Proceedings of the 2nd International Conference on Financial Technology and Business Analysis
DOI: 10.54254/2754-1169/60/20231144

Effective Redistribution of Donated Resources

– Application of Top Trading Cycles Algorithm

Xingran Wu[1,a,*]

[1]*Beijing-Dublin International College, Beijing University of Technology, Beijing, China*
a. xingran.wu@ucdconnect.ie
**corresponding author*

Abstract: Governments and people of many countries have paid more attention to the action of subsidizing people in distressed areas in all aspects. However, many donated resources cannot be accurately allocated to the poor who need them most, which will lead to waste of resources and inefficiency of poverty alleviation. This paper considers the perspective of poverty alleviation through education, and focuses on the problem of imprecise assignment of donated books. This problem is an important issue that needs to be solved immediately, as education for students in less developed areas is a very essential part of helping them get rid of poverty. Reading appropriate books can help improve their cognitive ability and make students develop in a better direction, inspire them to take the initiative to develop in a better direction. This paper applies the Top Trading Cycles algorithm proposed by Shapley and Scarf in 1974 to solve this problem, which can enable students to rematch the donated books they think are useless and exchange them for more suitable books.

Keywords: poverty alleviation through education, books allocation, Top Trading Cycles

1. Introduction

The world is developing rapidly, and the economic strength of many countries is also becoming stronger. However, there are still many impoverished areas and poor people, even in developed and top ranked advanced developing countries. Therefore, it is necessary to help people in need and drive the common prosperity of the world population. Many countries are increasingly attaching importance to poverty alleviation, and have formulated many relevant standards and policies based on their respective national conditions and development stages, providing a large amount of welfare and subsidies to people in mountainous and rural areas. For example, in China, through the government's constant efforts, by the end of 2020, the poor rural residents of 98.99 million were rescued from poverty, and 832 poor counties and 128000 villages have been freed from poverty [1]. In addition to the support of the country, many enthusiastic individuals have also joined the activities of aiding poor areas. They donate money, clothes, food, books, appliances, and many other things, which also provide a lot of help to the poor who are living in difficulties. However, many goods and donations have not played a significant role, due to inefficient material allocation and inaccurate matching, many resources cannot be fully utilized. For example, in some areas where the population is not large, they receive an excessive amount of food, which leads to a lot of food and water not being consumed until they expire, and ultimately can only be thrown into garbage bins, resulting in

DOI: 10.54254/2754-1169/60/20231144

waste. This is a very important issue that needs to be resolved as soon as possible. Various resources in the world are scarce and insufficient to meet everyone's needs, so it is necessary to find better ways to maximize resource utilization efficiency. If the donated materials cannot be effectively utilized and matched, the benefits brought by poverty alleviation actions will not meet expectations, and many resources will also be wasted. This paper will study how to rematch free donations that recipients consider to be of little use to themselves, so that after the exchange, more poor people can receive greater help and improve their quality of life. Many researchers have conducted surveys and studies on poverty and charitable donations. Poverty is a problem that exists in every country, and it brings serious social problems [2]. There are many reasons for poverty, such as the inability to meet the needs of food, education, and healthcare. The act of free donations can unite everyone in society, strengthen connections among all members of society, and create a more harmonious social environment [3]. Due to the complex reality of the situation and the large number of impoverished people, donors often do not understand the detailed information of the impoverished people and whether their donations have played a practical role [4].

2. Poverty Alleviation Through Education

2.1. Background

One of the most important aspects of poverty alleviation is education, as education for the poor helps them to improve their spiritual level and strengthens their initiative to extricate themselves from poverty. Taking China as an example, in 1984, The Notice for Helping Poor Areas to Change Their Faces as Soon as Possible was issued, which first put forward the concept of "poverty alleviation through education" and the connection between education and poverty eradication has been clarified [2]. However, although the Chinese government has been making efforts to promote rural education, some researchers have found that the utilization of educational supported resources in subsidized areas is inefficient and even wasteful. There are many cases of waste of educational resources. For instance, the student-to-teacher ratio in some regions is too high, while it is too low in some regions, all of which cannot maximize the use of teachers. This paper will discuss one aspect of inefficient utilization of educational resources: inaccurate book matching. Inaccurate book distribution means that the donated books received by students in poor areas are not their favorite, or the reading materials given to middle school students are mixed with a large number of reading materials for preschool children. Such problems will lead to children's low interest in reading, or they can only hoard books because the books are useless, which will only increase the obstacles to poverty alleviation through education.

