Gobang Based on Monte Carlo Tree Search

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一、 实验目的

围棋起源于 3000 多年前的中国，赢得这场棋盘游戏需要玩家有多层次的战略思维。围棋的规则是两名对弈者分别执白子和黑子，轮流将它们放置在 19✖19 的棋盘上，去包围和捕获对手的棋子或战略性地创造领土空间，一旦所有可能的动作都进行了，棋盘上的棋子和空点都会被计算在内，点数高者获胜。虽然围棋规则看似简单，但它的可能步数超过了已知宇宙中的所有原子数量，这使得围棋游戏比国际象棋更复杂，它也因此被称为人工智能最具挑战性的经典游戏。

AlphaGo 是第一个击败专业人类围棋选手的计算机程序、第一个击败围棋世界冠军的计算机程序，可以说是历史上最强的围棋玩家。其算法核心在于采用了高级搜索方法和两个神经网络（策略网络与价值网络）去达到强化学习的效果，其中的高级搜索方法就是最通用，功能最强大且使用最广泛的树搜索算法之一：蒙塔卡洛树（Monte Carlo Tree Search）搜索。

基于 MCTS 的广泛适用性，本实验旨在以蒙特卡洛树搜索算法为核心去实现一种世界上广为流传的连棋游戏：五子棋。五子棋是一种两人对弈的纯策略型棋类游戏，通常双方分别使用黑白两色的棋子，轮流下在棋盘直线与横线的交叉点上，先在横线、直线或斜对角线上形成 5 子连线者获胜。原始规则的 15✖15 五子棋已被证明先手必胜，前提是不引入禁手，由此可以看出五子棋在搜索空间上比围棋小不少，所以在普通民用电脑上使用 MCTS 实现一个可与人类对决的五子棋程序是值得一试并且有意义的。为带来良好用户体验，该程序应同时拥有交互性良好的 UI 界面与控制台输出。

二、 实验原理

蒙特卡洛树搜索是一种对抗搜索，是利用（Exploitation）与探索（Exploration）在游戏博弈树上的有机协调，谈到他就必须谈起单一状态的蒙特卡洛规划：**多臂赌博机**（Multi-armed Bandits）。

在摇臂赌博机问题中，每次以随机采样形式采取一种行动a, 好比随机拉动第k个赌博机的臂膀，得到$R(a_k)$ 的回报，问题是：下一次需要拉动那个赌博机的臂膀，才能获得最大回报呢？这种序列决策问题需要在利用（Exploitation）和探索（Exploration）之间保持平衡，**利用保证在过去决策中得到最佳回报**，意即过去抽到奖的老虎机可能会更大概率地带来好的收益；**探索寄希望在未来能够得到更大回报**，也就是说从其他老虎机碰碰运气可能会有意想不到的收获。

如果有k个赌博机，这k个赌博机产生的操作序列为$X_{i,1}, X_{i,2}, \dots\ (i = 1, 2\dots, k)$，在时刻$t = 1, 2\dots$，选择第$I_t$个赌博机后，可得到奖赏$X_{It,t}$，则在$n$次操作$I_1, \dots, I_n$后，可如下定义悔值函数：

$$R_n = \max_{i=1,\dots k} \sum_{t=1}^{n} X_{i,t} - \sum_{t=1}^{n} X_{I_t,t}$$

悔值函数表示了如下意思：在第t次对赌博机操作时，假设知道哪个赌博机能够给出最大奖赏（虽然在现实生活中这是不存在的），则将得到的最大奖赏减去实际操作第I_t个赌博机所得到的奖赏。将n次操作的差值累加起来，就是悔值函数的结果。很显然，一个良好的多臂赌博机操作的策略是在不同人进行了多次玩法后，能够让悔值函数的方差最小。

在多臂赌博机的研究过程中，上限置信区间（Upper Confidence Bound, UCB）成为一种较为成功的策略学习方法，因为其在探索-利用（exploration-exploitation）之间取得平衡。我们使X_{i,T_i}来记录第i个赌博机在过去 $t-1$ 时刻内的平均奖赏，则在第t时刻，选

择使如下具有最佳上限置区间的赌博机：

$$R_n = \max_{i=\{1,\dots k\}} \{\overline{X_{i,T_i(t-1)}} + C_{t-1,T_i(t-1)}\}$$

