CS 6045 Advanced Algorithms

Optimization of connect4 game using Mini-Max Algorithm and Alpha-Beta Pruning

Imported Libraries

In [1]:

```
from sklearn.datasets import make_classification
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn.metrics import confusion_matrix, accuracy_score
from sklearn.linear_model import LogisticRegression
# from IPython.display import set_matplotlib_formats
# set_matplotlib_formats('retina', quality=100)
import numpy as np
import pandas as pd
import random
import pygame
import sys
import time
import math
from math import inf
import seaborn as sns
import matplotlib.pyplot as plt
%matplotlib inline
plt.style.use('bmh')
```

```
pygame 2.1.2 (SDL 2.0.18, Python 3.8.8)
Hello from the pygame community. https://www.pygame.org/contribute.html
```

Code Implementation

In [2]:

```
%%time

# Input

Select_AI = input("Select the AI ('mini-max' or 'alpha-beta')?")

if Select_AI == "mini-max":
    DEPTH_VALUE = int(input("Enter depth value between 1 and 5?"))
if Select_AI == "alpha-beta":
    DEPTH_VALUE = int(input("Enter depth value between 1 and 8?"))

# Colors

GREY, LBLUE, DBLUE, WHITE, TEXT = (132,132,132), (61,89,171), (0,0,128), (255,255,240), (3,3,3)

# Grid Dimensions

HORI, VERT = 6, 7

# Utilizing Values

MAN, ALGO, MAN_CHANCE, ALGO_CHANCE  = 0, 1, 1, 2

# Defining weights

WEIGHT_MEASURE = 4
DUMMY = 0

# Function to Prepare an empty board
def game_grid():
    grid = np.zeros((HORI,VERT))
    return grid

# Sectioning the board
def drop_balls(grid, horizontal, vertical, ball):
    grid[horizontal][vertical] = ball

def true_loc(grid, vertical):
    return grid[HORI-1][vertical] == DUMMY

# Searching for vacant horizontal series
def check_next_vacant_row(grid, vertical):
    for ele in range(HORI):
        if grid[ele][vertical] == DUMMY:
            return ele

# Reverse the indexing of the board
def print_grid(grid):
    print(np.flip(grid, DUMMY))

# -- Function defines connect4 game concept
# -- checking the strikes for winning
def check_win_mov(grid, ball):
    # Checking win strikes in a row
    for v in range(VERT-3):
```

```python
        for h in range(HORI):
            if grid[h][v] == ball and grid[h][v+1] == ball and grid[h][v+2] == ball and grid[h][v+3] == ball:
                return True
    # Checking win strikes in a column
    for v in range(VERT):
        for h in range(HORI-3):
            if grid[h][v] == ball and grid[h+1][v] == ball and grid[h+2][v] == ball and grid[h+3][v] == ball:
                return True
    # Checking win strikes in +ve sloped diagonals
    for v in range(VERT-3):
        for h in range(HORI-3):
            if grid[h][v] == ball and grid[h+1][v+1] == ball and grid[h+2][v+2] == ball and grid[h+3][v+3] == ball:
                return True

    # Checking win strikes in -ve sloped diagonals
    for v in range(VERT-3):
        for h in range(3, HORI):
            if grid[h][v] == ball and grid[h-1][v+1] == ball and grid[h-2][v+2] == ball and grid[h-3][v+3] == ball:
                return True

# Assigning the weights to make an action
def declare_weights(weight, ball):
    priority = DUMMY
    opponent_chance = MAN_CHANCE
    if ball == MAN_CHANCE:
        opponent_chance = ALGO_CHANCE
    if weight.count(ball) == 4:
        priority += 100
    elif weight.count(ball) == 3 and weight.count(DUMMY) == 1:
        priority += 5
    elif weight.count(ball) == 2 and weight.count(DUMMY) == 2:
        priority += 2
    if weight.count(opponent_chance) == 3 and weight.count(DUMMY) == 1:
        priority -= 4
    return priority

# Where to focus first(Traing AI to focus)?
def Preference_of_AI(grid, ball):
    priority = DUMMY
    # priority makes to choose center of the grid
    grid_middle_series = [int(k) for k in list(grid[:, VERT//2])]
    grid_middle_count = grid_middle_series.count(ball)
    priority += grid_middle_count * 3
    # prioritizing Horizontal
    for h in range(HORI):
        horizontal_series = [int(k) for k in list(grid[h,:])]
        for v in range(VERT-3):
            weight = horizontal_series[v:v+WEIGHT_MEASURE]
            priority += declare_weights(weight, ball)
    # prioritixing Vertical
    for v in range(VERT):
        vertical_series = [int(k) for k in list(grid[:,v])]
        for h in range(HORI-3):
            weight = vertical_series[h:h+WEIGHT_MEASURE]
            priority += declare_weights(weight, ball)
    # prioritizing +ve Diagonal
    for h in range(HORI-3):
        for v in range(VERT-3):
            weight = [grid[h+k][v+k] for k in range(WEIGHT_MEASURE)]
            priority += declare_weights(weight, ball)
    # prioritizing -ve Diagonal
    for h in range(HORI-3):
        for v in range(VERT-3):
            weight = [grid[h+3-k][v+k] for k in range(WEIGHT_MEASURE)]
            priority += declare_weights(weight, ball)
    return priority

def node(grid):
    return check_win_mov(grid, MAN_CHANCE) or check_win_mov(grid, ALGO_CHANCE) or len(get_certain_loc(grid)) == DUMMY

# Implementation of Mini-Max Algorithm(Our Bench-Mark Algorithm)
lis_mm, mm_column, mm_value = [], [], []
#@profile
def Mini_Max(grid, depth, maximizinggame):
    start_time = time.time()*1000.0
    certain_loc, term_head = get_certain_loc(grid), node(grid)
    if depth == 0 or term_head:
        if term_head:
            if check_win_mov(grid, ALGO_CHANCE):
                return (None, math.inf)
            elif check_win_mov(grid, MAN_CHANCE):
                return (None, -math.inf)
            else: #Game finished, No more valid moves
                return (None, DUMMY)
        else: #Depth is zero
            return (None, Preference_of_AI(grid, ALGO_CHANCE))
    if maximizinggame:
        value, column = -math.inf, random.choice(certain_loc)
        for vertical in certain_loc:
            horizontal, duplicate_grid = check_next_vacant_row(grid, vertical), grid.copy()
            drop_balls(duplicate_grid, horizontal, vertical, ALGO_CHANCE)
            new_priority = Mini_Max(duplicate_grid, depth-1, False)[1]
            if new_priority > value:
                value, column = new_priority, vertical
        mm_column.append(column)
```

```
        mm_value.append(value)
        return column, value
    else: #minimizinggame
        value = math.inf
        column = random.choice(certain_loc)
        for vertical in certain_loc:
            horizontal = check_next_vacant_row(grid, vertical)
            duplicate_grid = grid.copy()
            drop_balls(duplicate_grid, horizontal, vertical, MAN_CHANCE)
            new_priority = Mini_Max(duplicate_grid, depth-1, True)[1]
            if new_priority < value:
                value = new_priority
                column = vertical
        end_time = time.time()*1000.0
        lis_mm.append(end_time - start_time)
        mm_column.append(column)
        mm_value.append(value)
        return column, value

# Implementation of Alpha_Beta Algorithm(Our Optimal Algorithm)
lis_ab, ab_column, ab_value = [], [], []
#@profile
def alpha_beta(grid, depth, alpha, beta, maximizingPlayer):
    start_time = time.time()*1000.0
    valid_locations = get_certain_loc(grid)
    is_terminal = node(grid)
    if depth == 0 or is_terminal:
        if is_terminal:
            if check_win_mov(grid, ALGO_CHANCE):
                return (None, math.inf)
            elif check_win_mov(grid, MAN_CHANCE):
                return (None, -math.inf)
            else: #Game finished, No more valid moves
                return (None, DUMMY)
        else: # Depth is zero
            return (None, Preference_of_AI(grid, ALGO_CHANCE))
    if maximizingPlayer:
        value = -math.inf
        vert_col = random.choice(valid_locations)
        for vertical in valid_locations:
            horizontal = check_next_vacant_row(grid, vertical)
            b_copy = grid.copy()
            drop_balls(b_copy, horizontal, vertical, ALGO_CHANCE)
            new_priority = alpha_beta(b_copy, depth-1, alpha, beta, False)[1]
            if new_priority > value:
                value = new_priority
                vert_col = vertical
            alpha = max(alpha, value)
            if alpha >= beta:
                break
        ab_column.append(vert_col)
        ab_value.append(vert_col)
        return vert_col, value
    else: # Minimizing component
        value = math.inf
        vert_col = random.choice(valid_locations)
        for vertical in valid_locations:
            horizontal = check_next_vacant_row(grid, vertical)
            b_copy = grid.copy()
            drop_balls(b_copy, horizontal, vertical, MAN_CHANCE)
            new_priority = alpha_beta(b_copy, depth-1, alpha, beta, True)[1]
            if new_priority < value:
                value = new_priority
                vert_col = vertical
            beta = min(beta, value)
            if alpha >= beta:
                break
        end_time = time.time()*1000.0
        lis_ab.append(end_time - start_time)
        return vert_col, value

def get_certain_loc(grid):
    certain_loc = [(vertical) for vertical in range(VERT) if true_loc(grid, vertical)]
    return certain_loc

# Function to predict moves(priority selection)
def optimal_prediction_mov(grid, ball):
    efficient_priority = -12022
    efficient_series = random.choice(get_certain_loc(grid))
