Optimizing Advertising Impression Allocation: Comparative Analysis of Two Algorithms for Online and Offline Instances in Generalized Assignment Problems

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INTRODUCTION

- Online advertisements are crucial in promoting products to specific audiences in this digital age. In this realm, ad allocation and optimizing the distribution of advertising impressions is essential for maximizing profits while adhering to budget constraints.
  - **Generalized assignment problems** (GAP) are well-studied online packing problems that affect ad allocation.
    - Gaps within this domain are pivotal when providing the framework of immediate allocation of ad impressions to budget-constrained advertisers when impressions arrive in real-time by focusing on optimizing impression allocation.

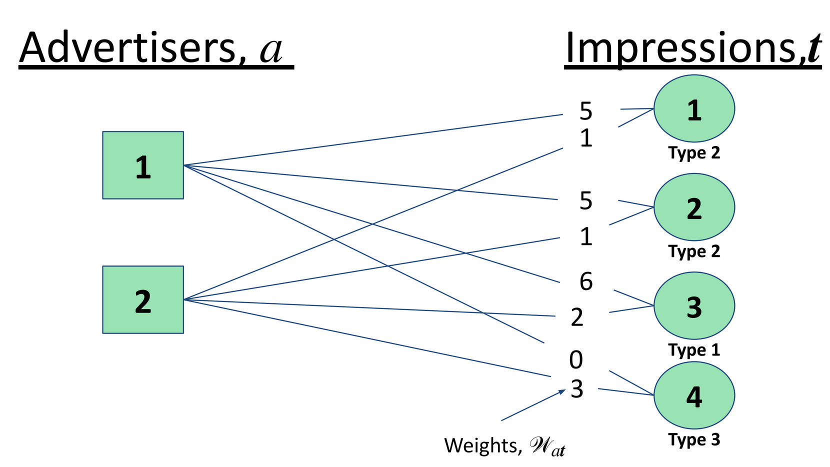
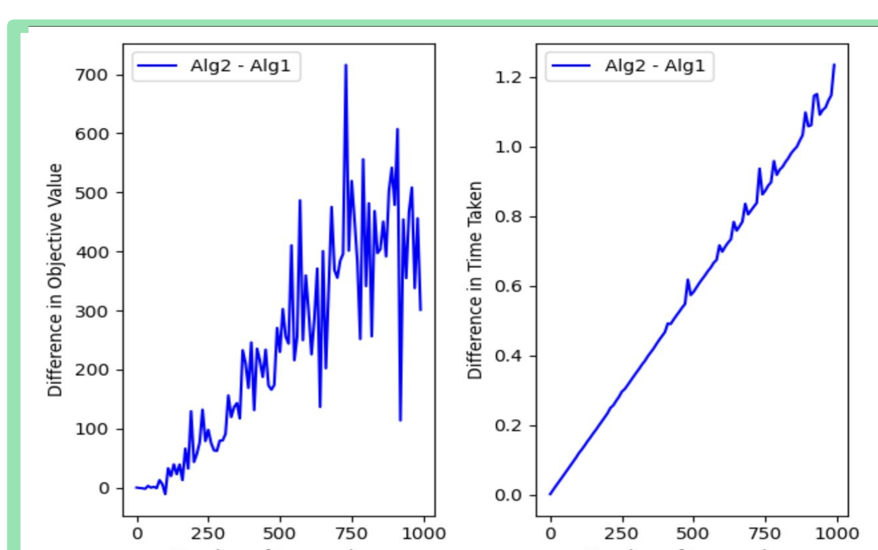