其中$c_{t,s}$取值定义如下：

$$c_{t,s} = \sqrt{\frac{2\ln t}{s}}$$

也就是说，在第t时刻，UCB 算法一般会选择具有如下最大值的第j个赌博机：

$$UCB = \overline{X_j} + C \times \sqrt{\frac{2\ln n}{n_j}}$$

Kocsis 和 Szepesvari 在 2006 年提出将上限置信区间算法 UCB 应用于游戏树的搜索方法，这就诞生了蒙特卡洛树搜索，其包括了四个步骤：选择(selection)，扩展(expansion)，模拟(simulation)，反向传播(back-propagation)：

- 选择

从根节点 R 开始，向下递归选择子节点，直至选择一个叶子节点 L，具体来说，通常用 UCB（Upper Confidence Bound，上限置信区间）选择最具“潜力”的后续节点

- 扩展

如果 L 不是一个终止节点（即游戏未结束），则随机创建其后的一个未被访问节点，选择该节点作为后续子节点 C

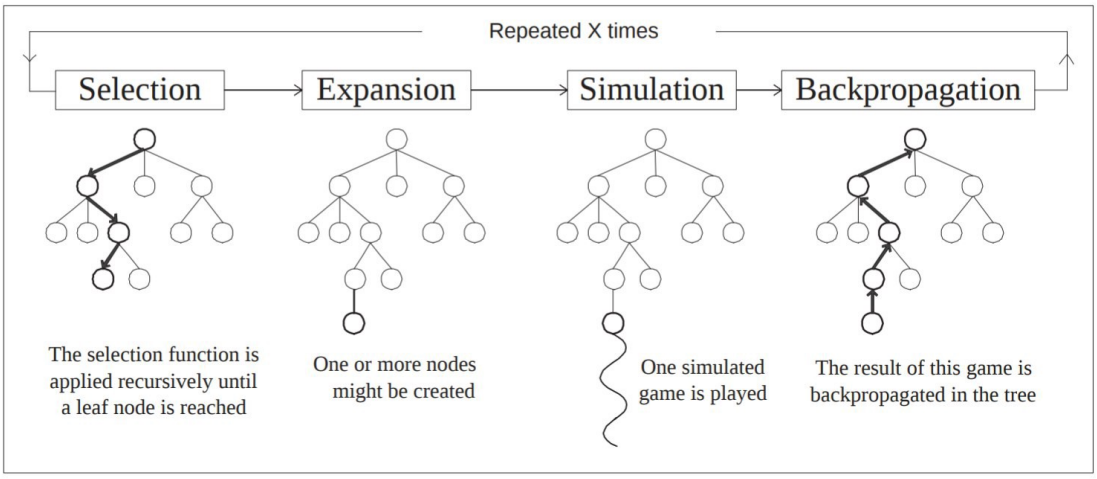
- 模拟

从节点 C 出发，对游戏进行模拟，直到游戏结束

- 反向传播

用模拟所得结果来回溯更新导致这个结果的每个节点中获胜次数和访问次数。

从中我们可以看到 MCTS 有两种策略学习机制，搜索树策略与模拟策略。前者需要在利用和探索之间保持平衡；而后者从非叶子结点出发模拟游戏，得到游戏仿真结果。



所以蒙特卡洛树搜索是基于采样来得到结果，而非穷尽式枚举。

三、 编程环境

本游戏全部基于 **Python 3.7.4** 完成，开发及测试环节都基于 MacOS Catalina 系统 10.15.1，以下是项目详情以及 *Pylint* 静态分析代码的报告

directory	***requirements.txt***	***External dependencies***
├── *Board.py*	*numpy==1.17.3*	*Board (gobang,mcts)*
├── *Node.py*		*Node (mcts)*
├── *README.md*		*mcts (gobang)*
├── *gobang.py*		
├── *mcts.py*		
└── *requirements.txt*		

Statistics by types

type	***number***	***old number***	***difference***	***%documented***	***%badname***
module	*4*	*NC*	*NC*	*0.00*	*50.00*
class	*3*	*NC*	*NC*	*33.33*	*0.00*
method	*22*	*NC*	*NC*	*54.55*	*0.00*
function	*6*	*NC*	*NC*	*0.00*	*0.00*

Raw metrics

type	***number***	***%***	***previous***	***difference***
code	*322*	*77.78*	*NC*	*NC*
docstring	*31*	*7.49*	*NC*	*NC*
comment	*7*	*1.69*	*NC*	*NC*
empty	*54*	*13.04*	*NC*	*NC*

Duplication

	now	*previous*	*difference*
nb duplicated lines	*0*	*NC*	*NC*
percent duplicated lines	*0.000*	*NC*	*NC*