There are many reasons for inaccurate book allocation. The lack of management personnel is a crucial aspect. When registering donations, there are not enough people and energy to view the attributes and categories of each book. After the books are transported to poor regions, due to the large number of poor people in the region, there are not enough managers to distribute the books one by one to the students who need them the most. In addition, many rural areas have not posted their specific needs on the public websites, which leads donors confused about what type of books are most suitable for local students. Moreover, there are many individual donors who make donations at will and do not carefully examine local needs. They often choose to donate to one of the distressed areas randomly, which can also lead to inefficient material distribution.

2.2. Current Mechanisms

There are now several mechanisms aimed at solving the problem of inaccurate matching between donation supply and recipient demand. The first existing mechanism is the "Ant Financial Alipay Donation" platform set up by China's Alipay software, which uses blockchain technology to improve

DOI: 10.54254/2754-1169/60/20231144

the transparency and traceability of charity donation process and reduce information asymmetry [5]. Blockchain technology allows poor residents to accurately describe the goods and resources they need on the platform, and donors can then browse that information and provide relevant materials. There would no longer be cases such as one recipient applies for funding from multiple charitable organizations, which may lead to an excess of material subsidies [6]. During the donation process, the logistics and transportation status can also be checked on the phone at any time, which increases the credibility and makes the funding process more convenient.

The second mechanism is an internet public welfare crowdfunding platform established by Tencent Charity Foundation using spatiotemporal big data technology. Spatiotemporal big data refers to a vast amount of data collected by different virtual and physical sensors, which has characteristics of temporal and spatial information and typically covers multiple dimensions of information such as time and geographic location [7]. By utilizing the characteristics of spatiotemporal big data visualization, it can continuously display the distribution and changing trends of donation data to the public, allowing donors to understand the spatiotemporal situation of crowdfunding information and make more effective decisions [8]. In addition, this technology can also analyze the location and the demand information of the recipients, then use algorithms to calculate in order to perform the correlation matching between the recipients and the potential donators in the surrounding area, helping donors to provide assistance more efficiently [8].

The third method is to call on contributors to donate more cash, so that distressed people can directly choose and buy items that are more suitable for themselves [9].

Although the above mechanisms can effectively solve the problem of low efficiency in the use of donated materials to a certain extent, each method still has shortcomings. The first mechanism, blockchain technology in many regions is not perfectly designed, and in the actual operation of the "Ant Financial Alipay Donation" platform, only a small number of recipients have fully described the specific materials they need, so item matching is still not accurate. The second mechanism has some limitations, which is only in regions where spatiotemporal big data technology is widely used can funding rates be higher. However, the current popularity of this technology is not yet dense enough to significantly improve the rates. Furthermore, there are still drawbacks in the accuracy of this technology, which may lead to imprecise correlation matching and low crowdfunding rates [8]. The third method, some people may not want to donate money and only want to donate discarded clothes or books. If they are forced to only donate money, it may have a counterproductive effect on the promotion of charity. Moreover, if a sudden earthquake occurs in a certain area and there is an urgent need for living supplies, donating money is useless at this time [9].

3. Introduction and Application of Top Trading Cycle Algorithm

In this section, a new method is applied to solve the problem of ineffective book matching, which is called Top Trading Cycles (TTC) algorithm put forward by Shapley and Scarf in 1974. This algorithm aims to solve economic problems that involve the exchange and matching of indivisible goods between agents, and should not include currency transfers. The TTC mechanism has already been successfully applied to the field of kidney exchange, house allocation and the school selection problem.