    for vertical in get_certain_loc(grid):
        horizontal = check_next_vacant_row(grid, vertical)
        temp_grid = grid.copy()
        drop_balls(temp_grid, horizontal, vertical, ball)
        priority = Preference_of_AI(temp_grid, ball)
        if priority > efficient_priority:
            efficient_priority = priority
            efficient_series = vertical
    return efficient_series

# Function to creat the grid according to my screen size.
def draw_grid(grid):
    for v in range(VERT):
        for h in range(HORI):
            pygame.draw.rect(screen, GREY, (v*weigh, h*weigh+weigh, weigh, weigh))
            pygame.draw.circle(screen, LBLUE, (int(v*weigh+weigh/2), int(h*weigh+weigh+weigh/2)), RADIUS)
```

```
    for v in range(VERT):
        for h in range(HORI):
            if grid[h][v] == MAN_CHANCE:
                pygame.draw.circle(screen, DBLUE, (int(v*weigh+weigh/2), Length-int(h*weigh+weigh/2)), RADIUS)
            elif grid[h][v] == ALGO_CHANCE:
                pygame.draw.circle(screen, WHITE, (int(v*weigh+weigh/2), Length-int(h*weigh+weigh/2)), RADIUS)
    pygame.display.update()

# Variables Declaration
grid = game_grid()
print_grid(grid)
end_game = False

pygame.init()

weigh = 100

breadth = VERT * weigh
Length = (HORI+1) * weigh

size = (breadth, Length)

RADIUS = int(weigh/2 - 5)

screen = pygame.display.set_mode(size)
draw_grid(grid)
pygame.display.update()

myfont = pygame.font.SysFont("monospace", 75)

chance = random.randint(MAN, ALGO)

# Logic Intialization
while not end_game:

    for event in pygame.event.get():
        if event.type == pygame.QUIT:
            sys.exit()

        if event.type == pygame.MOUSEMOTION:
            pygame.draw.rect(screen, LBLUE, (0,0, breadth, weigh))
            position = event.pos[0]

            if chance == MAN:
                pygame.draw.circle(screen, DBLUE, (position, int(weigh/2)), RADIUS)

        pygame.display.update()

        if event.type == pygame.MOUSEBUTTONDOWN:
            pygame.draw.rect(screen, LBLUE, (0,0, breadth, weigh))
            if chance == MAN:
                position = event.pos[0]
                vertical = int(math.floor(position/weigh))
                if true_loc(grid, vertical):
                    horizontal = check_next_vacant_row(grid, vertical)
                    drop_balls(grid, horizontal, vertical, MAN_CHANCE)

                    if check_win_mov(grid, MAN_CHANCE):
                        label = myfont.render("Blue wins!!", 1, DBLUE)
                        screen.blit(label, (20,10))
                        end_game = True
                    chance += 1
                    chance = chance % 2
                    print_grid(grid)
                    draw_grid(grid)

        if Select_AI == "mini-max":
            if chance == ALGO and not end_game:
                vertical, Mini_Max_priority = Mini_Max(grid, DEPTH_VALUE, True)
                if true_loc(grid, vertical):
                    pygame.time.wait(143)
                    horizontal = check_next_vacant_row(grid, vertical)
                    drop_balls(grid, horizontal, vertical, ALGO_CHANCE)
                    if check_win_mov(grid, ALGO_CHANCE):
                        label = myfont.render("White Wins!!", 1, WHITE)
                        screen.blit(label, (20, 10))
                        end_game = True
                    print_grid(grid)
                    draw_grid(grid)
                    chance += MAN_CHANCE
                    chance = chance % ALGO_CHANCE
            if end_game:
                pygame.time.wait(2022)

        if Select_AI == "alpha-beta":
            if chance == ALGO and not end_game:
                vertical, alpha_beta_priority = alpha_beta(grid, DEPTH_VALUE, -math.inf, math.inf, True)
                if true_loc(grid, vertical):
                    #pygame.time.wait(500)
                    horizontal = check_next_vacant_row(grid, vertical)
                    drop_balls(grid, horizontal, vertical, ALGO_CHANCE)
                    if check_win_mov(grid, ALGO_CHANCE):
                        label = myfont.render("White wins!!", 1, WHITE)
                        screen.blit(label, (40,10))
                        end_game = True
```

```python
                    print_grid(grid)
                    draw_grid(grid)
                    chance += 1
                    chance = chance % 2
            if end_game:
                pygame.time.wait(2022)

if Select_AI == "mini-max":
    try:
        t1 = sum(lis_mm)/len(lis_mm)
    except ZeroDivisionError:
        t1 = 0
    print()
    print("Gathering 'Mini-Max' Data to analyse 'Compilation Time':")
    print()
    print("Mini-Max time for depth value", DEPTH_VALUE, "is", round(t1, 3), "milliseconds")
    print()
    print("Gathering 'Mini-Max' Data to calculate 'Accuracy':")
    print()
    minimax_return = pd.DataFrame({"Minimax Column":mm_column, "Minimax Weight":mm_value})
    minimax_return[minimax_return == -inf], minimax_return[minimax_return == inf] = 0, 100
    acc_data_mm = minimax_return.groupby("Minimax Column").sum()
    print(acc_data_mm)
    print()
    print("Mini-Max Algorithm resultant data as putting weights for each column at depth", DEPTH_VALUE, ":",
          acc_data_mm['Minimax Weight'].tolist())
    print()

if Select_AI == "alpha-beta":
    try:
        t2 = sum(lis_ab)/len(lis_ab)
    except ZeroDivisionError:
        t2 = 0
    print()
    print("Gathering 'Alpha-Beta' Data to analyse 'Compilation Time':")
    print()
    print("Alpha-Beta time for depth value", DEPTH_VALUE, "is", round(t2, 3), "milliseconds")
    print()
    print("Gathering 'Alpha-Beta' Data to calculate 'Accuracy':")
    print()
    alphabeta_return = pd.DataFrame({"Alphabeta Column":ab_column, "Alphabeta Weight":ab_value})
    alphabeta_return[alphabeta_return == -inf], alphabeta_return[alphabeta_return == inf] = 0, 100
    acc_data_ab = alphabeta_return.groupby("Alphabeta Column").sum()
    print(acc_data_ab)
    print()
    print("Alpha-Beta Algorithm resultant data as putting weights for each column at depth", DEPTH_VALUE, ":",
          acc_data_ab['Alphabeta Weight'].tolist())
    print()
```

```
Select the AI ('mini-max' or 'alpha-beta')?alpha-beta
Enter depth value between 1 and 8?3
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 2. 0. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 2. 0. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 2. 0. 0. 0.]
 [0. 0. 1. 2. 0. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 2. 0. 0. 0.]
 [0. 0. 1. 2. 0. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 2. 2. 0. 0. 0.]
 [0. 0. 1. 2. 0. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 2. 2. 0. 0. 0.]
 [0. 0. 1. 2. 1. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 2. 2. 2. 0. 0.]
 [0. 0. 1. 2. 1. 0. 0.]]
```

```
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 2. 2. 2. 0. 0.]
 [1. 0. 1. 2. 1. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 2. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 2. 2. 2. 0. 0.]
 [1. 0. 1. 2. 1. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 2. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 0. 1. 2. 1. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 2. 0. 0. 0.]
 [0. 0. 0. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 0. 1. 2. 1. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 2. 0. 0. 0.]
 [1. 0. 0. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 0. 1. 2. 1. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 0. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 0. 1. 2. 1. 0. 0.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 0. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 0. 1. 2. 1. 0. 1.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 0. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 2. 1. 2. 1. 0. 1.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 1. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 2. 1. 2. 1. 0. 1.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 1. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 0.]
 [1. 2. 1. 2. 1. 0. 1.]]
[[0. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 1. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 1.]
 [1. 2. 1. 2. 1. 0. 1.]]
[[2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 1. 1. 2. 0. 0.]
 [1. 0. 2. 2. 2. 0. 1.]
 [1. 2. 1. 2. 1. 0. 1.]]
[[2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 1. 1. 2. 0. 1.]
 [1. 0. 2. 2. 2. 0. 1.]
 [1. 2. 1. 2. 1. 0. 1.]]
[[2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 0. 0. 0. 0.]
 [2. 0. 0. 2. 0. 0. 0.]
 [1. 0. 1. 1. 2. 0. 1.]
 [1. 2. 2. 2. 2. 0. 1.]
 [1. 2. 1. 2. 1. 0. 1.]]

Gathering 'Alpha-Beta' Data to analyse 'Compilation Time':

Alpha-Beta time for depth value 3 is 6.822 milliseconds

Gathering 'Alpha-Beta' Data to calculate 'Accuracy':

                  Alphabeta Weight
Alphabeta Column
0                               0
1                              43
2                             144
3                             174
4                             140
5                              40

Alpha-Beta Algorithm resultant data as putting weights for each column at depth 3 : [0, 43, 144, 174, 140, 40]

Wall time: 27 s
```