Messages by category

type	*number*	*previous*	*difference*
convention	*73*	*NC*	*NC*
refactor	*6*	*NC*	*NC*
warning	*16*	*NC*	*NC*
error	*7*	*NC*	*NC*

% errors / warnings by module

module	*error*	*warning*	*refactor*	*convention*
gobang	*42.86*	*31.25*	*66.67*	*46.58*
mcts	*28.57*	*56.25*	*16.67*	*24.66*
Board	*14.29*	*6.25*	*16.67*	*21.92*
Node	*14.29*	*6.25*	*0.00*	*6.85*

四、 测试方法

1) 打开终端/命令行程序，复制输入以下内容：

git clone https://github.com/cnarutox/Gobang; cd Gobang

2) 执行 ***pip3 install -r requirements.tx***t 去安装依赖库

3) 执行 ***python3 gobang.py***，游戏界面弹出，点击左上方的 Start 开始游戏

简洁复制版：

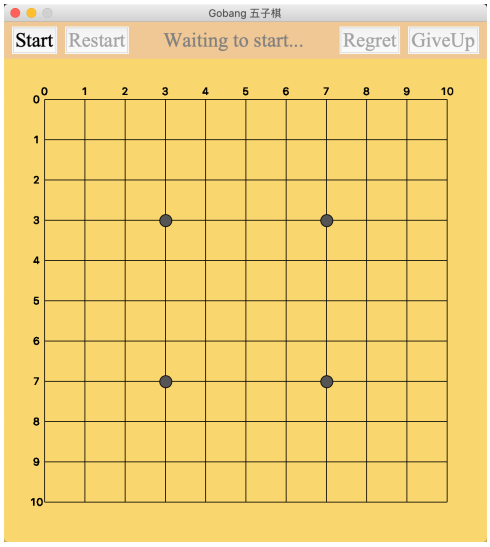
git clone https://github.com/cnarutox/Gobang ; cd Gobang ; pip3 install -r requirements.txt ; python3 gobang.py

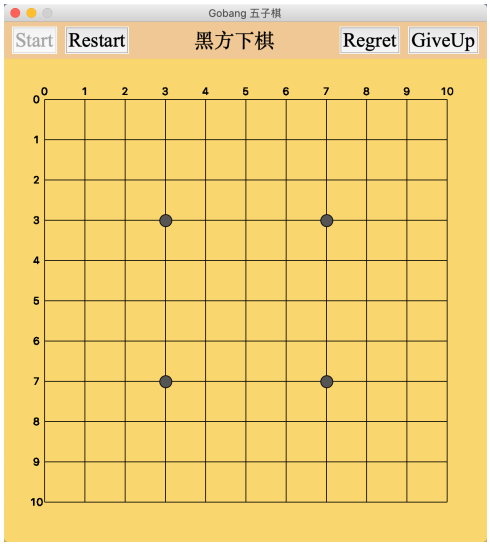
注：如果执行后控制台输出以下 warning

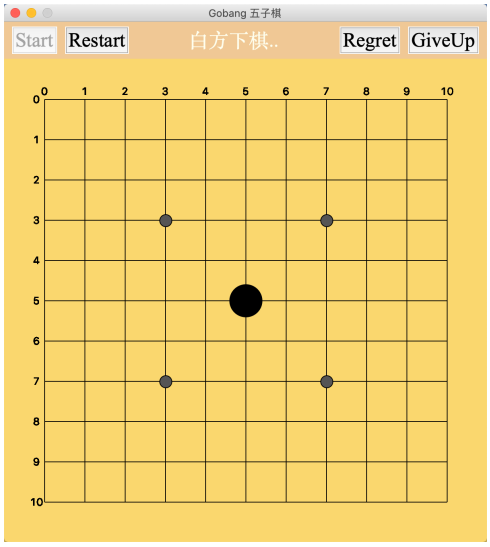
EPRECATION WARNING: The system version of Tk is deprecated and may be removed in a future release. Please don't rely on it. Set TK_SILENCE_DEPRECATION=1 to suppress this warning