3.1. Properties and Requirements of TTC Algorithm

The matching results of TTC algorithm has three properties, which are individual rationality, Pareto-efficiency and strategy-proofness [10,11]. Individual rationality means that agents who choose to join the matching process will not regret it, which also indicates that the matching result will not be worse than the agent's initial endowment. The final matching through the TTC algorithm is Pareto efficient

DOI: 10.54254/2754-1169/60/20231144

implies that there is no other matching which can make one agent better off without making others worse off. Moreover, strategy-proof means that all agents in the process report their true preferences.

There are also some requirements of the TTC algorithm, fulfilling which can make the algorithm work properly and satisfy the above properties. Firstly, each agent has his or her own initial endowment, which indicates that all agents should have one object in order to exchange with others. Secondly, the objects or goods have to be indivisible. Thirdly, the whole process contains no money transfer, and all the objects are exchanged for free. Finally, all the participants should write down strict preferences, which infer that indifferent preferences are not allowed.

It is clear that the matching books problem fits the premises of the algorithm. Firstly, the students in the rural areas already receive the books donated from other people as their initial endowment. Moreover, a book is an object that cannot be split between students. Furthermore, the management teachers can instruct students in writing their preferences in a strict order. Finally, since the book is donated from the public, it implies that the books are get for free, thus in the following exchange process, there is no monetary transfer. As the books waste problem satisfied all the prerequisites, the TTC mechanism could be supplied.

3.2. Properties and Requirements of TTC Algorithm

The TTC mechanism has some fixed procedures, which include directed graphs, containing nodes of agents and objects, as well as arcs pointing towards each other between agents and objects. The following is the process of TTC execution.

Step 0: All agents write down their strict preferences.

Step 1: Each agent points to their top object, and each object points to its original owner. At least one cycle is present and there are no cycles that intersect. Then the existing cycles are removed and the object which the agent pointing to is assigned to him or her.

Step t ($t \in [2,n)$, $t \in Z$): Each agent points to their top choice object among the remaining ones and each object points to its original owner. At least one cycle is present and there are no cycles that intersect. Afterwards, all the current cycles are eliminated, and each agent will be assigned the object he or she points to in the cycle. When there are no agents or items left, the algorithm suspends, and the matching result is the allocation formed during the algorithm process.

Based on the above procedure, the books matching problem can be solved by redistributing students' books so that they are all satisfied with the results.

To consider the problem in an easier way, only few students are included in the following matching example. The same method can be extended to an allocating process containing more students.

Step 0: Consider 8 students in a poor school, who get a total of 8 donated books. Six of the students are dissatisfied with the books they receive, so they participate in the algorithm. The set of the six students is S, S = {Ann, Bob, Claire, David, Sally, Tom}. The set of the six books is B, B = {book1, book2, book3, book4, book5, book6}.

Table 1: Preference profile R.

Ann	Bob	Claire	David	Sally	Tom
4	3	4	3	1	3
5	5	1	2	2	2
6	6	3	6	6	5
2	1	2	5	3	6
1	4	5	4	4	1
3	2	6	1	5	4

DOI: 10.54254/2754-1169/60/20231144

The initial endowment is sorted by the management teachers based on the alphabetical order of students' names. Thus, the primary matching is (Ann-book 1, Bob-book 2, Claire-book 3, David-book 4, Sally-book 5, Tom-book 6). Then, all the six students write down their strict preference in a form, then the preference profile R is as shown in Table 1.

Step 1: Each book points to its initial owner, and each student points to his or her top choice. It is clear that there exists one cycle 1, which is (Claire, book 4, David, book 3), as shown in Figure 1. Therefore, book 3 is assigned to David and book 4 is assigned to Claire. Then, cycle 1 should be removed from the algorithm.

