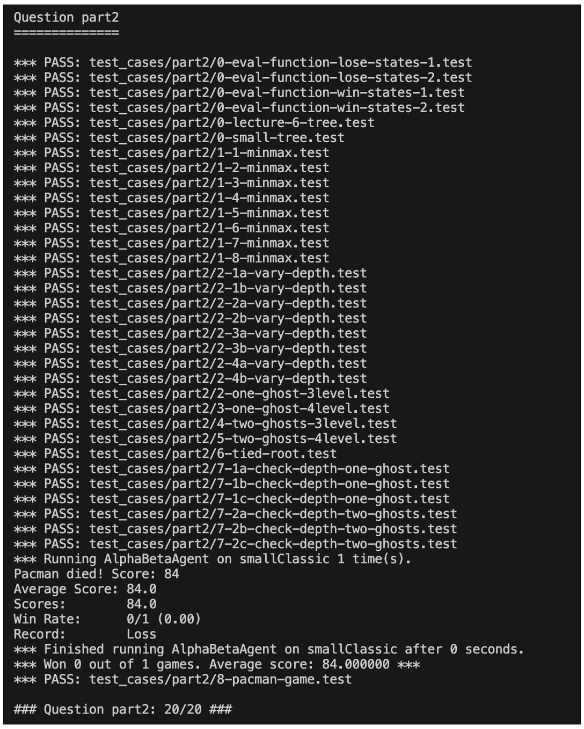
- ## Part 2



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Question part2
==============

*** PASS: test_cases/part2/0-eval-function-lose-states-1.test
*** PASS: test_cases/part2/0-eval-function-lose-states-2.test
*** PASS: test_cases/part2/0-eval-function-win-states-1.test
*** PASS: test_cases/part2/0-eval-function-win-states-2.test
*** PASS: test_cases/part2/0-lecture-6-tree.test
*** PASS: test_cases/part2/0-small-tree.test
*** PASS: test_cases/part2/1-1-minmax.test
*** PASS: test_cases/part2/1-2-minmax.test
*** PASS: test_cases/part2/1-3-minmax.test
*** PASS: test_cases/part2/1-4-minmax.test
*** PASS: test_cases/part2/1-5-minmax.test
*** PASS: test_cases/part2/1-6-minmax.test
*** PASS: test_cases/part2/1-7-minmax.test
*** PASS: test_cases/part2/1-8-minmax.test
*** PASS: test_cases/part2/2-1a-vary-depth.test
*** PASS: test_cases/part2/2-1b-vary-depth.test
*** PASS: test_cases/part2/2-2a-vary-depth.test
*** PASS: test_cases/part2/2-2b-vary-depth.test
*** PASS: test_cases/part2/2-3a-vary-depth.test
*** PASS: test_cases/part2/2-3b-vary-depth.test
*** PASS: test_cases/part2/2-4a-vary-depth.test
*** PASS: test_cases/part2/2-4b-vary-depth.test
*** PASS: test_cases/part2/2-one-ghost-3level.test
*** PASS: test_cases/part2/3-one-ghost-4level.test
*** PASS: test_cases/part2/4-two-ghosts-3level.test
*** PASS: test_cases/part2/5-two-ghosts-4level.test
*** PASS: test_cases/part2/6-tied-root.test
*** PASS: test_cases/part2/7-1a-check-depth-one-ghost.test
*** PASS: test_cases/part2/7-1b-check-depth-one-ghost.test
*** PASS: test_cases/part2/7-1c-check-depth-one-ghost.test
*** PASS: test_cases/part2/7-2a-check-depth-two-ghosts.test
*** PASS: test_cases/part2/7-2b-check-depth-two-ghosts.test
*** PASS: test_cases/part2/7-2c-check-depth-two-ghosts.test
*** Running AlphaBetaAgent on smallClassic 1 time(s).
Pacman died! Score: 84
Average Score: 84.0
Scores:        84.0
Win Rate:      0/1 (0.00)
Record:        Loss
*** Finished running AlphaBetaAgent on smallClassic after 0 seconds.
*** Won 0 out of 1 games. Average score: 84.000000 ***
*** PASS: test_cases/part2/8-pacman-game.test

