

Improving the deferred acceptance algorithm for efficient sponsor-recipient matching

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Abstract. As the gap between rich and poor in China has become increasingly prominent, various charity platforms have emerged. However, due to information asymmetry, many recipients cannot receive effective donations, and the emergence of fraudulent donations also makes donors unable to fulfill their intentions. We designed some improvements to the delayed acceptance (DA) algorithm and applied it flexibly in the donation platform. This can improve the efficiency of matching between donors and recipients. The variant of the DA algorithm is designed to carry out multiple rounds of matching, give donors and recipients the opportunity to select the matching priority list based on various factors and use a reasonable matching mechanism to achieve Pareto efficient, strategy-proof, and stable matching. Therefore, the application of the variation of the DA algorithm in the donation problem can better match the needs, so that the platform can complete a more reasonable and efficient donation matching.

Keywords: Deferred Acceptance Algorithm, Donation Matching, Charity Platforms, Information Asymmetry, Pareto Efficiency.

1. Introduction

According to a study by the Chinese National Institute of Poverty Alleviation, the income gap between urban and rural residents in China in 2017 was still as high as 2.71[1]. The increased demand for charitable donations has also led to more frequent giving, which has led to the development of the donation industry[2]. As it develops, its problems become more prominent. The overall poor information disclosure of the platform has led to a decline in its credibility. Tencent's "99 Charity Day" is a charity activity with the largest number of participants, the highest amount of fundraising, and the largest investment in communication and promotion resources in China's Internet field so far. It is fully relying on social networks to carry out and has a very strong representation in the field of online charity fundraising in China.

Not only the "99 Public Welfare Day", but also the 20 designated fundraising platforms have exposed some problems: the overall information disclosure of the platform is not good, some platforms have irregular operation, and passionate donations have not yet been transformed into regular donations. The report specifically mentions that since personal online help is outside the scope of the regulation of the Charity Law, individual adverse cases have affected the public's understanding of the legally designated fundraising platform, so it is necessary to regulate personal help.

For example, “Water Drop Fundraising” is still personal help in nature, but the use of online public platforms can be regarded as public fundraising initiated by individuals through public platforms, which tends to be negative, so it has caused mixed reviews from society.

In order to make the matching more reasonable, the paper first introduces the application of the DA algorithm in this kind of problem. Meanwhile, the article also proposes that sponsors donate money to recipients, who each have a demanded amount. Recipients can only accept one donation from one sponsor. Donations may be larger or smaller than the requested amount. The limitation of the DA algorithm causes this problem, and this paper also provides a solution for this problem.

2. Improvement: Use DA algorithm

DA Algorithm refers to the Deferred Acceptance Algorithm also known as the Gale-Shapley algorithm. This algorithm is used to solve the Stable Marriage Problem and the more general Stable Matching Problem. It was proposed by David Gale and Lloyd Shapley in 1962 [3].

The content of this algorithm can be well explained in the classic stable marriage problem. In this problem, there are two groups of equal numbers of participants, often referred to as male and female. Each participant had a list of preferences for all members of the other group. The goal is to find a match in such a way that no pair of men and women prefer each other over their spouse (a situation called unstable matching).

2.1. Application of DA algorithm in donation matching

When defining this problem first, there are three basic concepts:

Sponsors: An individual or organization that has a certain amount of funds.

Recipients: Individuals or organizations in need of financial support, and each recipient has a desired amount of donations.

Preferences: Preferences can be based on a number of factors, such as the amount of the recipient's donation, social impact, etc. Assume that each donor has a preference ranking for all recipients, and vice versa. In order for donors and recipients to form a more personalized and reasonable list of preferences, they can consider the following factors [4]:

Table 1. Consideration factors

Recipients	Donors
Money	Personal emotional identity
Urgency	Urgency
credibility	Publicity
sustainability	Transparency
ethical considerations	

In the scoring mechanism, we create a list of preferences for each recipient and donor and evaluate them quantitatively according to Table 1. We use a multi-factor evaluation model to score each factor and sum it up to get a comprehensive score for each entity. The following is a detailed explanation of the scoring system.