Time Graphs

Mini-Max & Alpha-Beta Time Datasets

In [3]:

```
minimax_time_dataset = pd.read_csv("Mini-Max Time Data.csv")
alphabeta_time_dataset = pd.read_csv("Alpha-Beta Time Data.csv")
```

In [4]:

```
minimax_time_dataset
```

Out[4]:

	Mini-Max Input	Mini-Max Time
0	1	0.000
1	1	0.000
2	1	0.000
3	1	0.000
4	1	0.000
5	1	0.000
6	1	0.000
7	1	0.000
8	1	0.000
9	1	0.000
10	2	2.717
11	2	2.893
12	2	2.864
13	2	2.930
14	2	2.779
15	2	2.791
16	2	3.742
17	2	2.651
18	2	2.467
19	2	3.098
20	3	15.440
21	3	18.582
22	3	16.476
23	3	17.920
24	3	16.723
25	3	18.017
26	3	19.323
27	3	18.132
28	3	17.401
29	3	17.342
30	4	5.178
31	4	5.321
32	4	5.000
33	4	4.986
34	4	4.944
35	4	5.051
36	4	4.658
37	4	5.107
38	4	5.160
39	4	5.429
40	5	30.143
41	5	32.403
42	5	35.632
43	5	31.758
44	5	34.134
45	5	30.017

	Mini-Max Input	Mini-Max Time
46	5	31.258
47	5	36.203
48	5	31.256
49	5	30.299

In [5]:

```
alphabeta_time_dataset
```

Out[5]:

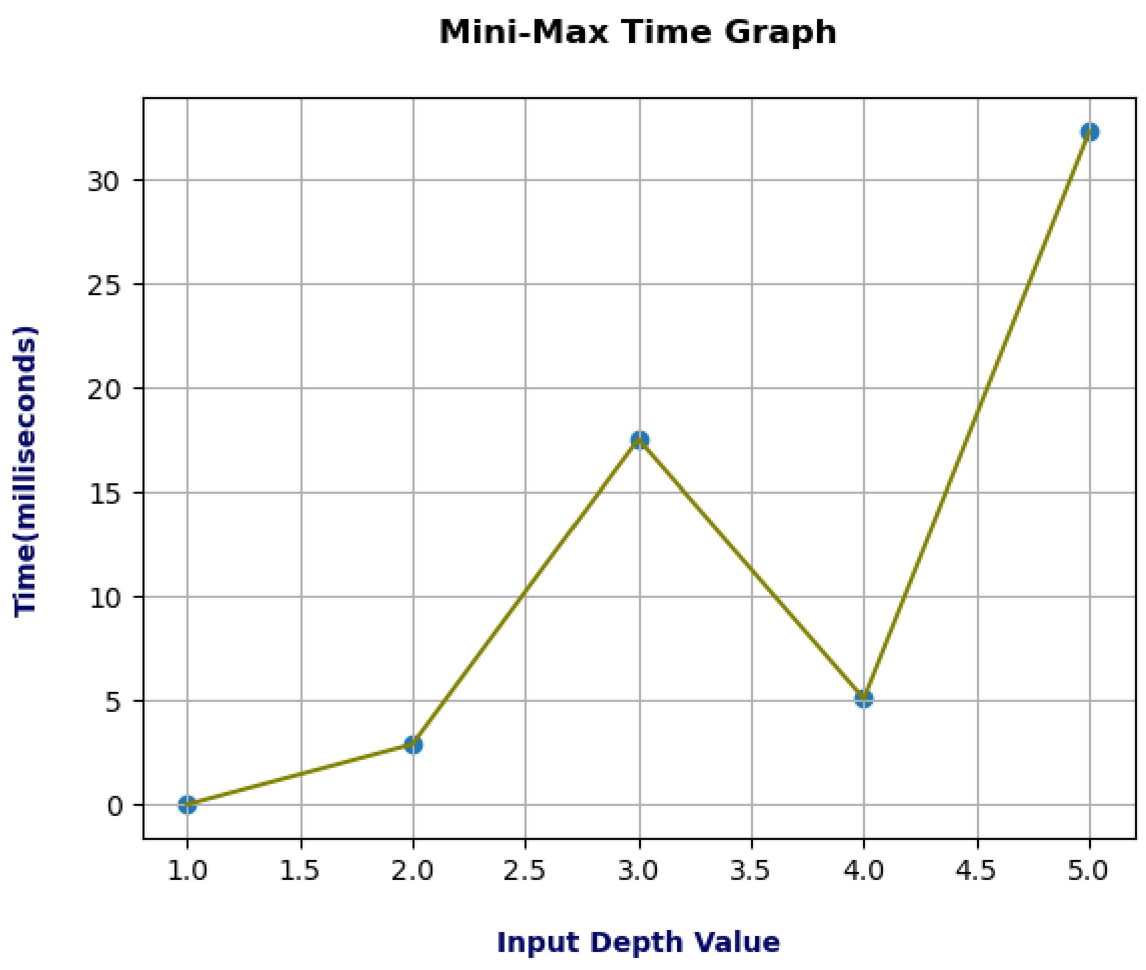
	Alpha-Beta Input	Alpha-Beta Time
0	1	0.000
1	1	0.000
2	1	0.000
3	1	0.000
4	1	0.000
...	...	...
65	7	18.339
66	7	16.884
67	7	15.482
68	7	14.950
69	8	7.618

