

## **1. The Rule of Hollow NoGo:**

- i. Generally speaking, 9x9 Hollow NoGo has the same rules as 9x9 NoGo. The only difference is that the center 3x3 board is cut out, which can not be counted as liberty.
- ii. Two players (black and white) alternatively take turns to play. The same as in NoGo, capturing, suicide, and pass are forbidden. The player who has no action to play loses the game.
  - a. Capturing: take the last liberty of an opponent block.
  - b. Suicide: create a block that has no liberty.
  - c. Pass: skip this turn without placing a stone.
- iii. The player should take actions based on MCTS and should be able to play as both sides. a. The thinking time of the player is 36 seconds for a game.

## **2. Task:**

- i. Implement a Hollow NoGo framework on the 9 x 9 board.
- ii. Design a Hollow NoGo player with Monte Carlo tree search (MCTS).
- iii. Use Go Text Protocol (GTP) to communicate with other programs.

## **3. Implement of MCTS:**

### **i. Build MCTS Search Tree :**

Establishing the root node by the current state and generate all child nodes of the root node.

### **ii. Selection :**

Greedy search a leaf node by rewards, where rewards = win rate + UCB.

### **iii. Expansion :**

Generate all child nodes of the node which is selected in **step ii**.

### **iv. Simulation :**

Random play on the state of the node which is selected in **step ii**. and record the winner.

**v. Backpropagation :**

Update the win rate of all nodes on the search path according to the result of **step iv**.

**vi. Loop :**

Evaluate available time and decide whether do more simulations. If yes, go to **step ii**.

**vii. Take action :**

Choose one child node of the root node which is with the highest visit count.

## **4. Improvement :**

### **Time management :**

I use a static table to decide how much time every step will take. According to the research, I use most of time in mid game because Using MCTS method to evaluate steps in early game is inefficient. In addition, in late game, because the number of available actions is smaller, it need less time to run MCTS.

Static table: (sec)

```
double time_schedule[36] = {0.2, 0.2, 0.2, 0.4, 0.4, 0.4,
                             0.7, 0.7, 0.7, 1.4, 1.4, 1.4,
                             1.7, 1.7, 1.7, 2.0, 2.0, 2.0,
                             1.7, 1.7, 1.7, 1.7, 1.7, 1.7,
                             1.0, 1.0, 1.0, 0.5, 0.5, 0.5,
                             0.4, 0.4, 0.4, 0.2, 0.2, 0.2 };
```

## **5. Environment:**

Linux – Ubuntu 20.04

## 6. Experiment result:

```
310554039@ec037-076:~/4.time_scheduler$ ./run-gogui-twogtp.sh
GoGui-TwoGTP Launcher V20211112
===== PLAYERS =====
P1B: ./nogo --shell --name="Hollow-Black" --black="mcts T=1000"
P1W: ./nogo --shell --name="Hollow-White" --white="mcts T=1000"
P2B: ./nogo-judge --shell --name="Judge-Weak-Black" --black="weak"
P2W: ./nogo-judge --shell --name="Judge-Weak-White" --white="weak"
===== GAMES =====
Storage: gogui-twogtp-20211219122837
Monitor: ./gogui-twogtp-20211219122837.mon
P1B vs P2W: ##### 5:0
P2B vs P1W: ##### 0:5
===== RESULTS =====
P1: (5+5)/10 = 100.0%
P2: (0+0)/10 = 0.0%
```

Figure 1 : Run 10 games against weak AI

```
310554039@ec037-076:~/4.time_scheduler$ ./run-gogui-twogtp.sh 35
GoGui-TwoGTP Launcher V20211112
===== PLAYERS =====
P1B: ./nogo --shell --name="Hollow-Black" --black="mcts T=1000"
P1W: ./nogo --shell --name="Hollow-White" --white="mcts T=1000"
P2B: ./nogo-judge --shell --name="Judge-Weak-Black" --black="weak"
P2W: ./nogo-judge --shell --name="Judge-Weak-White" --white="weak"
===== GAMES =====
Storage: gogui-twogtp-20211219123518
Monitor: ./gogui-twogtp-20211219123518.mon
P1B vs P2W: ##### 17:0
P2B vs P1W: ##### 0:17
===== RESULTS =====
P1: (17+17)/34 = 100.0%
P2: (0+0)/34 = 0.0%
```

Figure 2 : Run 35 games against weak AI

```
310554039@ec037-076:~/4.time_scheduler$ ./run-gogui-twogtp.sh 50
GoGui-TwoGTP Launcher V20211112
===== PLAYERS =====
P1B: ./nogo --shell --name="Hollow-Black" --black="mcts T=1000"
P1W: ./nogo --shell --name="Hollow-White" --white="mcts T=1000"
P2B: ./nogo-judge --shell --name="Judge-Weak-Black" --black="weak"
P2W: ./nogo-judge --shell --name="Judge-Weak-White" --white="weak"
===== GAMES =====
Storage: gogui-twogtp-20211219133046
Monitor: ./gogui-twogtp-20211219133046.mon
P1B vs P2W: ##### 25:0
P2B vs P1W: ##### 0:25
===== RESULTS =====
P1: (25+25)/50 = 100.0%
P2: (0+0)/50 = 0.0%
310554039@ec037-076:~/4.time_scheduler$
```

Figure 3 : Run 50 games against weak AI