

## 進捗報告

### 1 やったこと

- Suspicion-Agent[1] の検証
- GPT3.5 における動作
- GPT4 側のプレイスタイルを指定してみる

### 2 Suspicion-Agent[1] の検証

GPT4 がポーカーに似た不完全情報ゲームにおいて、深層強化学習で学習したエージェントよりも高い勝率を残した研究. 図 1 に Suspicion-Agent のアーキテクチャを示す. Observation だけでなく, Current Game History, All Game Play Game History 等を入力として複数の LLM モジュールから Action を出力している.

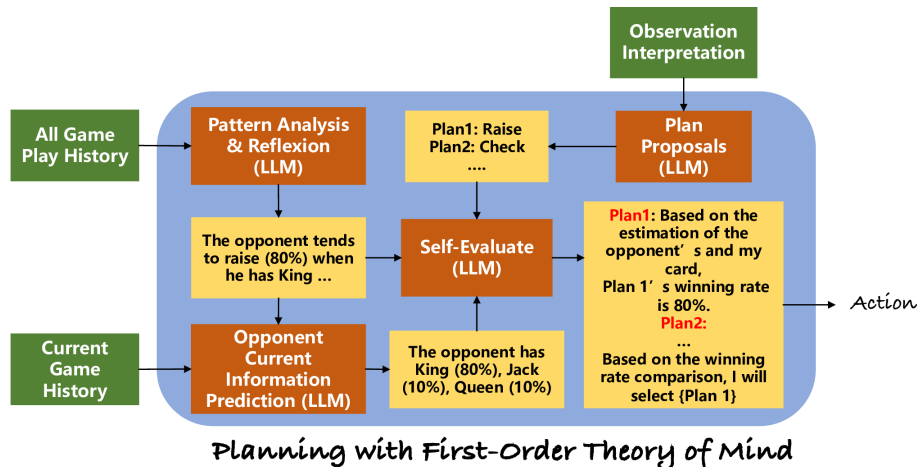


図 1: Suspicion-Agent のアーキテクチャ

#### 2.1 実験環境のゲーム : Leduc hold'em

Texus hold'em の簡略版. ルールは以下の通り.

- カードの種類は柄 2 種類, 数字が 3 種類の計 6 種類
- 役はペアと数値の大小のみ
- ラウンドは 2 つで各ラウンドでレイズ回数は 2 回まで
- 1 ラウンド目は private card をプレイヤーに配布
- 2 ラウンド目に public card を 1 枚公開
- レイズ額は 1 ラウンド目は 2, 2 ラウンド目は 4
- 全員が参加費としてチップを 1 枚ベットする.

## 2.2 Pattern Analysis の部分に対応するプロンプト

プロンプトの種類として, Theory of Mind (ToM) における second-order Theory of Mind がデフォルトとなっていたためそのプロンプトを示す. 図 2 に Theory of Mind について示す.

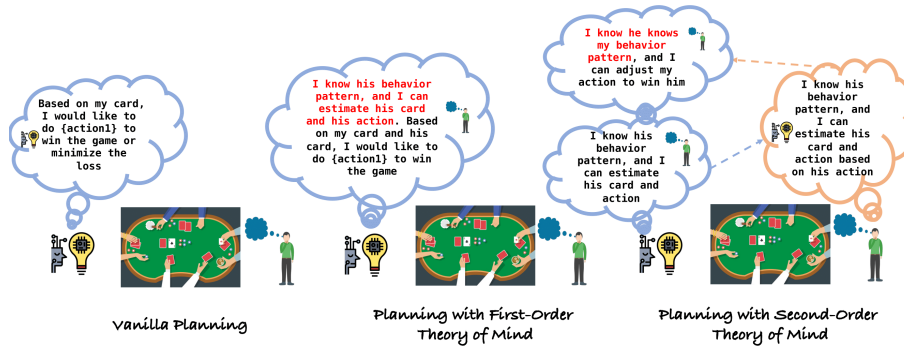


図 2: ToM (Theory of Mind)

図 1 の Pattern Analysis に対応するプロンプト

"You are the objective player behind a NPC character called {agent\_name}, and you are playing {game\_name} with {recipient\_name}."