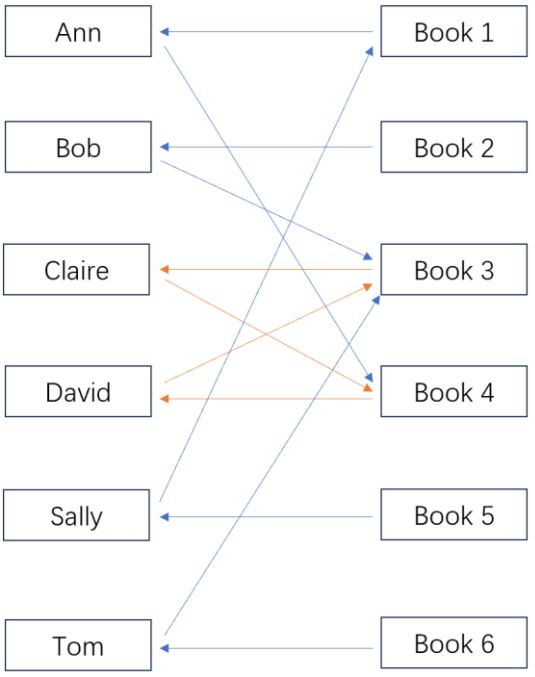

Figure 1: step 1 of TTC Algorithm.

Step 2: There are 4 students and 4 books left. Since book 3 and book 4 no longer exist in the procedure, Ann, Bob, and Tom need to switch their arrow to their second favorite books. Then, cycle 2 is formed, which is (Ann, book 5, Sally, book 1), as shown in Figure 2. Therefore, book 5 is allocated to Ann and book 1 is allocated to Sally. Then, cycle 2 should be removed from the algorithm.

DOI: 10.54254/2754-1169/60/20231144

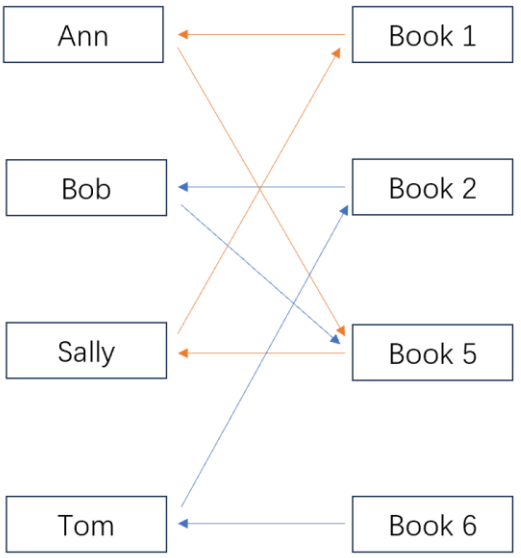

Figure 2: step 2 of TTC Algorithm.

Step 3: There are 2 students and 2 books left. Since book 2 and book 6 no longer exist in the step, Bob needs to switch his arrow to his third favorite books. Then, cycle 3 can be found, which is (Bob, book 6, Tom, book 2), as shown in Figure 3. Therefore, book 6 is assigned to Bob and book 2 is assigned to Tom. Then, cycle 3 should be removed from the algorithm.

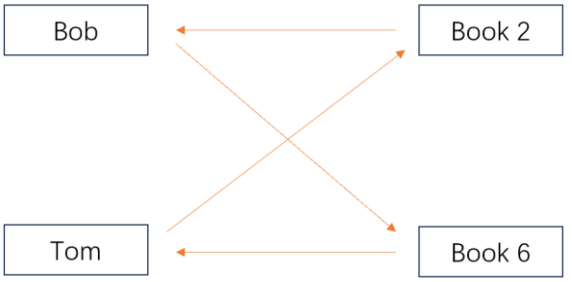

Figure 3: step 3 of TTC Algorithm.

The algorithm comes to an end because there are no students and books remaining, and the outcome is the allocation determined during its enforcement process.

The final allocation is shown in Table 2, which is {(Ann, book 5), (Bob, book 6), (Claire, book 4), (David, book 3), (Sally, book 1), (Tom, book 2)}.

DOI: 10.54254/2754-1169/60/20231144

Table 2: Final allocation of TTC Algorithm.