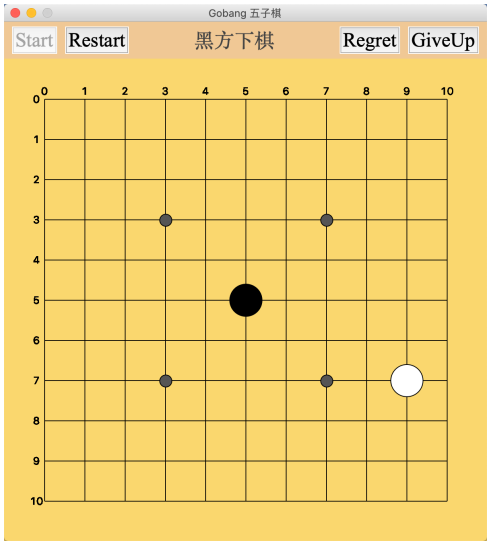
说明系统安装的 ***Tcl/Tk*** 与 *Python* 版本不契合，需要根据自己的 *Python* 版本去安装指定版本的 ***Tcl/Tk***，否则 UI 界面会出现色差与位移。

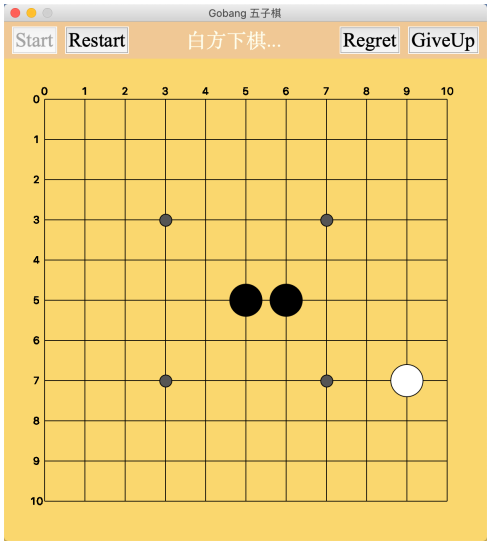
五、 结果展示

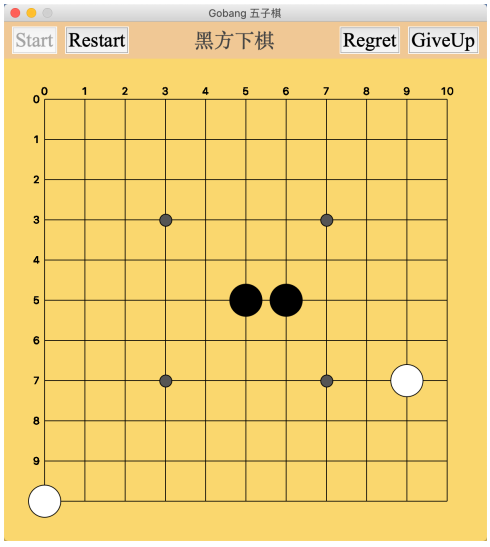


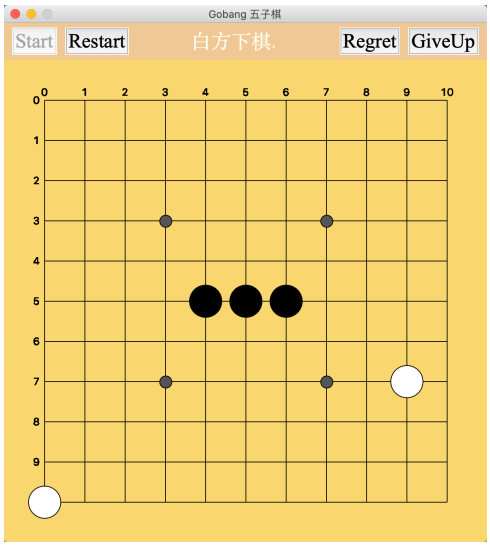


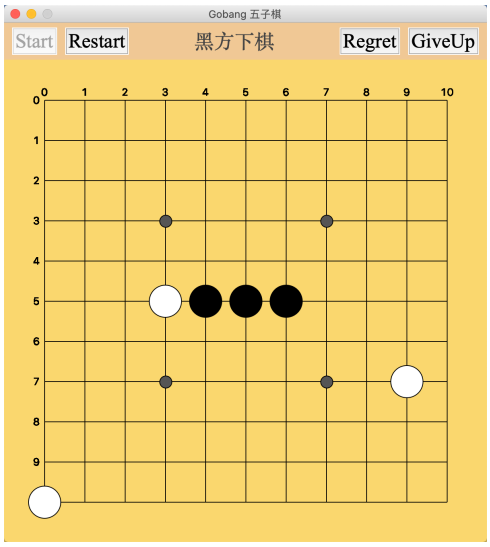


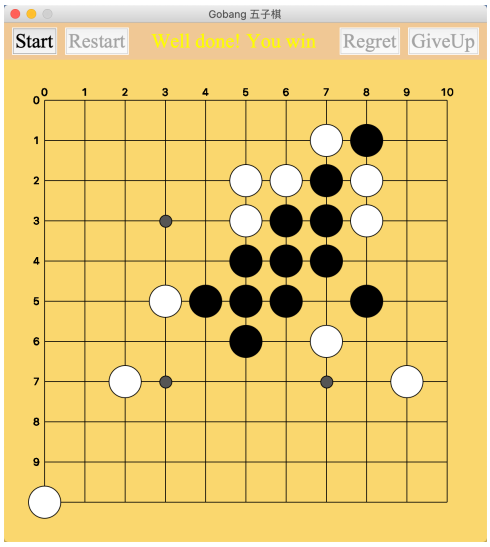












六、 实验源码（点击对应 py 文字可去查看源码）

Gobang Based on Monte Carlo Tree Search

> Author: cnarutox
> Lanuage: Python
> Platform: MacOS, Windows, Linux

gobang.py

> 程序启动的入口

- `Game` 类管控游戏的启动，重启，悔棋与认输
  - 成员变量 `board` 对应**Board.py**中的棋盘类
  - 成员变量 `player` 取值为-1(**玩家**)与1(**电脑**)
  - 成员变量 `previous` 为存储上一步走法的列表(最多两个元素：**玩家**与**电脑**)
  - 成员变量 `queue` 为存储**mcts.py**搜索结果的队列
  - 成员函数 `waiting` 负责从队列**queue**中获得搜索结果
    - 若**queue**为空则说明搜索未完成，需再次尝试获得
    - 若在等待过程中玩家选择 `regret` (悔棋)， `previous` 会被清空，此时程序会在拿到搜索结果后放弃该结果
  - 成员函数 `click` 为界面的绑定触发函数
    - 玩家(**黑棋**)出棋后会有另外一个进程去执行 `mcts` 函数
    - `after` 函数可以延迟指定时间(**100ms**)去执行 `waiting` 函数，防止阻塞负责渲染UI的主进程

Board.py

> 控制棋盘的类

- `Board` 类控制棋子的移动、搜索时判断棋局是否结束以及防御玩家的进攻
  - 成员函数 `move` 负责移动棋子
  - 成员函数 `update` 负责获得棋盘上的空闲位置
  - 成员函数 `end` 负责判断当前棋局胜负情况
  - 成员函数 `defend` 负责判断当前棋局胜负情况
