Multi-Agent AI

[Group Coursework 1]

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1. INTRODUCTION

2. LITERATURE REVIEW

3. APPROACH AND RESULT

Typically, the body of a paper is organized into a hierarchical structure, with numbered or unnumbered headings for sections, subsections, sub-subsections, and even smaller sections. [1]

3.1 Problem 1: Data Exploration

3.2 Problem 2: Basic Bidding Strategy

In this section, we analyse two basic bidding strategies, which are Constant Bidding Strategy and Random Bidding Strategy, and evaluate their performance based on the number of clicks within a limited budget of 6,250 CNY fen. Evaluation function: For the single-agent basic bidding strategies, the main metric to rank the strategies are based on the clicks from winning impressions.

3.2.1 Constant Bidding Strategy

In order to find an optimal constant value, we loop the constant bid prices from 0 to 300, which are the minimum bid price and maximum bid price, to find out the bid price with the highest clicks from winning impressions. Specifically, for each constant price, we retrieve the columns of 'payprice' and 'click' for all the bids in the training set. Then we compare our constant bid price with the 'payprice' for each bid and add up the click into our total clicks if our constant bid price is great than or equal to the 'payprice' while the total spend is calculated at the mean time. Afterwards we remove the clicks from bottom to top where the total spend has been over our limited budget.

Analysis: Figure 1 shows that how the number of clicks changes based on the increment of the constant bidding price. The clicks increase dramatically when the constant bidding price increases from 1 to 24 and the climax of clicks is 134 when the constant bidding price is 24. Then the clicks drop sharply when the bidding price increases from 25 to 69. Afterwards, the clicks decrease smoothly.

In order to evaluate our result on validation set, initially we need to normalize the budget based on the Equation 1.

[1]This is the second footnote.

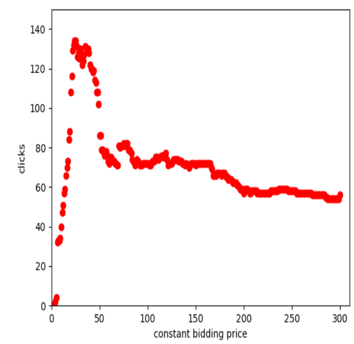

Figure 1: Validation set - bid price and clicks

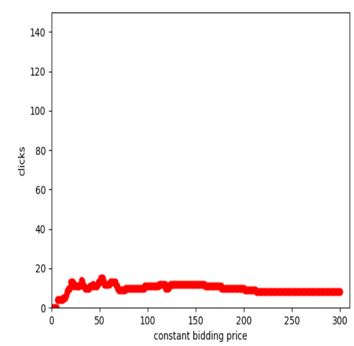

Figure 2: Validation set - bid price and clicks

$$bidPrice_{validation} = \frac{sizeOfValidation}{sizeOfTrain} * bidPrice_{train} \quad (1)$$

Figure 2 shows the changes of number of clicks depending on bid price in the validation set with a normalized budget. We could see the clicks are relatively high when the bid price is between 18 to 68. Moreover, the highest clicks are 15 while the clicks are 12 when bid price is 24. Therefore, bid price 24 is a relatively satisfactory price in the validation set.

3.2.2 Random Bidding Strategy

In order to find the optimal bidding range for random bidding, we step through a range of lower bound and a range

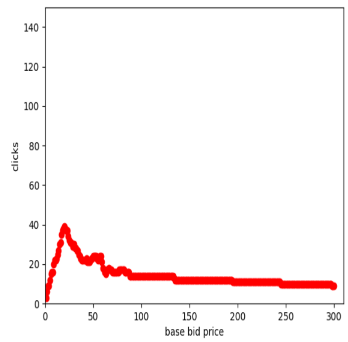

Figure 3: Validation set - base price and clicks

of upper bound to find out the bid price with the highest clicks from winning impressions. Similarly, we use the same method as the one in Constant Bidding Strategy to calculate the clicks.

Analysis: The highest clicks are 132 generated from range(30, 40) and the second highest clicks are 131 generated by range(0, 50) in the training set. By normalizing the budget in the validation set based on equation 1, we find the highest clicks are 15 generated from the range(0, 50). Therefore, the findings in training set successfully match validation set.