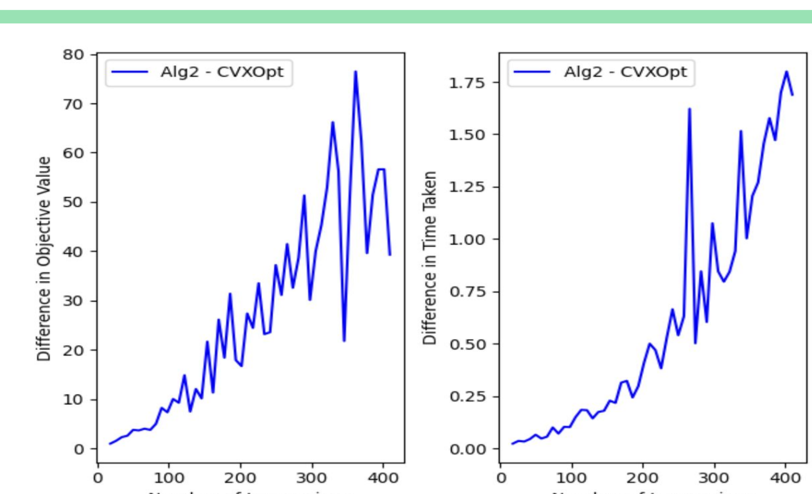
Fig.1 A small scale example of valuations. With advertisers value impressions of the same type

- Implementing and evaluating two distinct algorithms to solve the optimization problems based on synthetic and real-world advertising data into a weight matrix that quantifies the impression value for each advertiser created the foundation for the assessment and comparison of the two algorithms against the **optimal solution.**
  - This comparative analysis showcased the solution quality and computation effort of each algorithm, highlighting the relative efficiency and effectiveness of the algorithms.

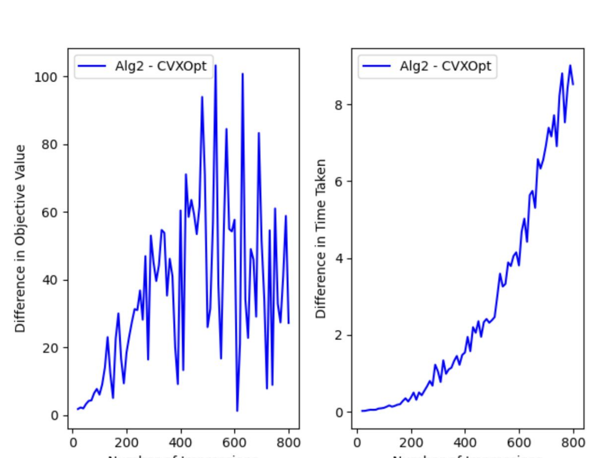
RESULTS



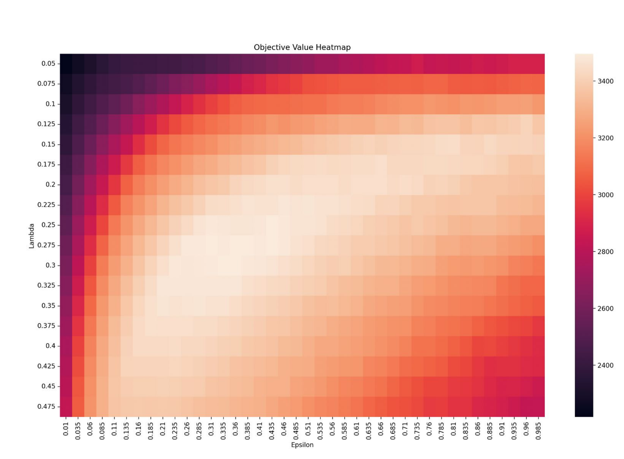
This graph compares Alg 1 and Alg2 across several impressions. Where Alg2 appears to perform better in terms of objective value but slower compared to Alg1



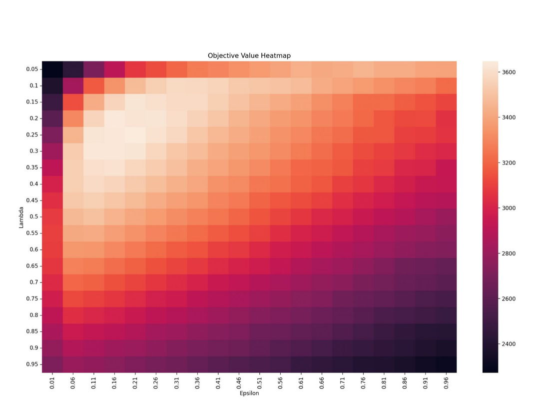
This graph compares Alg2 to CVXopt across several impressions. Alg2 appears to perform better regarding objective value but is less time-efficient than CVXOPt.