    - 如果对方已有四子连珠，优先围堵该处

Node.py

> MCTS中的结点类

- 成员函数 `succ_fail` 负责搜索过程中的回溯更新结点

mcts.py

> 控制Monte Carlo Tree Search的一组函数

- 函数 `selection` 负责使用**UCB算法**选择最优结点
- 函数 `expansion` 负责随机选择一个子结点去扩展
- 函数 `stimulation` 负责模拟棋局的胜负
- 函数 `backdate` 负责回溯更新整个搜索树
- 函数 `intervene` 负责回溯更新整个搜索树人为干预搜索结果，如有下一步必输的局面优先执行
- 函数 `mcts` 负责搜索过程的全过程，搜索结果会放入队列，等待主进程获取结果并去渲染

Pylint 静态分析结果

Statistics by type

type	number	old number	difference	%documented	%badname
module	4	NC	NC	0.00	50.00
class	3	NC	NC	33.33	0.00
method	22	NC	NC	54.55	0.00
function	6	NC	NC	0.00	0.00

External dependencies

```
Board (gobang,mcts)
Node (mcts)
mcts (gobang)
```

Raw metrics

type	number	%	previous	difference
code	322	77.78	NC	NC
docstring	31	7.49	NC	NC
comment	7	1.69	NC	NC
empty	54	13.04	NC	NC

Duplication

	now	previous	difference

	now	previous	difference
nb duplicated lines	0	NC	NC
percent duplicated lines	0.000	NC	NC

Messages by category

type	number	previous	difference
convention	73	NC	NC
refactor	6	NC	NC
warning	16	NC	NC
error	7	NC	NC

% errors / warnings by module

module	error	warning	refactor	convention
gobang	42.86	31.25	66.67	46.58
mcts	28.57	56.25	16.67	24.66
Board	14.29	6.25	16.67	21.92
Node	14.29	6.25	0.00	6.85