70 rows × 2 columns

Mini-Max Time Graph

In [23]:

```
fig, ax = plt.subplots()
res_minimax = pd.DataFrame(minimax_time_dataset.groupby("Mini-Max Input").mean())
res_minimax.reset_index(inplace = True)
res_minimax.columns = ('Inp','Time')
plt.rcdefaults()
plt.plot(res_minimax['Inp'], res_minimax['Time'], color = 'Olive')
plt.xlabel("Input Depth Value", color = '#030764', labelpad = 16, weight = 'bold')
plt.ylabel("Time(milliseconds)", color = '#030764', labelpad = 16, weight = 'bold')
plt.title('Mini-Max Time Graph', color = 'Black', pad = 20, weight = 'bold')
ax.yaxis.grid(True)
ax.xaxis.grid(True)
plt.scatter(res_minimax['Inp'], res_minimax['Time'])
plt.show()
```

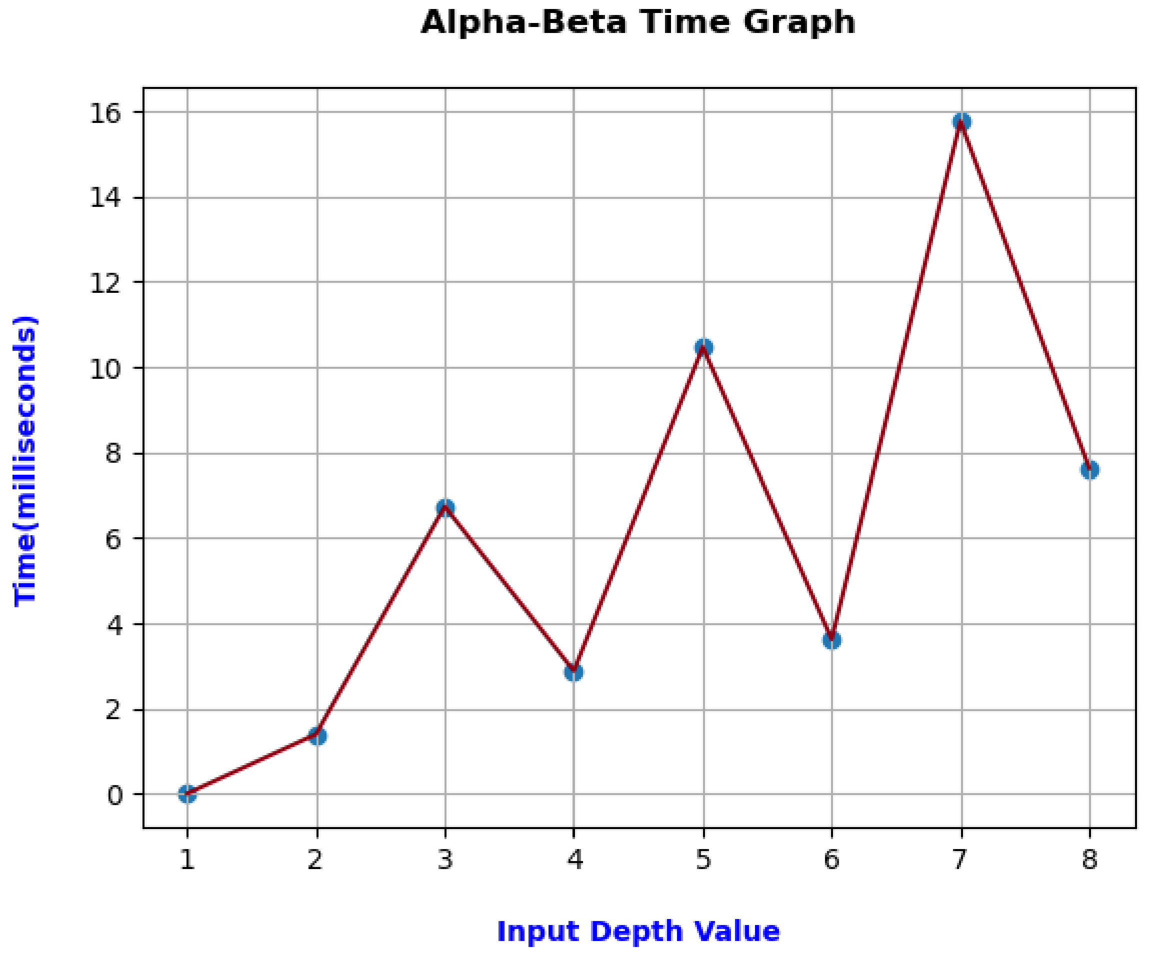


Alpha-Beta Time Graph

In [7]:

```
fig, ax = plt.subplots()
res_alphabeta = pd.DataFrame(alphabeta_time_dataset.groupby("Alpha-Beta Input").mean())
res_alphabeta.reset_index(inplace = True)
res_alphabeta.columns = ('Inp','Time')
plt.rcdefaults()
```

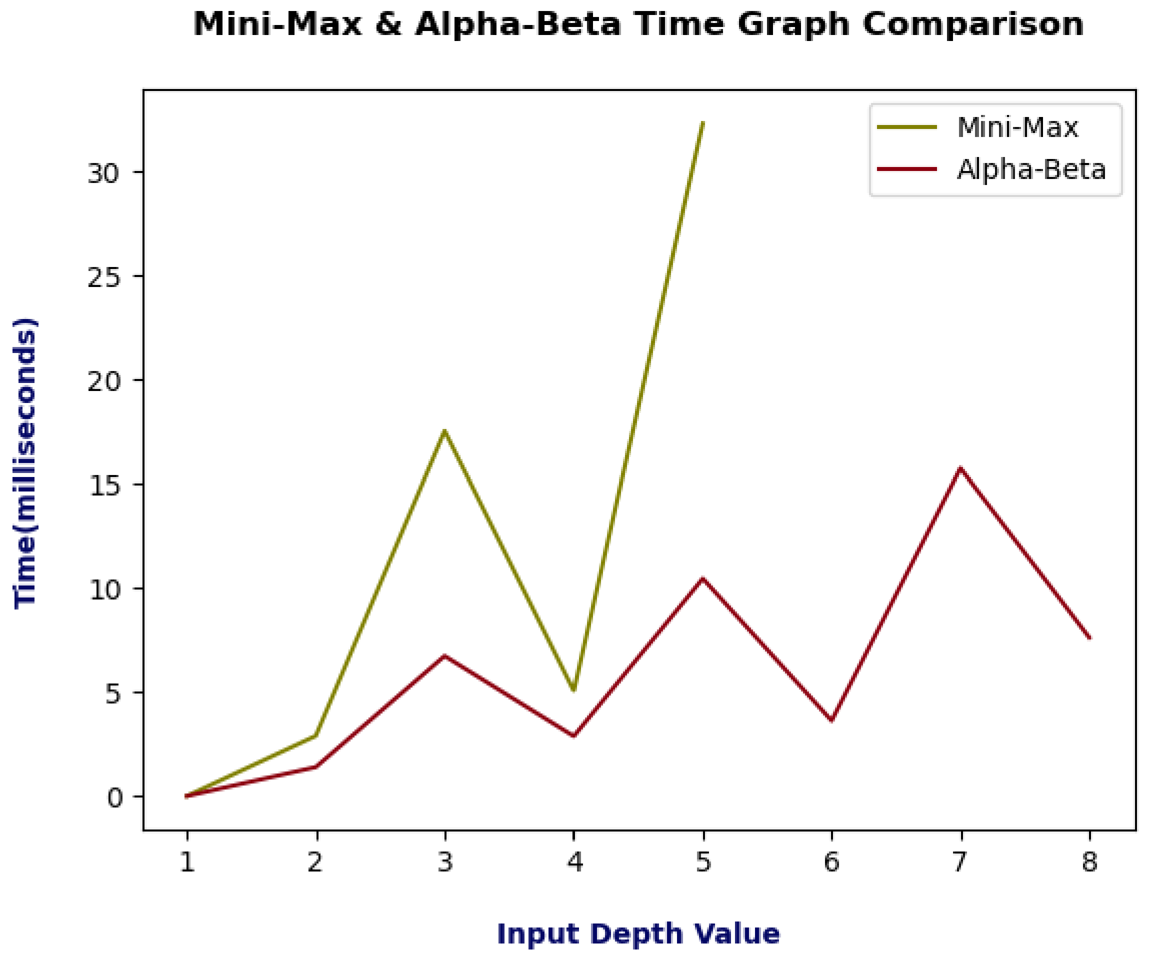
```
plt.plot(res_alphabeta['Inp'], res_alphabeta['Time'], color = '#8c000F')
plt.xlabel("Input Depth Value", color = 'Blue', labelpad = 16, weight = 'bold')
plt.ylabel("Time(milliseconds)", color = 'Blue', labelpad = 16, weight = 'bold')
plt.title('Alpha-Beta Time Graph', color = 'Black', pad = 20, weight = 'bold')
ax.yaxis.grid(True)
ax.xaxis.grid(True)
plt.scatter(res_alphabeta['Inp'], res_alphabeta['Time'])
plt.show()
```