This graph compares the differences between Alg2 and CVXOpt. Alg2 provides different objective values than CVXOpt, with higher variability; CVXOpt appears more time-efficient than Alg2, especially as the workload increases.



First heatmap attempt (took 45 mins)
Eps (0.01, 1.0, 0.025)
Lam (0.05, 0.5, 0.025)
Rounds = 15



Second heatmap attempt (took 20 mins)
Eps (0.01, 1.0, 0.05)
Lam (0.05, 1.0, 0.05)
Rounds = 50

DISCUSSION/CONCLUSIONS

- This research highlights a balance between risk and reward within budget limitations.
- This research enhances our understanding of algorithmic performances in ad allocation and provides a valuable prediction for improving online decision-making processes and resource allocation strategies.

Future work

- Further improvements in performance
- Implement improved machine learning predictions to enhance the efficiency of the algorithms against the optimal solutions

Methods

Algorithm 1

- An implementation of a solution for a Generalized Assignment Problem(GAP) focuses on optimizing the allocation of ad impressions to advertisers.
  - In algorithm one, the parameter **"beta"** represents each advertiser's threshold/adjustment factor.
  - There are three methods to updating **"beta."**
    - **One** is a conservative method that computes "beta" considering the advertiser's budget and impression weights.
    - **Two** calculated "beta" as the average weight of impressions for the advertiser to compute a uniform adjustment factor
    - **Three** sets "beta" to the weight of the lowest weight impression to simplify the selection process or to mitigate the impact of low-weight impressions
- The algorithm ensures efficient impression allocation by tracking the total allocated value and checking budget constraints. The results include a matrix of allocations and the time taken to perform each allocation, allowing for performance analysis and further improvement.

Algorithm 2

- Implements an optimization algorithm to allocate impressions to advertisers while managing constraints and maximizing efficiency by iterating over multiple rounds to refine the allocation and priorities based on specific criteria.
  - For each impression, the algorithm computes the weighted contribution of each advertiser based on their priority score and the value calculated using "calculateD."
  - To ensure that the total allocation of each impression does not exceed 1, normalize the contributions by dividing the computed values by the sum of all the contributions.
  - Update the priority scores for each advertiser based on the total allocation relative to their budget. If the allocation is less them "(budget / (1 + eps))" and decrease if the allocation exceeds "(budget * (1 + eps))"

Optimal algorithm

- Using **"CVXopt"** to find the optimal solution and measure the computation time allows optimization under constraints, ensuring that the solution adheres to budget limits and allocation requirements while maximizing the given object's functions.
  - The objective function converts weights to a minimization problem format.

Synthetic data

- Synthetic data is simulated data for advertising-related scenarios by generating a list of **"impressions"** and **"advertisers"** and calculating associated weights; it also introduces data corruption to simulated real-world inaccuracies.
  - Data corruption functions to introduce random errors into the weights to test the robustness of the algorithms.
- Synthetic data is used to evaluate and optimize the algorithms.

Tuning

- Evaluates the performance of an optimization algorithm with different values of **"eps"** and **'lam."**
  - uses synthetic datasets
  - runs optimizations algorithms with varying eps and lam values and computes the average objective values and their standard deviations
  - Plots a heatmap of the objective values to showcase how different parameter combinations affect the algorithm's performance

REFERENCES

[1] Fabian Spaeh and Alina Ene. (2023). Online ad allocation with predictions. URLhttps://doi.org/10.48550/arxiv.2302.01827.

[2]*proceedings of Machine Learning Research FAQ*. (n.d.). Proceedings of Machine Learning Research. https://proceedings.mlr.press/faq.html

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