返回 gobang

```
from itertools import cycle
from multiprocessing import Process, Queue
from tkinter import (BOTH, DISABLED, LEFT, NORMAL, RIGHT, YES, Button, Canvas, Frame, La
from tkinter.messagebox import showinfo

import numpy as np

from Board import Board
from mcts import mcts


class Game:
    """Summary of Game here.

    Attributes:
        player: 1 or -1 indicating if player is person computer.
        grid: An integer count of the length of board grid.
    """
    def __init__(self):
        self.size = 11
        self.grid = 50
        self.shrink = 0.8
        self.player = 0
        self.board = None
        self.previous = []
        self.is_start = False
        self.half_grid = self.grid / 2
        self.chess_radius = self.half_grid * self.shrink
        self.special_point = self.half_grid * 0.3
        self.queue = Queue()
        self.board_color = "#FAD76E"
        self.func_bg = "#F0C896"
        self.font = ("Times New Roman", 25, "normal")
        # This is resposible for the GUI, so you do not need
        # to care more about this because they are mostly
        # formulated code
        self.tk = Tk()
        self.tk.title("Gobang 五子棋")
        self.tk.resizable(width=False, height=False)

        self.tk_header = Frame(self.tk, highlightthickness=0, bg=self.func_bg)
        self.tk_header.pack(fill=BOTH, ipadx=10)

        self.func_start = Button(self.tk_header, text="Start", command=self.start, font=
        self.func_restart = Button(self.tk_header, text="Restart", command=self.restart,
        self.info = Label(self.tk_header,
                          text="Waiting to start...",
                          bg=self.func_bg,
                          font=("Times New Roman", 25, "normal"),
                          fg="grey")
        self.func_regret = Button(self.tk_header, text="Regret", command=self.regret, st
```

```
        self.func_giveup = Button(self.tk_header, text="GiveUp", command=self.giveup, st

        self.func_start.pack(side=LEFT, padx=10)
        self.func_restart.pack(side=LEFT)
        self.info.pack(side=LEFT, expand=YES, fill=BOTH, pady=5)
        self.func_giveup.pack(side=RIGHT, padx=10)
        self.func_regret.pack(side=RIGHT)

        self.canvas = Canvas(self.tk,
                             bg=self.board_color,
                             width=(self.size + 1) * self.grid,
                             height=(self.size + 1) * self.grid,
                             highlightthickness=0)
        self.draw_board()
        self.canvas.bind("<Button-1>", self.click)
        self.canvas.pack()

        self.tk.mainloop()

    def draw_grid(self, x, y):
        """Draw a grid of given x and y.

        Args:
            x: The x of a coordinate.
            y: The y of a coordinate.

        Returns:
            None.

        Raises:
            None.
        """
        shrink = (1 - self.shrink) + 1
        center_x, center_y = self.grid * (x + 1), self.grid * (y + 1)
        self.canvas.create_rectangle(center_y - self.half_grid,
                                     center_x - self.half_grid,
                                     center_y + self.half_grid,
                                     center_x + self.half_grid,
                                     fill=self.board_color,
                                     outline=self.board_color)
        a, b = [0, shrink] if y == 0 else [-shrink, 0] if y == self.size - 1 else [-shr
        c, d = [0, shrink] if x == 0 else [-shrink, 0] if x == self.size - 1 else [-shr
        self.canvas.create_line(center_y + a * self.half_grid, center_x, center_y + b *
        self.canvas.create_line(center_y, center_x + c * self.half_grid, center_y, cente
        [self.canvas.create_text(self.grid * (i + 1), self.grid * 0.8, text=f'{i}') for
        [self.canvas.create_text(self.grid * 0.8, self.grid * (i + 1), text=f'{i}') for

        # draw special points
        if ((x == 3 or x == 7) and (y == 3 or y == 7)):
            self.canvas.create_oval(center_y - self.special_point,
                                    center_x - self.special_point,
```

```
                                center_y + self.special_point,
                                center_x + self.special_point,
                                fill="#555555")

    def draw_chess(self, x, y, color):
        """Draw a chess of given x and y with color.

        Args:
            x: The x of a coordinate.
            y: The y of a coordinate.
            color: The color of the chess (black or white).
        """
        center_x, center_y = self.grid * (x + 1), self.grid * (y + 1)
        self.canvas.create_oval(center_y - self.chess_radius,
                                center_x - self.chess_radius,
                                center_y + self.chess_radius,
                                center_x + self.chess_radius,
                                fill=color)

    def draw_board(self):
        """Draw a chess of given x and y with color."""
        [self.draw_grid(x, y) for y in range(self.size) for x in range(self.size)]

    def start(self):
        """Set the initial states of components and initialize the board."""
        self.set_state("start")
        self.is_start = True
        self.player = -1
        self.board = Board(self.size)
        self.draw_board()
        self.info.config(text="黑方下棋", fg='black')

    def restart(self):
        self.start()

    def regret(self):
        # Regretting when it's your turn to walk is not allowed (len(self.previous) == 2
        if not self.previous or len(self.previous) == 2:
            showinfo("提示", "您已没有机会悔棋")
            self.previous = []
            return
        x, y = self.previous[0]
        self.draw_grid(x, y)
        self.board.chess[x, y] = 0
        self.info.config(text="黑方下棋", fg='#444444')
        self.previous = []
        self.player = -1

    def giveup(self):
        '''The player can choose to give up by his/her own.
        '''
```

```
        self.set_state("init")
        self.is_start = False
        self.info.config(text="The player gives up!", fg='red')

    def waiting(self):
        if not self.previous and not self.queue.empty():
            print('\r')
            self.queue.get()
            return
        elif not self.queue.empty():
            pos = self.queue.get()
            self.draw_chess(*pos, "white")
            self.player = -1
            self.board.move(pos, 1)
            print(f' {pos}')
            self.info.config(text="黑方下棋", fg='#444444')
            self.previous.append(pos)
            return
        self.info.config(text="白方下棋" + next(self.points), fg='#ffffee')
        self.tk.after(1000, self.waiting)

    def click(self, e):
        if self.player != -1: return
        self.player = 1
        x, y = int((e.y - self.half_grid) / self.grid), int((e.x - self.half_grid) / se
        if not ((0, ) * 2 <= (x, y) < (self.size, ) * 2):
            self.player = -1
            return
        center_x, center_y = self.grid * (x + 1), self.grid * (y + 1)
        distance = np.linalg.norm(np.array([center_x, center_y]) - np.array([e.y, e.x]))
        if not self.is_start or distance > self.half_grid * 0.95 or self.board.chess[x,
            self.player = -1
            return
        self.draw_chess(x, y, "black")
        print(f'=> 黑方: {(x, y)}')
        self.board.move((x, y), -1)
        self.previous = [(x, y)]
        if self.player_win(x, y, -1):
            self.is_start = False
            self.set_state("init")
            self.info.config(text="Well done! You win", fg='yellow')
            return
        self.points = cycle(['.' * i for i in range(7)])
        self.info.config(text="白方下棋" + next(self.points), fg='#ffffee')
        print(f'=> 白方:', end='')
        Process(target=mcts, args=(self, self.queue, 200)).start()
        self.tk.after(1000, self.waiting)

    def player_win(self, x, y, tag):
        four_direction = [[self.board.chess[i][y] for i in range(self.size)]]
        four_direction.append([self.board.chess[x][j] for j in range(self.size)])
```

```
        four_direction.append(self.board.chess.diagonal(y - x))
        four_direction.append(np.fliplr(self.board.chess).diagonal(self.size - 1 - y - x
        for v_list in four_direction:
            count = 0
            for v in v_list:
                if v == tag:
                    count += 1
                    if count == 5:
                        return True
                else:
                    count = 0
        return False

    def set_state(self, state):
        '''Set the states of functional buttons.
        '''
        state_list = [NORMAL, DISABLED, DISABLED, DISABLED] if state == "init" else [DIS
        self.func_start.config(state=state_list[0])
        self.func_restart.config(state=state_list[1])
        self.func_regret.config(state=state_list[2])
        self.func_giveup.config(state=state_list[3])


if __name__ == '__main__':
    Game()
```