### Question part2: 20/20 ###
```
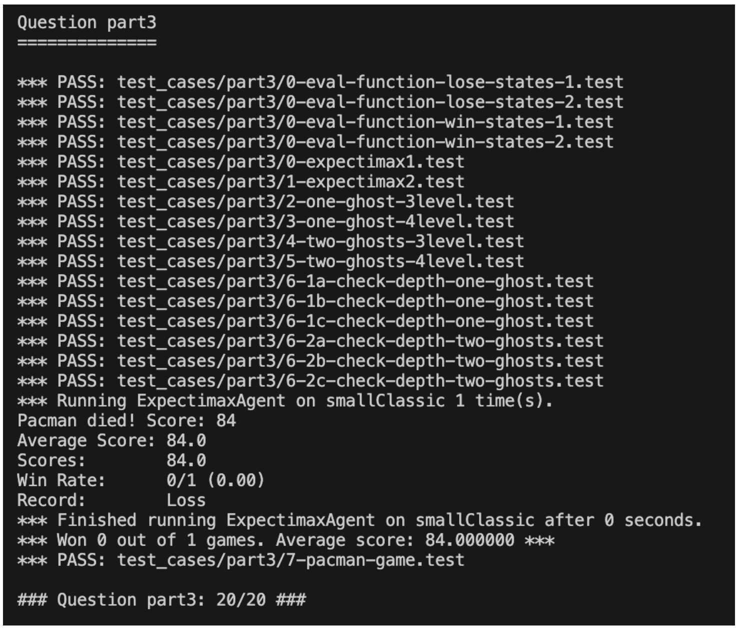

- **Part 3**



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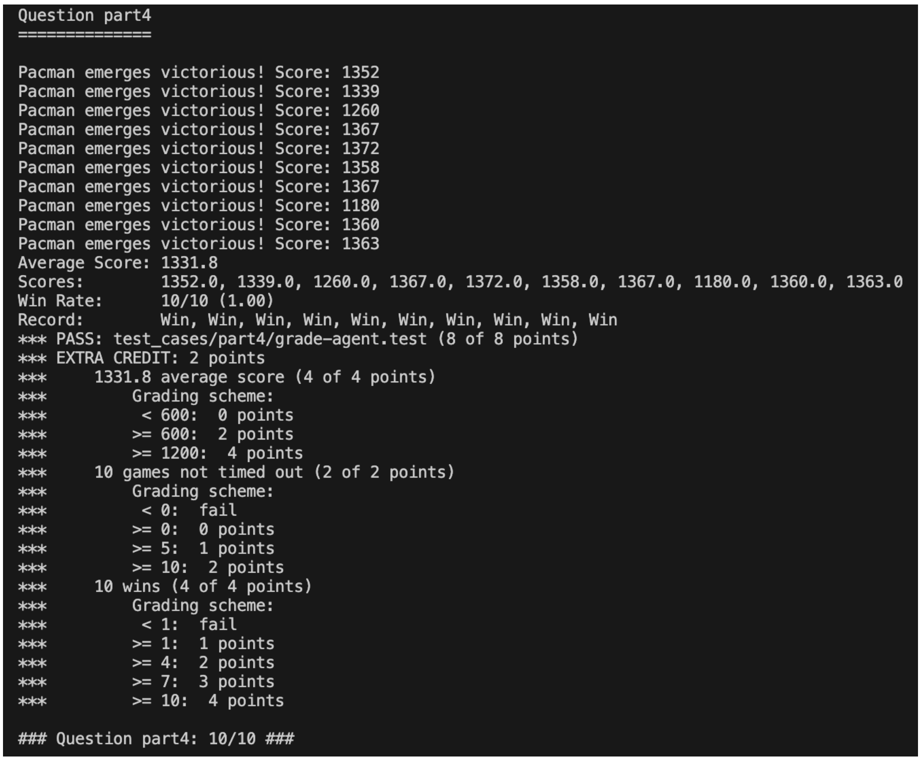
Question part3
==============

*** PASS: test_cases/part3/0-eval-function-lose-states-1.test
*** PASS: test_cases/part3/0-eval-function-lose-states-2.test
*** PASS: test_cases/part3/0-eval-function-win-states-1.test
*** PASS: test_cases/part3/0-eval-function-win-states-2.test
*** PASS: test_cases/part3/0-expectimax1.test
*** PASS: test_cases/part3/1-expectimax2.test
*** PASS: test_cases/part3/2-one-ghost-3level.test
*** PASS: test_cases/part3/3-one-ghost-4level.test
*** PASS: test_cases/part3/4-two-ghosts-3level.test
*** PASS: test_cases/part3/5-two-ghosts-4level.test
*** PASS: test_cases/part3/6-1a-check-depth-one-ghost.test
*** PASS: test_cases/part3/6-1b-check-depth-one-ghost.test
*** PASS: test_cases/part3/6-1c-check-depth-one-ghost.test
*** PASS: test_cases/part3/6-2a-check-depth-two-ghosts.test
*** PASS: test_cases/part3/6-2b-check-depth-two-ghosts.test
*** PASS: test_cases/part3/6-2c-check-depth-two-ghosts.test
*** Running ExpectimaxAgent on smallClassic 1 time(s).
Pacman died! Score: 84
Average Score: 84.0
Scores:        84.0
Win Rate:      0/1 (0.00)
Record:        Loss
*** Finished running ExpectimaxAgent on smallClassic after 0 seconds.
*** Won 0 out of 1 games. Average score: 84.000000 ***
*** PASS: test_cases/part3/7-pacman-game.test

### Question part3: 20/20 ###
```

- **Part 4**



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Question part4
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Pacman emerges victorious! Score: 1352
Pacman emerges victorious! Score: 1339
Pacman emerges victorious! Score: 1260
Pacman emerges victorious! Score: 1367
Pacman emerges victorious! Score: 1372
Pacman emerges victorious! Score: 1358
Pacman emerges victorious! Score: 1367
Pacman emerges victorious! Score: 1180
Pacman emerges victorious! Score: 1360
Pacman emerges victorious! Score: 1363
Average Score: 1331.8
Scores:        1352.0, 1339.0, 1260.0, 1367.0, 1372.0, 1358.0, 1367.0, 1180.0, 1360.0, 1363.0
Win Rate:      10/10 (1.00)
Record:        Win, Win, Win, Win, Win, Win, Win, Win, Win, Win
*** PASS: test_cases/part4/grade-agent.test (8 of 8 points)
*** EXTRA CREDIT: 2 points
***     1331.8 average score (4 of 4 points)
***         Grading scheme:
***          < 600:  0 points
***         >= 600:  2 points
***         >= 1200:  4 points
***     10 games not timed out (2 of 2 points)
***         Grading scheme:
***          < 0:  fail
***         >= 0:  0 points
***         >= 5:  1 points
***         >= 10:  2 points
***     10 wins (4 of 4 points)
***         Grading scheme:
***          < 1:  fail
***         >= 1:  1 points
***         >= 4:  2 points
***         >= 7:  3 points
***         >= 10:  4 points

### Question part4: 10/10 ###
```