The recipient scoring system considers the following five main factors, each assigned a weight according to its importance:

Money:

Scoring Criterion: The alignment between the amount offered by the donor and the recipient's financial needs. The closer the match, the higher the score.

Score Range: 0 - 100

Weight: 1.5 (adjustable based on actual needs)

Urgency:

Scoring Criterion: The urgency of the recipient's needs. Donors who can provide support quickly receive higher scores.

Score Range: 0 - 100

Weight: 2.0

Credibility:

Scoring Criterion: The donor's reputation and background check. More credible donors receive higher scores.

Score Range: 0 - 100

Weight: 1.0

Sustainability:

Scoring Criterion: The donor's commitment to long-term projects and sustainable development goals, such as environmental protection.

Score Range: 0 - 100

Weight: 1.2

Ethical Considerations:

Scoring Criterion: The alignment of the donor's ethical standards with the recipient organization's values. The more aligned, the higher the score.

Score Range: 0 - 100

Weight: 1.3

Overall Score Calculation Formula

The overall score for each recipient concerning a donor is calculated as follows:

Total Score = $\sum(\text{Factor Score} \times \text{Weight})$

For example, if a recipient scores a donor as follows:

Money: 80, Urgency: 70, Credibility: 90, Sustainability: 60, Ethical Considerations: 85

The total score would be:

Total Score = $(80 \times 1.5) + (70 \times 2.0) + (90 \times 1.0) + (60 \times 1.2) + (85 \times 1.3)$

Similarly, the donor scoring mechanism is structured in the same way. The weights are as follows:

Personal Emotional Identity:

Scoring Criterion: The donor's personal emotional connection with the recipient's project. The stronger the connection, the higher the score.

Score Range: 0 - 100

Weight: 1.0

Urgency:

Scoring Criterion: The urgency of the recipient's project. The more urgent, the higher the score. The platform can also show how much money the recipient has already received.

Score Range: 0 - 100

Weight: 1.5

Publicity:

Scoring Criterion: The potential publicity and external impact of the donation. The greater the potential for positive publicity, the higher the score.

Score Range: 0 - 100

Weight: 1.2

Transparency:

Scoring Criterion: The transparency of the recipient's financial and operational processes. The more transparent, the higher the score.

Score Range: 0 - 100

Weight: 1.0

Overall Score Calculation Formula

The overall score for each donor concerning a recipient is calculated as follows:

Total Score = $\sum(\text{Factor Score} \times \text{Weight})$

For example, if a donor scores a recipient as follows:

Personal Emotional Identity: 85, Urgency: 75, Publicity: 80, Transparency: 90

The total score would be:

$$\text{Total Score}=(85\times 1.0)+(75\times 1.5)+(80\times 1.2)+(90\times 1.0)$$

We hope the platform will provide donors and recipients with enough information so that they can use a scoring mechanism to specify their list of preferences from highest to lowest.

After the problem is defined, the DA algorithm can be applied to achieve a reasonable match. The first step is for each donor to make a proposal to their preferred donor. Each donor makes an acceptance offer to the donor at the top of the preference list who has not rejected them. This offer will indicate that they want to receive funding from the donor. Next, donors hold off on accepting offers. Donors do not make a decision immediately after receiving an offer. They will hold off on all offers until all potential offers are received. In the meantime, donors keep the proposals they receive and wait for more options. If the recipient's proposal is not immediately accepted, they will continue to make an offer to the next best donor. This process continues until their list of preferences is exhausted or the proposal is accepted. Once all proposals arrive, donors will be evaluated against their list of preferences. They choose their favorite donor proposal and forgo the others. Recipients who are dropped will return to unmatched status and move on to the next preferred offer. The next step is to repeat steps 3 and 4 until all recipients are matched. The process repeats, with the recipient continually making proposals and the donor continually evaluating and selecting until all recipients are matched or there are no more recipients to make new proposals.