返回 Board

```python
from copy import deepcopy
from itertools import groupby

import numpy as np


class Board:
    def __init__(self, size=11):
        self.size = size
        self.chess = np.zeros((size, size), int)
        print(f'==> Board initializing:\n{self.chess}')
        self.update()

    def update(self):
        self.vacuity = list(map(lambda x: tuple(x), np.argwhere(self.chess == 0)))

    def move(self, pos, player):
        self.chess[pos[0], pos[1]] = player
        self.update()

    def end(self, player):
        seq = list(self.chess)
        seq.extend(self.chess.transpose())
        fliplr = np.fliplr(self.chess)
        for i in range(-self.size + 1, self.size):
            seq.append(self.chess.diagonal(i))
        for i in range(-self.size + 1, self.size):
            seq.append(fliplr.diagonal(i))
        for seq in map(groupby, seq):
            for v, i in seq:
                if v == 0: continue
                if v == player and len(list(i)) == 5:
                    return v
        return 0

    def defend(self):
        for x, y in self.vacuity:
            origin = map(groupby, [
                self.chess[x],
                self.chess.transpose()[y],
                self.chess.diagonal(y - x),
                np.fliplr(self.chess).diagonal(self.size - 1 - y - x)
            ])
            origin = [x for x in origin]
            chess = deepcopy(self.chess)
            chess[x][y] = -1
            for index, seq in enumerate(
                    map(groupby, [
                        chess[x],
                        chess.transpose()[y],
                        chess.diagonal(y - x),
```

```
                    np.fliplr(chess).diagonal(self.size - 1 - y - x)
                ])):
            seq = [(v, len(list(i))) for v, i in seq]
            org_seq = [(v, len(list(i))) for v, i in origin[index]]
            for i, v in enumerate(seq):
                if v[0] != -1: continue
                if v[1] >= 5: return x, y
                if v[1] == 4 and seq.count((-1, 4)) != org_seq.count((-1, 4)):
                    if i - 1 >= 0 and seq[i - 1][0] == 0 and i + 1 < len(seq) and se
    return None


if __name__ == "__main__":
    Board()
```