Ann	Bob	Claire	David	Sally	Tom
4	3	4	3	1	3
5	5	1	2	2	2
6	6	3	6	6	5
2	1	2	5	3	6
1	4	5	4	4	1
3	2	6	1	5	4

4. Conclusion

In conclusion, this study first introduces the general background and consequences of the problem of resource waste in impoverished regions caused by inaccurate matching of rescue resources. Then, the paper focuses on a specific aspect of the matching suboptimal problem, which is book allocation problems in local poor schools. The subsequent section illustrates the cause of this issue, and exhibits some existing mechanisms for improving the efficiency of assigning books to impecunious students. Nevertheless, all the three mechanisms mentioned have some drawbacks in addressing the challenge. Therefore, TTC algorithm is introduced to solve the donated book matching imprecise problem in a different perspective. The properties and restrictive conditions of the TTC mechanism are mentioned, meanwhile a specific example is given which illustrates the steps to attaining the final Pareto efficient result.

However, in reality, there still existed some problems. The example in this paper only includes six students. If applying the algorithm to support the resource re-matching for all needy areas and residents, a TTC algorithm system for automatic matching is necessary to be established, otherwise it may be impossible to complete such a large number of calculations. The development of TTC algorithm system may require a lot of manpower and funding, which the government needs to carefully consider. In addition, one of the conditions of the TTC mechanism is that all students must have strict preferences for books. However, in the actual executive process, there is a high possibility that students' preferences for some books are indifferent. This problem should be solved in the future, otherwise, if there are cases where some students are interested in two or more books, the final matching result is likely to be Pareto inefficient.

References

[1] *Xie, J., Zheng, X., Chen, Y., Cheng, J., Zhang, Y., Guo, X., Zhao, Y. and Wu, Q. (2021). How China has lifted nearly 800 mln people out of poverty. Xinhuanet. Retrieved from http://www.xinhuanet.com/english/2021-04/06/c_139862741.htm*

[2] *Hu, T. and Sun, M. (2022). A visualization analysis of poverty alleviation through education research in China. Cogent Social Sciences. Retrieved from https://www.tandfonline.com/doi/epdf/10.1080/23311886.2022.2132674?needAccess=true&role=button*

[3] *Bensaid, B., Grine, F., Nor, M.R., MohdYusoff, M.Y. and Gombak, J. (2013). Ethico-Spiritual Dimensions of Charity: An Islamic Perspective. Middle-East Journal of Scientific Research. 13 (2), 171-182.*

[4] *Farooq, M.S., Khan, M., and Abid, A. (2020). A framework to make charity collection transparent and auditable using blockchain technology. Computers Electrical Engineering. 83, 106588.*

[5] *Almaghrabi, A., and Alhogail, A. (2022). Blockchain-based donations traceability framework. Journal of King Saud University - Computer and Information Sciences. 34(10), 9442 – 9454.*

[6] *Li, Y. (2020). Research on the application of blockchain technology in fundraising based on "Internet plus + Charity". Intelligent Computers and Applications. 10(6), 86-88,91.*

[7] *Zhou, B., Zhao, J., Chen, G. and Yin, Y. (2023). Security Authentication Mechanism of Spatio-Temporal Big Data Based on Blockchain. Applied Sciences. 13(11), 6641.*

[8] *Ren, Y., Cai, H., Zhang, S., Gao, J. and Deng, X. (2021). Research on public welfare crowdfunding behavior based on spatiotemporal big data - Taking "Tencent Public Welfare" as an example. Shanghai Commercial (08), 30-31.*

DOI: 10.54254/2754-1169/60/20231144

[9] Bisaha, S. (2021). Three reasons more charities are giving people cash (And one reason not to). Economy. Retrieved from https://www.npr.org/2021/11/16/1055835911/more-charities-are-giving-cash-directly-to-people-in-need

[10] Alcalde-Unzu, J. and Molis, E. (2011). Exchange of indivisible goods and indifferences: The Top Trading Absorbing Sets mechanisms. Games and Economic Behavior. 73, 1-16.

[11] Jaramillo, P. and Manjunath, V. (2012). The difference indifference makes in strategy-proof allocation of objects. Journal of Economic Theory. 147, 1913-1946.