



Extreme Min – Cut Max – Flow Algorithm

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ABSTRACT

In this article, the authors propose a maximum flow algorithm based on flow matrix. The algorithm only requires the effort to reduce the capacity of the underutilized arcs to that of the respective flow. The optimality of the algorithm is proved by the max-flow min-cut theorem. The algorithm is table-based, thus avoiding augmenting path and residual network concepts. The authors used numerical examples and computational comparisons to demonstrate the efficiency of the algorithm. These examples and comparisons revealed that the proposed algorithm is capable of computing exact solutions while using few iterations as compared to some existing algorithms.

KEYWORDS

Maximum Flow Problem, Minimum Cut, Algorithm, Flow Matrix, Max-Flow Min-Cut Theorem

INTRODUCTION

The maximum flow problem is a network-based problem, whose objective is to determine the maximum amount of units that can pass through a network. All links in the network have capacity restrictions. Given a network with given capacity restrictions on each link, the maximum flow problem usually deals with the determination of flow patterns thorough various links in the network, so that a maximum flow can arrive at a specified node known as the “destination node” from another specified node, known as the “origin,” where the supply is unlimited. Ahmed et al. (2013), Kaml (2017), Munapo et al. (2021), Sarukhi et al. (2017), and Yuan et al. (2010), among others, tackled this problem. The maximum flow network can be directed or non-directed; water networks and road networks are examples of nondirected and directed networks, respectively.

The maximum flow problem has many applications, which include maximizing movement of water from dams, rivers, and boreholes to treatment sites, and then from treatment sites to residents. The maximum flow problem can be used to determine congestion points in urban road networks that require road expansion, so as to minimize congestion and delays. Also, the maximum flow problem is one of the network-based combinatorial optimization problems that requires the development of algorithms and heuristics to determine the maximum flow value in any given network. Researchers

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have been developing methods to solve maximum flow problems using concepts based on augmenting path, maximum flow – minimum cut theorem, and residual networks, among others.

Motivation

The various applications and the complexity of the maximum flow problem have motivated this research. The minimum cut theorem is very powerful and helps to determine the maximum flow value in any given network. The drawback is that it consumes time to determine all the cuts in the network and evaluate them to determine the minimum cut in the set of all possible cuts. Making the position of the minimum cut deterministic in any given network has motivated this research. It becomes very easy to determine the maximum flow value in any given network when the minimum cut position is deterministic. Most algorithms use augmenting paths to determine the maximum flow value in a network; however, in this research, the authors exploited other directions to avoid the use of augmenting paths and residual network concepts.

This research has the following contributions:

1. The authors developed a new algorithm that is based on the concepts of maximum flow – minimum cut theorem. The design of the algorithm is simple; thus, it can be used for teaching purposes and without the aid of computer software.
2. The authors proposed table-based maximum flow algorithm concepts, thus avoiding the augmenting paths and residual networks. The literature revealed that most of the existing algorithms are based on augmenting paths and residual network concepts.
3. The authors proposed two theorems based on the max-flow min-cut theorem. These theorems are very useful in making the position of the minimum cut in any given network deterministic. The authors also proved their proposed theorems mathematically using max-flow min-cut theorem concepts.

This paper is organized in seven sections. The second section presents the literature related to the maximum flow problem; the third section presents the proposed algorithm and theorems, definitions of related terms, and notations; the fourth section offers numerical results and discussions; The fifth and sixth sections report the worst case time complexity of the algorithm and computational results, respectively; lastly, the seventh section provides the conclusion and further research suggestions.

LITERATURE REVIEW

Ma et al. (2019) developed maximum flow algorithms using the concepts of dynamic networks information to maximize the transmission rate in communication networks. Computational experiments have proved 40% increase in throughput and 30% decrease in completion time. Wang (2019) applied the maximum flow algorithms to determine the feasibility of foreign trade transformation and upgrading for China. More in detail, Wang implemented the maximum flow algorithm to design and to improve the China distribution system. This application proved how maximum flow algorithms can be used to solve real world challenges. Zhang et al. (2015) presented a maximum-flow-based data transmission algorithm for distributed computing systems. Rajalakshmi and Vaidyanathan (2019) applied Edmonds-Karp maximum flow algorithm to traffic management system, so as to minimize congestion by finding alternative routes and traffic flow regulating. Ahmed et al. (2013) introduced lexicographic search technique to obtain exact solutions to the problem of maximum flow with minimum attainable cost in a flow network. Their computational experiments revealed that the proposed algorithm computes the maximum flow value in any given network in the least time. Their research demonstrated that powerful maximum flow algorithm can be developed using borrowed or new techniques, thus departing from finding maximum flow using augmenting path and residual path

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