3.2.3 *Competition among homogeneous random bidding agents*

3.3 Problem 3: Linear Bidding Strategy

In order to apply CTR estimation to for a linear bidding strategy, we initially retrieve the these features as independent variables X: day, hour, region, ad exchange, slot width, slot height, advertiser, slot visibility, slot format, OS, browser, and slot price from the data set. Specifically, we categorize the slot price to five categories based on the price values, and we extract the OS and browser from the column useragent. And the rest features could be simply fetched from the data. The click from the data is our predictor Y. Afterwards, we import the Logistic Regression model from sklearn and train the model with the independent variables and predictor from the training set. Then we use the trained model to predict the click of test data and validation data separately. The pCTR of the validation data could be calculated with the equation 2.

$$pCTR = \frac{numOfClicks}{numOfWinningImpressions} \tag{2}$$

The bid price for each bid is calculated as equation 3. As shown in Figure 3, the total clicks increase sharply when base bid increases from 1 to 20 and drop smoothly after then. The value clicks is maximized as 39 when the base bid is 20.

$$bidPrice = \frac{baseBidPrice * pCTR}{avgCTR} \tag{3}$$

Comparison:

Obviously, the behavior of the linear bidding strategy is much better than random bidding and constant bidding strategies. The optimal value of clicks in linear bidding is 39 while the ones of constant bidding and random bidding are merely 12 and 15 separately.

Table 1: Behavior Comparison

	Constant Bidding	Random Bidding	Linear Bidding
price	24	range(0, 50)	20(base)
clicks	12	15	39

3.4 Problem 4: Non-Linear Bidding Strategy

We calculate the non-linear bidding price based on ORTB (equation 4), and we step through some combination of c and lamda to find the optimal pair generating the optimal bid prices. We find the value of clicks is 39 when c equals to 39 and lamda equals to 1.31072e-05. Therefore, our non-linear bidding strategy just generates the same result as linear bidding strategy.

$$bidPrice = \sqrt{\frac{c}{\lambda} * pCTR + c^2} - c \tag{4}$$

3.5 Problem 5: Multiagent Bidding Strategy

4. CONCLUSIONS

This paragraph will end the body of this sample document. Remember that you might still have Acknowledgments or Appendices; brief samples of these follow.

5. SAMPLE FORMAT

5.0.1 *Inline (In-text) Equations*

A formula that appears in the running text is called an inline or in-text formula. It is produced by the **math** environment, which can be invoked with the usual `\begin. . .\end` construction or with the short form `$. . .$`. You can use any of the symbols and structures, from α to ω, available in LaTeX[?]; this section will simply show a few examples of in-text equations in context. Notice how this equation: $\lim_{n\rightarrow\infty} x = 0$, set here in in-line math style, looks slightly different when set in display style. (See next section).

5.0.2 *Display Equations*

A numbered display equation – one set off by vertical space from the text and centered horizontally – is produced by the **equation** environment. An unnumbered display equation is produced by the **displaymath** environment.

Again, in either environment, you can use any of the symbols and structures available in LaTeX; this section will just give a couple of examples of display equations in context. First, consider the equation, shown as an inline equation above:

$$\lim_{n\rightarrow\infty} x = 0 \tag{5}$$

Notice how it is formatted somewhat differently in the **displaymath** environment. Now, we'll enter an unnumbered equation:

$$\sum_{i=0}^{\infty} x + 1$$

and follow it with another numbered equation:

$$\sum_{i=0}^{\infty} x_i = \int_{0}^{\pi+2} f \tag{6}$$

Table 2: Frequency of Special Characters

Non-English or Math	Frequency	Comments
Ø	1 in 1,000	For Swedish names
π	1 in 5	Common in math
\$	4 in 5	Used in business
Ψ_1^2	1 in 40,000	Unexplained usage

Figure 4: A sample black and white graphic.

just to demonstrate LaTeX's able handling of numbering.