返回 Node

```
import numpy as np


class Node:
    # node类初始化f
    def __init__(self, pos=None):
        self.succ = 0
        self.total = 0
        self.child = []
        self.pos = pos
        self.ucb = 0

    def succ_fail(self, win):
        if win == 1:
            self.succ += 1
        self.total += 1

    def __repr__(self):
        return f'{self.pos}=>{self.succ}/{self.total}={self.ucb}'

    def __eq__(self, node):
        return self.pos == node.pos

    def __hash__(self):
        return id(self)
```

返回 mcts

```
from copy import deepcopy
from random import choice, randint, shuffle

import numpy as np

from Board import Board
from Node import Node


def selection(node, total, path):
    while node.child:
        ucb = None
        if len(path) % 2:
            ucb = list(map(lambda c: 1 - c.succ / c.total + 2 * np.sqrt(np.log(total) /
        else:
            ucb = list(map(lambda c: c.succ / c.total + 2 * np.sqrt(np.log(total) / c.t
        node = node.child[choice(np.argwhere(ucb == max(ucb)))[0]]
        path.append(node)
    return node


def expansion(node, vacuity, path):
    waiting = set(map(lambda v: tuple(v), vacuity)) - set(map(lambda p: tuple(p.pos), pa
    if waiting:
        node.child.append(Node(choice(list(waiting))))
        path.append(node.child[-1])
        return node.child[-1]
    return node


def stimulation(node, board, path):
    player = 1
    for p in path:
        board.move(p.pos, player)
        player *= -1
    result = board.end(-player)
    while len(board.vacuity) and not result:
        pos = choice(board.vacuity)
        board.move(pos, player)
        result = board.end(player)
        player *= -1
    return result


def backdate(root, path, result):
    for n in path + [root]:
        n.succ_fail(result)


def intervene(root, board):
    pos = board.defend()
```

```
    if pos:
        print(f' defend', end='')
        return pos
    ucb = list(
        map(lambda c: (c.succ / c.total + 2 * np.sqrt(np.log(root.total) / c.total), c.s
    for i, u in enumerate(ucb):
        root.child[i].ucb = u[0]
    pos = root.child[np.argmax(ucb)].pos
    return pos


def mcts(game, queue, iteration=500):
    root = Node()
    board = game.board
    vacuity = board.vacuity  # 可选落子处
    for i in range(iteration):
        path = []  # 截止到当前节点的搜索路径
        node = root
        if len(path) + len(node.child) >= len(vacuity):
            node = selection(node, root.total, path)
        player = -1 if len(path) % 2 else 1
        # 判断胜负
        result = board.end(-(-1 if len(path) % 2 else 1))
        if result == 0:
            node = expansion(node, vacuity, path)
            result = stimulation(node, deepcopy(board), path)
        backdate(root, path, result)
    pos = intervene(root, board)
    queue.put(pos)


if __name__ == "__main__":
    board = Board()
    while True:
        x, y = [int(x) for x in input('=> you move ').split()]
        board.move((x, y), -1)
        mcts(board)
        if board.end(-1) is not 0:
            break
```