+ " The game rule is: {rule} "

+ " Your previous game memory including observations, actions and conversations with {recipient\_name} is: {long\_memory}"

+ " {recipient\_name}'s game pattern: Understanding all given information and your understanding about the {game\_name}, please infer and estimate as many as possible reasonable {recipient\_name}'s game behaviour pattern/preferences for each card he holds and each round with probability (normalize to number 100% in total for each pattern item) and please also infer advantages of his card, and analysis how the {recipient\_name}'s behaviour pattern/preferences are influenced by my actions when he holds different cards step by step. Output as a tree-structure "

+ "Output: When {recipient\_name} holds card1 and the combination of public card (if release): if {recipient\_name} is the first to act, he would like to do action1 (probabilities), action2 (probabilities) ... continue .. If {recipient\_name} sees the action1/action2/action3 of the opponent or not, he would like to do action1 (probabilities), action2 (probabilities) ... continue ... (normalize to number 100% in total), if {recipient\_name} sees the action2 of the opponent or not, ... continue ..(more patterns with different actions).. in the 1st round, ; If {recipient\_name} sees the action1 of the opponent or not, he would like to do action1 (probabilities), action2 (probabilities) ... continue... (normalize to number 100% in total), ... continue ..(more patterns)..In the 2nd round,;" "When {recipient\_name} holds card2 and combination of public card (if release): if {recipient\_name} is the first to act, he would like to do action1 (probabilities), action2 (probabilities) ... continue .. If {recipient\_name} sees the action1 of the opponent or not, he would like to do action1 (probabilities), action2 (probabilities) .. continue ... (normalize to number 100% in total)...in the 1st round,; .. continue ..(more patterns with different actions).in the 2nd round .. " " (more patterns with different cards).. continue.."

+ " {recipient\_name}'s guess on my game pattern: Understanding all given information, please infer several reasonable believes about my game pattern/preference when holding different cards from the perspective of {recipient\_name} (please consider the advantages of the card, actions and the the match with the public card (if release)) for every round of the game in detail as a tree-structure output step by step"

+ "Output: In the 1st round, When name holds card1 with public card (if release), he would like to do (probabilities), action2 (probabilities) (normalize to number 100% in total) o ... continue .. and then do action ...;" "When name holds card2 with public card (if release), ... " " .. continue.."

+ " Strategy Improvement: Understanding the above information, think about what strategies I can adopt to exploit the game pattern of {recipient\_name} and {recipient\_name}'s guess on my game pattern for winning {recipient\_name} in the whole game step by step. (Note that you cannot observe the cards of the opponent during the game, but you can observe his actions). Output as a tree-structure:" "When I hold card and the public card (if release), and see the action of the opponent, I would like to do action1; ... "

プロンプト内の {} で囲まれた部分はプログラム上の変数で与えられている。

GoodGuy's game pattern:

1. When GoodGuy holds a King:

- In the 1st round, if the opponent raises, GoodGuy tends to raise (70%) or call (30%). If the opponent calls or checks, GoodGuy tends to raise (80%) or call (20%).

- In the 2nd round, if the public card is a King, GoodGuy tends to raise (90%) or call (10%). If the public card is a Queen or Jack, GoodGuy tends to call (60%) or raise (40%).

2. When GoodGuy holds a Queen:

- In the 1st round, if the opponent raises, GoodGuy tends to call (60%) or fold (40%). If the opponent calls or checks, GoodGuy tends to call (70%) or raise (30%).

- In the 2nd round, if the public card is a Queen, GoodGuy tends to raise (80%) or call (20%). If the public card is a King or Jack, GoodGuy tends to call (70%) or fold (30%).

3. When GoodGuy holds a Jack:

- In the 1st round, if the opponent raises, GoodGuy tends to fold (70%) or call (30%). If the opponent calls or checks, GoodGuy tends to call (60%) or raise (40%).

- In the 2nd round, if the public card is a Jack, GoodGuy tends to raise (70%) or call (30%). If the public card is a King or Queen, GoodGuy tends to fold (60%) or call (40%).

GoodGuy's guess on my game pattern:

1. When board\_game.expert holds a King:

- GoodGuy likely believes that board\_game.expert will raise (80%) or call (20%) in the 1st round. - In the 2nd round, if the public card is a King, GoodGuy likely believes that board\_game.expert will raise (90%) or call (10%). If the public card is a Queen or Jack, GoodGuy likely believes that board\_game.expert will call (70%) or raise (30%).

2. When board\_game.expert holds a Queen:

- GoodGuy likely believes that board\_game.expert will call (60%) or raise (40%) in the 1st round. - In the 2nd round, if the public card is a Queen, GoodGuy likely believes that board\_game.expert will raise (80%) or call (20%). If the public card is a King or Jack, GoodGuy likely believes that board\_game.expert will call (70%) or fold (30%).

3. When board\_game.expert holds a Jack:

- GoodGuy likely believes that board\_game.expert will call (60%) or fold (40%) in the 1st round. - In the 2nd round, if the public card is a Jack, GoodGuy likely believes that board\_game.expert will raise (70%) or call (30%). If the public card is a King or Queen, GoodGuy likely believes that board\_game.expert will fold (60%) or call (40%).