Mini-Max & Alpha-Beta Time Graph Comparison

In [8]:

```
plt.rcdefaults()
plt.plot(res_minimax['Inp'], res_minimax['Time'], label = "Mini-Max", color = 'Olive')
# plt.scatter(res_minimax['Inp'], res_minimax['Time'])
plt.plot(res_alphabeta['Inp'], res_alphabeta['Time'], label = "Alpha-Beta", color = '#8c000F')
# plt.scatter(res_alphabeta['Inp'], res_alphabeta['Time'])
plt.xlabel("Input Depth Value", color = '#030764', labelpad = 16, weight = 'bold')
plt.ylabel("Time(milliseconds)", color = '#030764', labelpad = 16, weight = 'bold')
plt.title('Mini-Max & Alpha-Beta Time Graph Comparison', color = 'Black', pad = 20, weight = 'bold')
plt.legend()
plt.show()
```



Space Allocation

Mini-Max & Alpha-Beta Space Datasets

In [9]:

```
minimax_space_dataset = pd.read_csv("Mini-Max Space Data.csv")
```

```python
alphabeta_space_dataset = pd.read_csv("Alpha-Beta Space Data.csv")
```

In [10]:

```python
minimax_space_dataset
```

Out[10]:

	Mini-Max Input Depth	Space Required
0	1	99.387
1	1	99.332
2	1	99.371
3	1	99.387
4	1	99.263
5	1	99.355
6	1	99.327
7	1	99.258
8	1	99.236
9	1	99.312
10	2	99.574
11	2	99.625
12	2	99.453
13	2	99.357
14	2	99.256
15	2	99.298
16	2	99.420
17	2	99.168
18	2	99.250
19	2	99.762
20	3	99.383
21	3	99.418
22	3	99.326
23	3	99.256
24	3	99.362
25	3	99.418
26	3	99.326
27	3	99.297
28	3	99.363
29	3	99.441
30	4	99.184
31	4	99.371
32	4	99.344
33	4	99.446
34	4	99.568
35	4	99.578
36	4	99.625
37	4	99.758
38	4	99.624
39	4	99.458
40	5	99.832
41	5	99.863
42	5	99.726
43	5	99.945
44	5	99.868
45	5	99.898
46	5	99.870
47	5	99.927
48	5	99.807

In [11]:

```python
alphabeta_space_dataset
```

Out[11]:

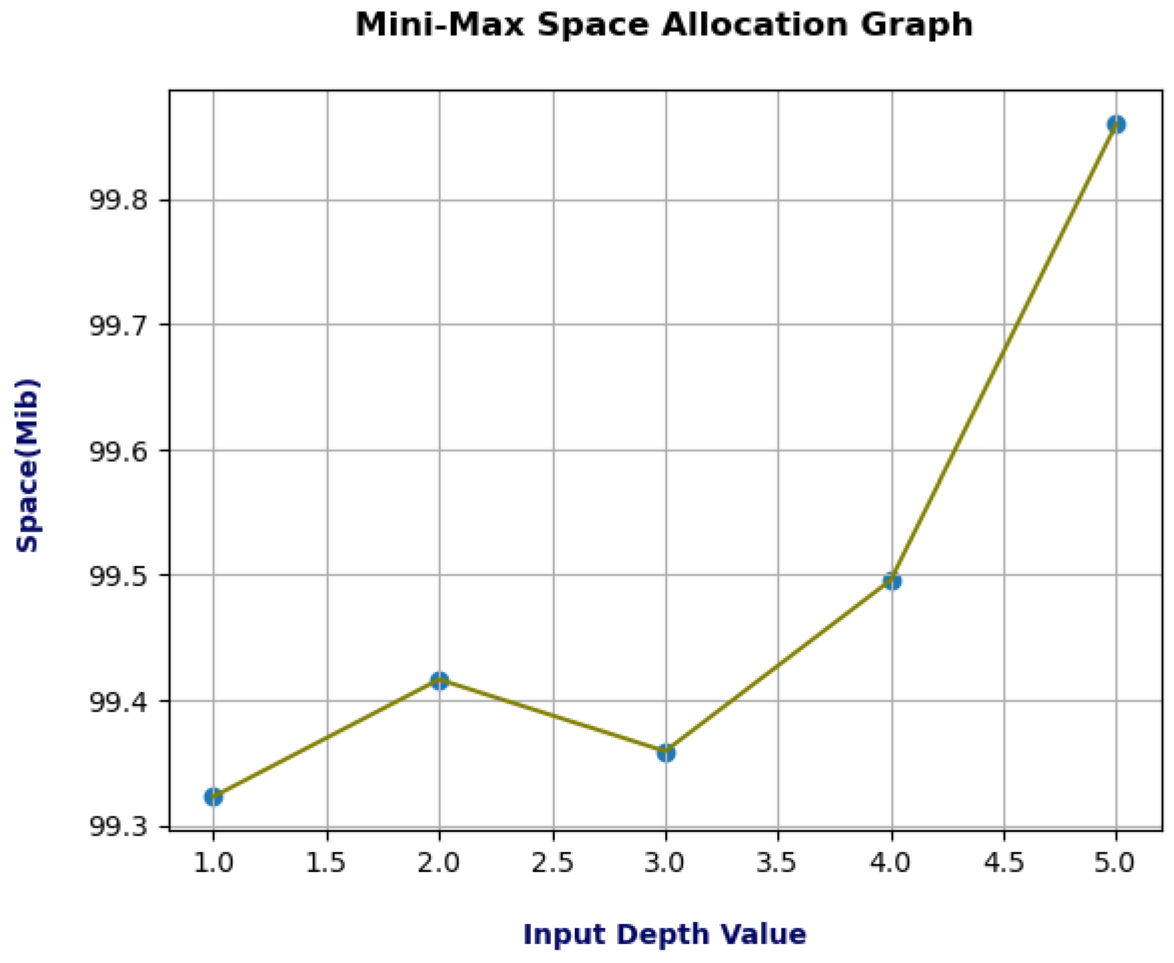
	Alpha-Beta Input Depth	Space Allocation
0	1	99.578
1	1	99.523
2	1	99.545
3	1	99.550
4	1	99.533
...	...	...
75	8	99.999
76	8	101.241
77	8	101.471
78	8	101.671
79	8	101.333

80 rows × 2 columns

Mini-Max Space Allocation Graph

In [12]:

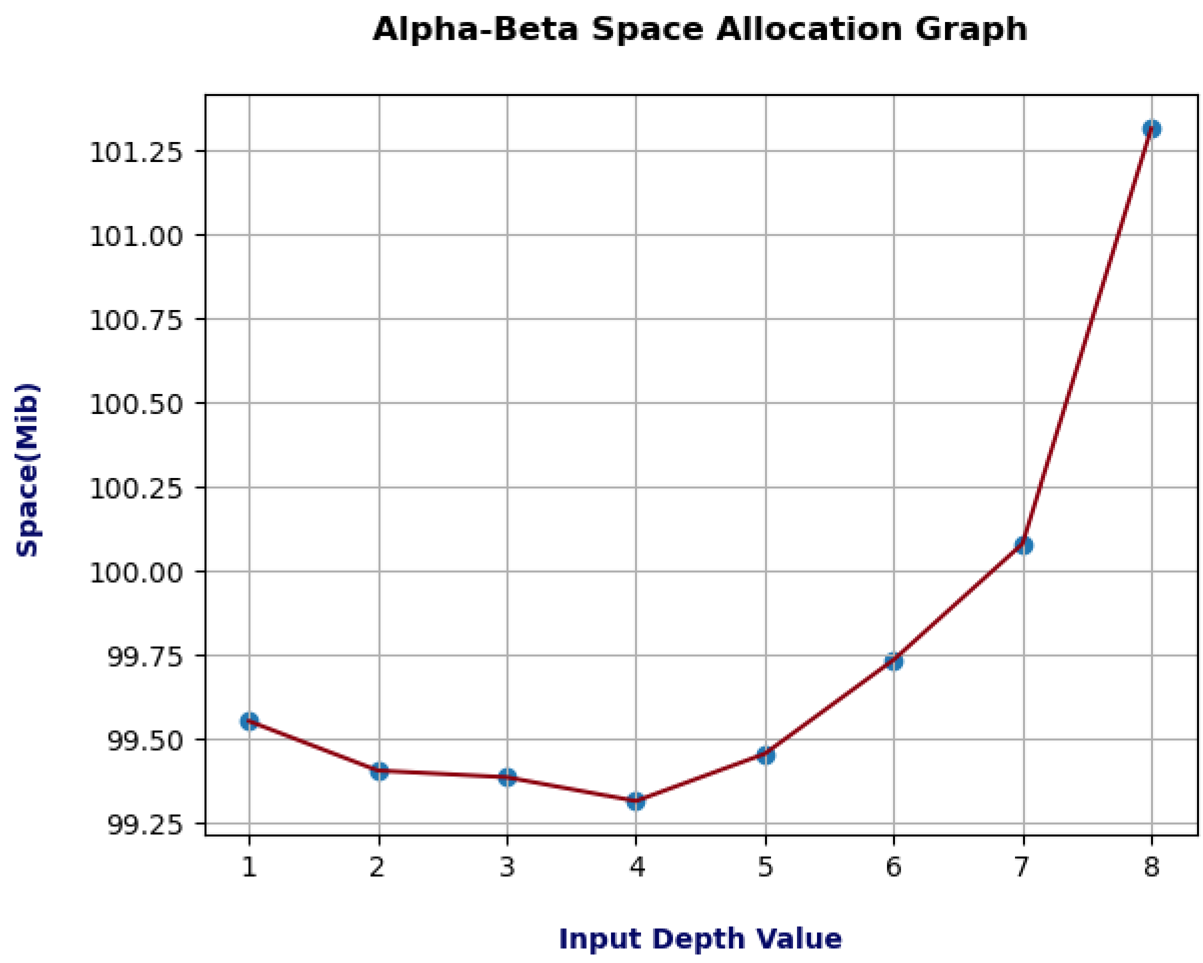
```
fig, ax = plt.subplots()
res_minimax_space = pd.DataFrame(minimax_space_dataset.groupby("Mini-Max Input Depth").mean())
res_minimax_space.reset_index(inplace = True)
res_minimax_space.columns = ('Inp','Space')
plt.rcdefaults()
plt.plot(res_minimax_space['Inp'], res_minimax_space['Space'], color = 'Olive')
plt.xlabel("Input Depth Value", color = '#030764', labelpad = 16, weight = 'bold')
plt.ylabel("Space(Mib)", color = '#030764', labelpad = 16, weight = 'bold')
plt.title('Mini-Max Space Allocation Graph', color = 'Black', pad = 20, weight = 'bold')
ax.yaxis.grid(True)
ax.xaxis.grid(True)
plt.scatter(res_minimax_space['Inp'], res_minimax_space['Space'])
plt.show()
```



Alpha-Beta Space Allocation Graph

In [13]:

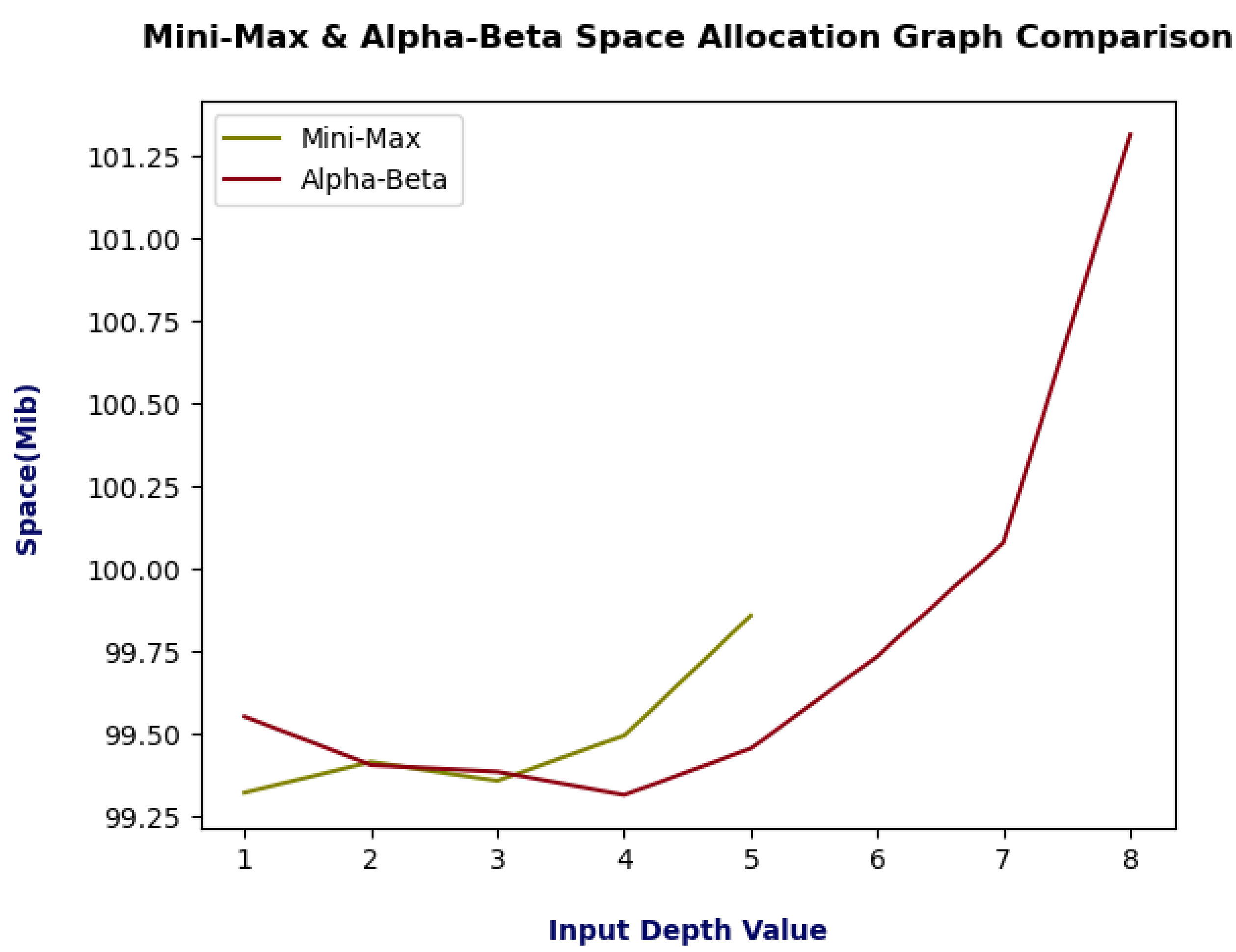
```
fig, ax = plt.subplots()
res_alphabeta_space = pd.DataFrame(alphabeta_space_dataset.groupby("Alpha-Beta Input Depth").mean())
res_alphabeta_space.reset_index(inplace = True)
res_alphabeta_space.columns = ('Inp','Space')
plt.rcdefaults()
plt.plot(res_alphabeta_space['Inp'], res_alphabeta_space['Space'], color = '#8c000F')
plt.xlabel("Input Depth Value", color = '#030764', labelpad = 16, weight = 'bold')
plt.ylabel("Space(Mib)", color = '#030764', labelpad = 16, weight = 'bold')
plt.title('Alpha-Beta Space Allocation Graph', color = 'Black', pad = 20, weight = 'bold')
ax.yaxis.grid(True)
ax.xaxis.grid(True)
plt.scatter(res_alphabeta_space['Inp'], res_alphabeta_space['Space'])
plt.show()
```