Here is the Python code implementation of the algorithm for this problem for reference:

```
def recipient_proposal_matching(recipient_prefs, sponsor_prefs):
```

```
    unmatched_recipients = list(recipient_prefs.keys())
    proposals = {recipient: [] for recipient in recipient_prefs}
    matches = {}
    current_proposals = {sponsor: None for sponsor in sponsor_prefs}
```

```
    while unmatched_recipients:
```

```
        recipient = unmatched_recipients[0]
        recipient_pref = recipient_prefs[recipient]
```

```
        for sponsor in recipient_pref:
            if sponsor not in proposals[recipient]:
                proposals[recipient].append(sponsor)
```

```
            if current_proposals[sponsor] is None:
                current_proposals[sponsor] = recipient
                matches[recipient] = sponsor
                unmatched_recipients.pop(0)
```

```
            else:
                current_recipient = current_proposals[sponsor]
                sponsor_pref = sponsor_prefs[sponsor]
```

```
                if sponsor_pref.index(recipient) < sponsor_pref.index(current_recipient):
                    current_proposals[sponsor] = recipient
                    matches[recipient] = sponsor
                    unmatched_recipients[0] = current_recipient
```

```
                break
```

```
            else:
                unmatched_recipients.pop(0)
```

return matches

2.2. Stability of DA algorithm

Using this algorithm guarantees that the match is stable if and only if no recipient and no donor are more willing to give up the current match in favor of each other; that is, there is no so-called blocking pair[5].

In order to prove that the matching between the recipient and the donor is stable after applying this algorithm, it is assumed that there is a blocking pair (B, D), that is, recipient B and donor D, who have a higher preference for each other than the current matching object. According to the operation mechanism of the DA algorithm, if donor B likes donor D more, and donor D likes donor B more, donor B will apply to donor D during the matching process, and donor D will choose B as a match at the end. Therefore, the design of the DA algorithm eliminates all blocking pairs and ensures the stability of matching.

2.3. DA algorithm is Pareto efficient

This match is also a match that is Pareto efficient if no other match can make at least one person better without making anyone worse.

In order to prove that this match is Pareto efficient, suppose that if there is another match that can improve the satisfaction of a donor, then during the execution of the original DA algorithm, the donor will apply to that donor, and depending on the donor's preferences, they may accept this match. However, the algorithm's final match has taken into account all such possibilities and ruled out any promotion opportunities. Therefore, the final match of the DA algorithm is Pareto efficient.

2.4. DA algorithm is strategy proof

The algorithm is also strategy-proof, and participants cannot get better matches by lying about their preferences than by honestly reporting them. This is crucial in the issue of contributions and can reduce cases of fraudulent contributions.

Suppose that in the DA algorithm proposed by the donor, the donor always applies to the donor with the highest preference, so that they can get the best matching result. Thus, lying about preferences does not confer an advantage, only the possibility of a worse match. Donors also select the best applicants based on a list of true preferences, so lying about preferences does not improve the quality of matches.

3. Defects in the application of DA algorithm in donation problems

3.1. Irrationality in the application of the DA algorithm

In the application of the DA algorithm described above, it has been assumed that the participants, that is, the donors and recipients, are rational. However, the reality is that irrationality can exist.