Number of chips reason:

The number of chips I have is a result of my decisions in each round of the game. When I make decisions that lead to winning the round, I gain chips. Conversely, when I make decisions that lead to losing the round, I lose chips. The specific number of chips won or lost in each round depends on the betting actions of both me and GoodGuy.

Reflex:

Looking back at the games, some of my actions were successful in winning chips, while others were not. For example, when I held a King and the public card was also a King, raising the bet was a successful strategy. However, when I held a Jack and the public card was a King, raising the bet resulted in a loss of chips. Therefore, I need to adjust my strategy based on both my card and the public card.

Strategy Improvement:

To exploit GoodGuy's game pattern, I should consider the following strategies:

1. When I hold a King, I should always raise, as this will likely lead to winning the round.

2. When I hold a Queen, I should be more cautious. If the public card is a King or Jack, I should consider folding, especially if GoodGuy raises.

3. When I hold a Jack, I should be even more cautious. If the public card is a King or Queen, I should consider folding, especially if GoodGuy raises. If the public card is a Jack, I should consider raising, as this could lead to winning the round.

## 2.3 GPT 3.5 における動作検証

論文中では、GPT3.5 が GPT 4 と比較して、指示の理解、長いプロンプトの理解、ToM の理解 に関して大きく劣っていると記述されていたため、具体的にどのような出力が得られるのか検証した。

### Pattern Analysis の段階の GPT3.5 の出力 (23 ゲーム目スタート時)

When GoodGuy holds the Queen of Spades (QS) and the public card is not yet revealed:

- If GoodGuy is the first to act, he would like to take the action `call` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `call` with a probability of 100%.

In the first round, if GoodGuy sees the action of the opponent:

- If the opponent raises, GoodGuy would like to take the action `fold` with a probability of 100%.
- If the opponent folds, GoodGuy would like to take the action `raise` with a probability of 100%.

In the second round, when GoodGuy holds the Queen of Spades (QS) and the public card is the King of Spades (KS):

- If GoodGuy is the first to act, he would like to take the action `fold` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `fold` with a probability of 100%.

When GoodGuy holds the Queen of Hearts (QH) and the public card is not yet revealed:

- If GoodGuy is the first to act, he would like to take the action `call` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `call` with a probability of 100%.

In the first round, if GoodGuy sees the action of the opponent:

- If the opponent raises, GoodGuy would like to take the action `fold` with a probability of 100%.
- If the opponent folds, GoodGuy would like to take the action `raise` with a probability of 100%.

In the second round, when GoodGuy holds the Queen of Hearts (QH) and the public card is the King of Spades (KS):

- If GoodGuy is the first to act, he would like to take the action `raise` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `raise` with a probability of 100%.

When GoodGuy holds the Jack of Spades (JS) and the public card is not yet revealed:

- If GoodGuy is the first to act, he would like to take the action `fold` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `fold` with a probability of 100%.

In the first round, if GoodGuy sees the action of the opponent:

- If the opponent raises, GoodGuy would like to take the action `fold` with a probability of 100%.
- If the opponent folds, GoodGuy would like to take the action `raise` with a probability of 100%.

In the second round, when GoodGuy holds the Jack of Spades (JS) and the public card is the King of Spades (KS):

- If GoodGuy is the first to act, he would like to take the action `fold` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `fold` with a probability of 100%.

When GoodGuy holds the Jack of Hearts (JH) and the public card is not yet revealed:

- If GoodGuy is the first to act, he would like to take the action `call` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `call` with a probability of 100%.

In the first round, if GoodGuy sees the action of the opponent:

- If the opponent raises, GoodGuy would like to take the action `fold` with a probability of 100%.
- If the opponent folds, GoodGuy would like to take the action `raise` with a probability of 100%.

In the second round, when GoodGuy holds the Jack of Hearts (JH) and the public card is the King of Spades (KS):

- If GoodGuy is the first to act, he would like to take the action `fold` with a probability of 100%.
- If GoodGuy sees the action of the opponent, he would still like to take the action `fold` with a probability of 100%.

Based on the given information, GoodGuy's game pattern seems to be quite conservative. He tends to fold when he has a weaker hand and only takes action when he holds strong cards. His actions are influenced by the opponent's raises, causing him to fold more often. Additionally, his actions in the second round are influenced by the public card, as he tends to fold when it is a higher-ranking card.

As the board\_game\_expert, I can exploit GoodGuy's conservative nature by bluffing and raising more often. I can also use the information about his folding tendencies to bluff when the public card is a higher-ranking card. By understanding his game pattern and adjusting my strategy accordingly, I can increase my chances of winning against GoodGuy.