Mini-Max & Alpha-Beta Space Allocation Comparison

In [14]:

```
plt.rcdefaults()
plt.plot(res_minimax_space['Inp'], res_minimax_space['Space'], label = "Mini-Max", color = 'Olive')
# plt.scatter(res_minimax['Inp'], res_minimax['Time'])
plt.plot(res_alphabeta_space['Inp'], res_alphabeta_space['Space'], label = "Alpha-Beta", color = '#8c000F')
# plt.scatter(res_alphabeta['Inp'], res_alphabeta['Time'])
plt.xlabel("Input Depth Value", color = '#030764', labelpad = 16, weight = 'bold')
plt.ylabel("Space(Mib)", color = '#030764', labelpad = 16, weight = 'bold')
plt.title('Mini-Max & Alpha-Beta Space Allocation Graph Comparison', color = 'Black', pad = 20, weight = 'bold')
plt.legend()
plt.show()
```



Acuracy

Mini-Max & Alpha-Beta Accuracy Datasets

In [15]:

```
minimax_acc_dataset = pd.read_csv("Mini-Max Accuracy Data.csv")
alphabeta_acc_dataset = pd.read_csv("Alpha-Beta Accuracy Data.csv")
```

In [16]:

```
minimax_acc_dataset
```

Out[16]:

	Mini-Max Input	Col1	Col2	Col3	Col4	Col5	Col6	Col7
0	1	14.0	525.0	33.0	179.0	195.0	270.0	0.0

	Mini-Max Input	Col1	Col2	Col3	Col4	Col5	Col6	Col7
1	1	13.0	51.0	220.0	76.0	141.0	392.0	135.0
2	1	12.0	100.0	32.0	9.0	120.0	100.0	0.0
3	1	16.0	100.0	30.0	17.0	131.0	210.0	0.0
4	1	18.0	67.0	52.0	44.0	41.0	200.0	0.0
5	1	19.0	0.0	152.0	47.0	173.0	167.0	0.0
6	1	10.0	0.0	67.0	47.0	139.0	140.0	0.0
7	1	14.0	525.0	33.0	179.0	195.0	27.0	0.0
8	1	10.0	0.0	67.0	47.0	139.0	140.0	0.0
9	1	20.0	168.0	172.0	170.0	136.0	57.0	59.0
10	2	430.0	525.0	303.0	79.0	95.0	27.0	0.0
11	2	130.0	251.0	220.0	76.0	41.0	392.0	135.0
12	2	230.0	218.0	175.0	55.0	34.0	10.0	0.0
13	2	250.0	516.0	188.0	62.0	113.0	155.0	232.0
14	2	184.0	483.0	142.0	28.0	138.0	55.0	19.0
15	2	204.0	353.0	159.0	83.0	149.0	37.0	0.0
16	2	140.0	253.0	159.0	83.0	149.0	37.0	0.0
17	2	250.0	516.0	280.0	62.0	113.0	155.0	232.0
18	2	213.0	351.0	220.0	76.0	41.0	392.0	135.0
19	2	230.0	108.0	175.0	55.0	34.0	10.0	0.0
20	3	117.0	1187.0	3291.0	1734.0	4418.0	3406.0	700.0
21	3	162.0	1310.0	2245.0	852.0	4859.0	5262.0	1061.0
22	3	195.0	1516.0	3800.0	1430.0	4462.0	4002.0	1200.0
23	3	120.0	1049.0	3339.0	1262.0	4832.0	3987.0	1158.0
24	3	176.0	1330.0	3107.0	1136.0	4137.0	4269.0	1137.0
25	3	120.0	1049.0	3339.0	1262.0	4832.0	5987.0	1158.0
26	3	176.0	1303.0	3107.0	1316.0	4137.0	5269.0	1137.0
27	3	195.0	1006.0	3800.0	1430.0	4620.0	5002.0	2010.0
28	3	117.0	1187.0	4291.0	1734.0	4418.0	5340.0	1700.0
29	3	162.0	1010.0	4245.0	1852.0	4859.0	5262.0	1061.0
30	4	845.0	15493.0	15137.0	3741.0	4250.0	8810.0	425.0
31	4	927.0	79560.0	3980.0	15705.0	5198.0	5497.0	101.0
32	4	918.0	75080.0	3443.0	18686.0	3818.0	5650.0	381.0
33	4	839.0	10650.0	4328.0	12425.0	3202.0	2776.0	1526.0
34	4	688.0	13780.0	4856.0	1656.0	2348.0	7894.0	250.0
35	4	642.0	15517.0	3041.0	1185.0	5574.0	1986.0	1788.0
36	4	845.0	15493.0	5137.0	1741.0	4250.0	8810.0	4258.0
37	4	839.0	10655.0	5328.0	12425.0	3202.0	2776.0	1526.0
38	4	927.0	17956.0	4980.0	15705.0	4198.0	5497.0	101.0
39	4	839.0	11065.0	5328.0	12425.0	3202.0	2776.0	1526.0
40	5	798.0	7246.0	5010.0	5532.0	5968.0	12859.0	356.0
41	5	1372.0	2818.0	5232.0	4325.0	4100.0	17021.0	507.0
42	5	1356.0	7113.0	3321.0	5431.0	7162.0	11765.0	778.0
43	5	1718.0	2004.0	2475.0	5362.0	2551.0	14996.0	449.0
44	5	1395.0	7003.0	3461.0	5444.0	7764.0	17578.0	407.0
45	5	654.0	7299.0	3624.0	5703.0	8677.0	12221.0	421.0
46	5	2640.0	7626.0	4796.0	5745.0	12775.0	13352.0	778.0
47	5	5798.0	21246.0	6010.0	6532.0	1696.0	1285.0	356.0
48	5	395.0	7003.0	3461.0	5444.0	7764.0	7578.0	407.0
49	5	718.0	7004.0	10475.0	7362.0	2551.0	14996.0	449.0

In [17]:
```
alphabeta_acc_dataset
```

Out[17]:

	Alpha-Beta Input	Col1	Col2	Col3	Col4	Col5	Col6	Col7
0	1	14.0	525.0	33.0	179.0	195.0	270.0	100.0

	Alpha-Beta Input	Col1	Col2	Col3	Col4	Col5	Col6	Col7
1	1	13.0	51.0	220.0	76.0	141.0	392.0	135.0
2	1	12.0	100.0	32.0	9.0	120.0	100.0	168.0
3	1	16.0	100.0	30.0	17.0	131.0	210.0	0.0
4	1	18.0	67.0	52.0	44.0	41.0	200.0	0.0
...	...	...	...	...	...	...	...	...
75	8	11182.0	21682.0	11400.0	81186.0	52152.0	9350.0	11314.0
76	8	21182.0	10782.0	25480.0	79308.0	42152.0	10370.0	1474.0
77	8	10182.0	20882.0	19630.0	80499.0	40552.0	12300.0	11434.0
78	8	24182.0	10982.0	29720.0	50650.0	40652.0	9300.0	1414.0
79	8	16182.0	20482.0	35001.0	60240.0	40352.0	9330.0	17434.0

