Report For PS1

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Variation 1:

General Strategy:

1. Since our **payoff depends on the current value** that we have, it is better to play **conservative** and try to avoid any losses. So general approach would be to use average of winning bids and second highest bids and compare it with our current value to get a rough estimate of how much to bet.
2. At each round, avg_winning_bid and avg_second_highest bid is calculated, and initial guesses are made for 1st round.
3. When current_value > avg_winning_bid, we try to bid **above avg_winning_bid** at the same time get a profit of atleast 4.
4. When current_value >avg_winning_bid, we try to get a lucky win with a decent profit.
5. Managing bid restrictions.

Weakness:

1. Luck plays a major factor in each auction, since bidding is w.r.t to our current_value.
2. Using averages to bid, could be a common strategy.

Strengths:

1. Guarantees Profit in every round.
2. Stable strategy.

Variation 2:

General Strategy:

1. Starting with **an ideal_value** (derived in Pg No 2) that can give the best profit assuming everyone bids randomly, and dynamically changing this value based on whether we won the previous round or not. A check is also done to ensure that we **don't cross maximum expectation value** (Constant bidding at Expectation Value will give 0 profit on an average).

2. Dynamic Change of bid initially at +1 and -1 and changing it based on the progress of the auction to ensure the following:
    - We always bid close to bidding behaviour of opponents in **shortest amount of rounds**, maximizing the profit in each round.
    - Coping up with immediate change in behaviour of opponents. (Using an avg value-based strategy cannot handle periodic bidding-based strategy where the opponent tends to bid higher only in certain phases of the auction.)

- **Change in factor to 0.5, 0.25** at a later stage of auction so that profit is maximized when avg_bidding_value increases substantially, and opponents move to a stable strategy.
- Change in factor is also a way to **counter average based strategy** because I would be bidding above the bid of average value bidders more times than below it.

3. Using a **self.behaviour list** to know the behaviour of opponents:
    - Care is taken so that values that are lesser than expected maximum values are only passed on to the behaviour list using the data of top two bids.
    - My bidding amount is not appended to behaviour list so that the list shows **only the behaviour of opponents** even if I win more rounds.

4. Using the behaviour list to counter constant bidders:
    - The current algorithm faces a slight issue against constant bidders above the ideal_value. This is because the algorithm would keep oscillating around the bid value of the constant bidder.
    - To rectify this, there is **check on the frequency** of a certain bid using the behaviour list with an optimal **round off up to 1 decimal digit**. When a specific frequency is crossed, my strategy changes itself to a constant bidding strategy for a specific number of upcoming rounds.
    - The number of rounds that must be played this way depends on the **closeness of the most frequent bid** to the maximum expected value so that profit is maximized without high risk.

5. Using a **backup strategy** to minimize losses incase my strategy fails:
    - Backup is used in 3 cases: If the distribution of random numbers causes a large variation from expected value causing more losses in initial rounds; If my capital does not increase after 600 rounds; If any opponent has a **constant counter** to my strategy, causing a decrease in my capital.
    - Backup strategy is **a conservative strategy** aiming to increase capital without suffering heavy losses. Since it uses the average bidding method with a **check on expected value**, it ensures that we don't lose much even if the main strategy fails.

6. Care is taken to bid within the restriction of (0,100)

Derivation of Ideal Value/ Initial Bid:

Let b be the bidding amount.
a_{max} be the maximum random number of a particular.
$P(b) \rightarrow$ Probability of winning when b amount is bidded.

When $b \uparrow$ profit $\downarrow$ $P(b) \uparrow$.
$b \downarrow$ profit $\uparrow$ $P(b) \downarrow$

Let us assume both have an equal contribution.

$$\text{Profit} \times P(b) = f(b)$$

$$\Rightarrow f(b) = (a_{max} - b)\left(\frac{b}{100}\right)^{n-1}$$

We need to find maximum of $f(b)$.

$$\Rightarrow \frac{df}{db} = (a_{max}-b)(n-1)\left(\frac{b}{100}\right)^{n-2}\frac{1}{100} - \left(\frac{b}{100}\right)^{n-1} = 0$$

$$\Rightarrow (a_{max}-b)(n-1) = b$$

$$\Rightarrow a_{max}(n-1) - bn + b = b$$

$$\Rightarrow \boxed{b = a_{max}\frac{(n-1)}{n}}$$

Now, we can assume that a_{max} is the maximum expected value for the random distribution.

a_{max} is given by, $\boxed{a_{max} = 100\frac{n}{n+1}}$

$$\Rightarrow b = 100\frac{n}{n+1} \times \frac{n-1}{n} \Rightarrow \boxed{b = 100\frac{(n-1)}{n+1}}$$

This is the ideal bidding amount b assuming all opponent bid a random bid value, which is a initial value to start with.

Strengths:

1. Focuses on **maximizing profi**t as much as possible at the same time **takes calculated risk** based on opponents behaviour. This is done by analyzing opponent behaviour.
2. Reduces loss through backup strategy incase main strategy fails.
3. Counters variety of opponent strategies like average bidding, constant bidding, periodic bidding etc.

Weakness:

1. There could be a reduction in profit when an opponent plays a constant bid close to the maximum expected value. In this case, the amount of profit depends on the distribution of random numbers and since the number of auctions are only 3**, luck plays a huge role** in this.

Variation 3:

General Strategy:

1. Since the second highest bidder gets a **negative payoff**, most of the oppentens would go for an average bidding strategy, we should try to get the maximum profit **and take risks at the start** of the auction before the average increases a lot. After that a conservative strategy should be used to keep the profit flowing.

2. Bidding near the ideal value (calculated similar to the previous variation) for a few rounds till the average settles up a bit.

3. Once average is settled (~7 rounds) we move on to a slightly aggressive approach:
    - My bidding amount would be greater than avg_winning bid+**1.5* self.aggression**. A check is also made on the bidding amount so that it doesn't go more than max expected value+1.
    - Self.aggression is set initially as 1 and every 20 rounds it is decreased by a **factor of 0.9**. Care is also taken to decrease the aggression factor when the avg_winning bid is close to the maximum expected value.
    - A separate **self.loss_counter** is maintained and using self.previous_bid and the previous second highest bid, counter is increased. When counter reaches 15 or capital=0.8* initial_capital, strategy changes to conservative mode.
    - This is also a **counter to average based strategies** since I am increasing the avg_winning_bid every round through the aggression factor so that avg based bidders can't catch up quickly.

4. Conservative Strategy is then used for 400 rounds to increase profit slowly and steadily:
    - In this strategy, if current_value > avg_winning bid, bid=avg_winning_bid+1 else bid=ideal_value declared at beginning.

- A **self.counter** variable is used to keep track of number of rounds played in Conservative mode and changes back to aggressive mode when needed.
- Care is also taken to bid near expected value, when current_value is greater than max expected value to increase number of wins.

5. Now, strategy changes back to aggressive mode again in which the self.aggression is really low as the avg_winning_big would tend close to max expected value.

6. Care is taken to bid within the bid restrictions (0,100)

Strengths:

1. This strategy has one of the **best odds of beating an average based strategy** which is one of the most common strategies to this problem.
2. Switches between aggressive and conservative mode so that maximum profit is achieved at the start of the round and then the profit is steadily increased.
3. Gives the opponents **rigged values to average** as I would stop bidding after 15 losses and they would have to bid at an average much closer to max expected value, decreasing their profit.

Weakness:

1. The initial aggressive approach may not be fruitful if avg_winning_bid is above expected value during initial rounds **causing loss in opponents' capital**, at the same time not allowing me to bid above the avg_winning_bid as it is likely to get a loss above expected value.