When donors draw up a list of preferences, they decide that getting a donation in a match is always better than not getting a donation. This results in a one-shot game, any expected payoff larger than 0 is acceptable, leading to the preference order: {a, b, c, d, match with nothing}. In practice, this is irrational and unreasonable and may have a negative impact on the interests of other donors. This behavior is problematic because some recipients may require a substantial amount. For example, the recipient needs 10,000 RMB for surgery for surgery. However, if his preference order is {a, b, c, d, match with nothing}, he may not get the 10,000 RMB donation, but he can get a smaller amount of aid. For example, he will receive 1000 RMB assistance after matching. Although he received assistance through matching, it was not enough and did not cover the cost of his surgery. But he will still take the opportunity not to refuse unhelpful aid, because he may think it is better than no donation. So even though his true preference is {a, b, matched with nothing, c, d}, he still submits a false list of preferences {a, b, c, d, match with nothing}. In practice, this can also spread out donations, so that recipients who really need a specific amount of donations do not receive a certain amount of donations that they should. This messes up the matching mechanism and weakens its effectiveness.

3.2. Proposed Solution: A Variant of the DA Algorithm

In order to avoid the above problems as much as possible, the DA algorithm needs to be improved to better apply to the donation matching problem. First of all, the matching of donations is changed from a single round to multiple rounds. In the multi-round matching, the DA algorithm is applied once per round. In each match, n recipients and n donors are randomly selected by the system. After matching participants are identified, recipients and donors submit their priority lists into the system. The platform uses the DA algorithm to match them.

In this multi-round DA algorithm operation, recipients or donors who are not successfully matched will enter the next round of matching candidates. In this case, the inefficient matching caused by misreporting {a, b, c, d, match with nothing} can be avoided because recipients know that future rounds may offer better options than the unacceptable c and d. Recipients are more likely to wait for the next batch of sponsors, reducing their motivation to compromise.

The benefits of improving the DA algorithm with the above method include encouraging recipients to report their true preferences and leading to more efficient and meaningful matches. Each match made by the donor and recipient in the match is meaningful, the recipient can actually receive the help that is needed, and the donor can also aid those who wish to be assisted. This can reduce the likelihood of recipients accepting insufficient donations that do not meet their needs. This would also allow for a more equitable distribution of donations by considering recipients' genuine requirements. This can promote the effectiveness of matching, motivate more people to donate, and also encourage those who need to donate to initiate a call for help and promote the platform.

3.3. Limitation

This donation matching mechanism is still immature, and there are some potential problems. The first is the limitation of scale. In this donation matching mechanism, donors and recipients need to score potential matches and form a preference list, which requires them to spend a lot of time looking up the information of potential matches, which will cause huge time costs. At the same time, due to the limited time, the number of recipients and donors in each match cannot be too much; otherwise, it will affect the authenticity and accuracy of the preference list. This means that matching cannot be carried out on a large scale, which poses a challenge to accurately matching donors and recipients. With limited matching sizes, donors and recipients may not be able to find a match they are happy with.

In addition, in the establishment of a donation matching platform, although the platform has a definite matching mechanism, the promotion of the platform is also uncertain. The quantity and quality of recipients and donors are very important in matching donations. In particular, the involvement of donors is essential. The platform needs the right marketing to attract decisive donors and give donors the confidence to participate in the platform. This is an important part of platform operation. It also depends on various factors, such as the social credibility of the founder of the donation platform, the marketing strategy of the donation platform, the page design of the platform website, and the donation amount range of the donation platform.

In practical terms, the needs of donors and recipients are complex, and ensuring the fairness of the donation platform is challenging. When specific mechanisms are used to meet the needs of donation matching problems, the system needs to be continuously improved and optimized to provide satisfactory services to participants.

4. Conclusion

In general, the application of the DA algorithm in donation matching can better meet the needs of recipients and donors for matching to a certain extent. The proposed variant of the DA algorithm also addresses the limitations of the original algorithm in the context of sponsor-recipient matching. By introducing multiple rounds of matching, recipients are more likely to report their true preferences, resulting in more efficient and effective matches. This approach has the potential to improve the overall outcomes for both sponsors and recipients in the donation process. The mechanism of the donation

platform also needs to be continuously improved according to the actual situation, so as to better serve the donation and charity.

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