80 rows × 8 columns

Mini-Max Accuracy Caluclation

In [18]:

```
from sklearn.linear_model import LinearRegression
mm_y = minimax_acc_dataset.iloc[:,0:1].values
mm_X = minimax_acc_dataset.iloc[:, 1:].values
mm_X_train, mm_X_test, mm_y_train, mm_y_test = train_test_split(mm_X, mm_y, test_size = 0.25, random_state = 0)
sc = StandardScaler()
mm_X_train = sc.fit_transform(mm_X_train)
mm_X_test = sc.transform(mm_X_test)
classifier = LogisticRegression(random_state = 0)
classifier.fit(mm_X_train, mm_y_train)
mm_y_pred = classifier.predict(mm_X_test)
cm = confusion_matrix(mm_y_test, mm_y_pred)
#print(cm)
print("Accuracy of Mini-Max Implementation:", accuracy_score(mm_y_test, mm_y_pred)*100, "%")
```

```
Accuracy of Mini-Max Implementation: 84.61538461538461 %
C:\Users\hp\anaconda3\lib\site-packages\sklearn\utils\validation.py:63: DataConversionWarning: A column-vector y was pass
ed when a 1d array was expected. Please change the shape of y to (n_samples, ), for example using ravel().
  return f(*args, **kwargs)
```

Alpha-Beta Accuracy Calculation

In [19]:

```
ab_y = alphabeta_acc_dataset.iloc[:,0:1].values
ab_X = alphabeta_acc_dataset.iloc[:, 1:].values
ab_X_train, ab_X_test, ab_y_train, ab_y_test = train_test_split(ab_X, ab_y, test_size = 0.25, random_state = 0)
sc = StandardScaler()
ab_X_train = sc.fit_transform(ab_X_train)
ab_X_test = sc.transform(ab_X_test)
classifier = LogisticRegression(random_state = 0)
classifier.fit(ab_X_train, ab_y_train)
ab_y_pred = classifier.predict(ab_X_test)
cm = confusion_matrix(ab_y_test, ab_y_pred)
#print(cm)
print("Accuracy of Mini-Max Implementation:", accuracy_score(ab_y_test, ab_y_pred)*100, "%")
```

```
Accuracy of Mini-Max Implementation: 85.0 %
C:\Users\hp\anaconda3\lib\site-packages\sklearn\utils\validation.py:63: DataConversionWarning: A column-vector y was pass
ed when a 1d array was expected. Please change the shape of y to (n_samples, ), for example using ravel().
  return f(*args, **kwargs)
```

In [20]:

```
print("Accuracy of Mini-Max Implementation:", round(accuracy_score(mm_y_test, mm_y_pred)*100,3), "%")
```

```
Accuracy of Mini-Max Implementation: 84.615 %
```

In [21]:

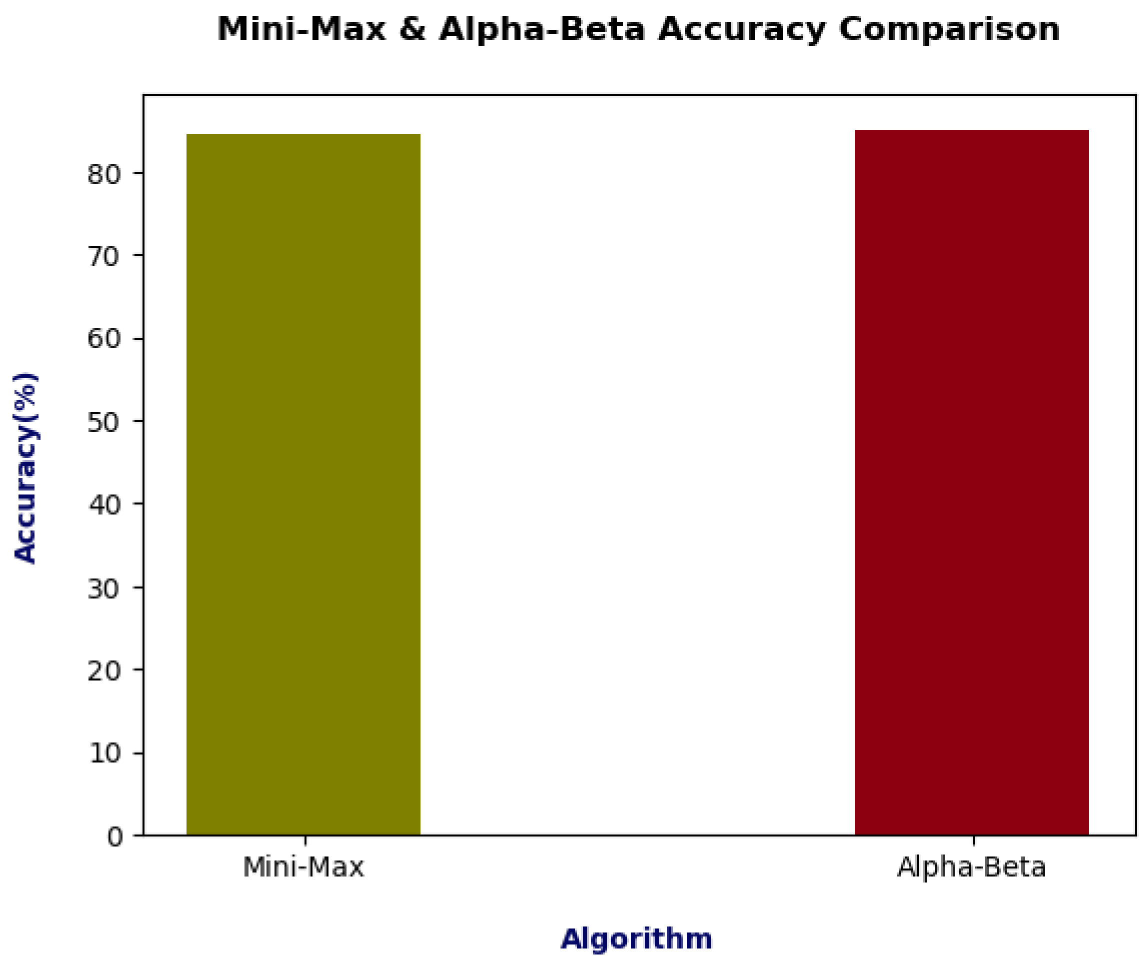
```
print("Accuracy of Alpha-Beta Implementation:", round(accuracy_score(ab_y_test, ab_y_pred)*100,3), "%")
```

```
Accuracy of Alpha-Beta Implementation: 85.0 %
```

Accuracy Comparison

In [22]:

```
Method = ["Mini-Max", "Alpha-Beta"]
Accuracy = [round(accuracy_score(mm_y_test, mm_y_pred)*100,3), round(accuracy_score(ab_y_test, ab_y_pred)*100,3)]
plt.rcdefaults()
plt.bar(Method, Accuracy, width = 0.35, align = "center", color = ['Olive', '#8c000F'])
plt.title("Mini-Max & Alpha-Beta Accuracy Comparison", pad = 20, weight = 'bold')
plt.xlabel("Algorithm", color = "#030764", labelpad = 16, weight = 'bold')
plt.ylabel("Accuracy(%)", color ="#030764", labelpad = 16, weight = 'bold')
plt.show()
```



Conclusion

Both algorithms should give the same answer. However, their main difference is that alpha-beta does not explore all paths, like minimax does, but prunes those that are guaranteed not to be an optimal state for the current player, that is max or min. So, alpha-beta is a better implementation of minimax.