5.1 Citations

Citations to articles [**?**, **?**, **?**, **?**], conference proceedings [**?**] or books [**?**, **?**]

5.2 Tables

Because tables cannot be split across pages, the best placement for them is typically the top of the page nearest their initial cite. To ensure this proper "floating" placement of tables, use the environment **table** to enclose the table's contents and the table caption. The contents of the table itself must go in the **tabular** environment, to be aligned properly in rows and columns, with the desired horizontal and vertical rules. Again, detailed instructions on **tabular** material is found in the *LaTeX User's Guide*.

5.3 Figures

Like tables, figures cannot be split across pages; the best placement for them is typically the top or the bottom of the page nearest their initial cite. To ensure this proper "floating" placement of figures, use the environment **figure** to enclose the figure and its caption.

This sample document contains examples of **.eps** files to be displayable with LaTeX. If you work with pdfLaTeX, use files in the **.pdf** format. Note that most modern TeX system will convert **.eps** to **.pdf** for you on the fly. More details on each of these is found in the *Author's Guide*.

As was the case with tables, you may want a figure that spans two columns. To do this, and still to ensure proper "floating" placement of tables, use the environment **figure*** to enclose the figure and its caption. and don't forget to end the environment with figure*, not figure!

5.4 Theorem-like Constructs

Other common constructs that may occur in your article are the forms for logical constructs like theorems, axioms, corollaries and proofs. There are two forms, one produced by the command `\newtheorem` and the other by the command `\newdef`; perhaps the clearest and easiest way to distinguish them is to compare the two in the output of this sample document:

This uses the **theorem** environment, created by the `\newtheorem` command:

THEOREM 1. *Let f be continuous on $[a,b]$. If G is an antiderivative for f on $[a,b]$, then*

$$\int_a^b f(t)dt = G(b) - G(a).$$

The other uses the **definition** environment, created by the `\newdef` command:

Definition 1. If z is irrational, then by e^z we mean the unique number which has logarithm z:

$$\log e^z = z$$

Two lists of constructs that use one of these forms is given in the *Author's Guidelines*.

There is one other similar construct environment, which is already set up for you; i.e. you must *not* use a `\newdef` command to create it: the **proof** environment. Here is a example of its use:

PROOF. Suppose on the contrary there exists a real number L such that

$$\lim_{x\to\infty} \frac{f(x)}{g(x)} = L.$$

Then

$$l = \lim_{x\to c} f(x) = \lim_{x\to c}\left[gx \cdot \frac{f(x)}{g(x)}\right] = \lim_{x\to c} g(x) \cdot \lim_{x\to c} \frac{f(x)}{g(x)} = 0 \cdot L = 0,$$

which contradicts our assumption that $l \neq 0$. $\square$

Complete rules about using these environments and using the two different creation commands are in the *Author's Guide*; please consult it for more detailed instructions. If you need to use another construct, not listed therein, which you want to have the same formatting as the Theorem or the Definition[**?**] shown above, use the `\newtheorem` or the `\newdef` command, respectively, to create it.

Figure 5: A sample black and white graphic that has been resized with the `includegraphics` command.

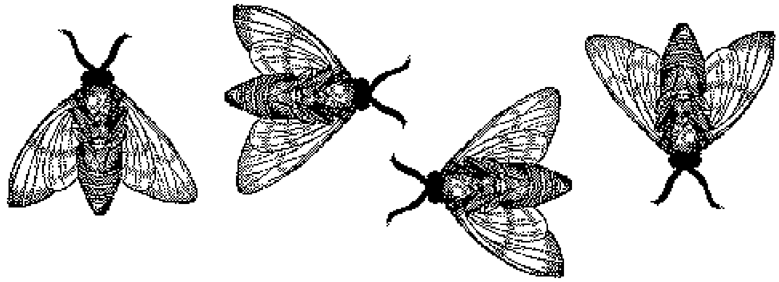

Figure 6: A sample black and white graphic that needs to span two columns of text.

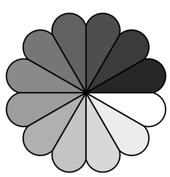

Figure 7: A sample black and white graphic that has been resized with the `includegraphics` command.