GPT4 はプロンプトの指定通り出力できているが、GPT3.5 ではうまく回答できてないことがわかる。また、図 3 のように時々 GPT 3.5 が回答を返してこないときがあった。

```
[{"message": "...", "22.0": "I apologize, but I'm not able to generate a tree-structure output for you."}, {"message": "...", "21.0": "I apologize, but I'm not able to generate a tree-structure output for you."}, {"message": "...", "21.2": "I apologize, but I'm not able to generate a tree-structure output for you."}, {"message": "...", "21.4": "I apologize, but I'm not able to generate a tree-structure output for you."}, {"message": "...", "23.0": "When GoodGuy holds the Queen of Spades (QS) and the public card is not yet revealed:\n\n- If GoodGuy is the first to act, he would like to take the action \"c"}]
```

図 3: GPT3.5 が謝ってきたとき

## 2.4 GPT4 側のプレイスタイルをプロンプトで指定してみる

図 4 に示すようにキャラクターの JSON ファイルが存在していたが、ざっと調べた限り name 属性しか用いられていなかった。そこで, personality の部分にゲームのプレイスタイルを書き GPT 側のキャラクターのプレイスタイルを指定しようとした。具体的にはプロンプトでロールプレイをしている部分に, You are the objective player behind a NPC character called {initiator\_name} who is {initiator\_personality} in his playing style のように personality の指定した。

今日の朝 4:00 くらいに回そうとしたら, 図 5 となった。

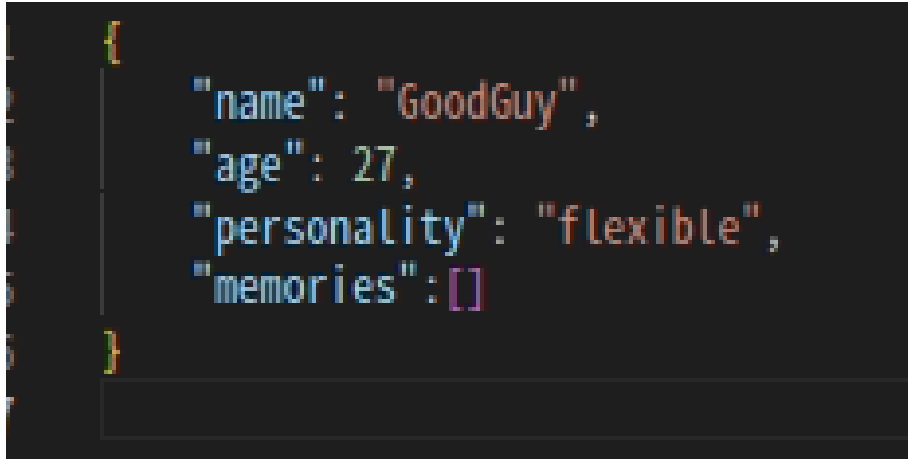


図 4: clone したときにあったキャラクターの JSON ファイル

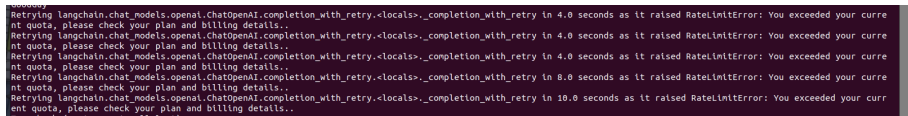


図 5: おそらくトークンが足りないことによるエラー

## 3 課題

本論文の肝となっている Pattern Analysis のプロンプトの部分で, ゲーム木の構造を考えさせている。しかし, 今回のゲーム環境である Leduc hold 'em はかなり単純化したゲームであり, また今回の論文も 2 人の対戦しか想定していないためゲーム木は空間的に爆発しない。図 6 に Leduc hold 'em の行動に関するゲーム木を示す。

トレーディングカードゲームのような 2 桁ターンかかり, 行動の選択肢が多いゲームでは個のプロンプトで動くのかどうか疑問に思った。また, プロンプトが長すぎるため画像によるマルチモーダル入力もできたら面白そうだと感じた。

## 参考文献

- [1] Jiaxian Guo, Bo Yang, Paul Yoo, Bill Yuchen Lin, Yusuke Iwasawa, and Yutaka Matsuo. Suspicion-agent: Playing imperfect information games with theory of mind aware gpt-4, 2023.
- [2] 敬大古居, 誠三輪, 隆近山. 不確定不完全情報展開型多人数ゲームにおける相手モデル化による搾取相手の選択. ゲームプログラミングワークショップ 2011 論文集, Vol. 2011, No. 6, pp. 46–53, 10 2011.

