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An Efficient Greedy Minimum Spanning Tree Algorithm Based on Vertex Associative Cycle Detection Method

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Abstract

The minimal spanning tree problem is a popular problem of discrete optimization. Numerous algorithms have been developed using the traditional approach but with the emergence of modern-day complex data structures, new algorithms have been proposed which are more complex yet asymptotically efficient. In this paper we present a cycle detection based greedy algorithm, to obtain a minimal spanning tree of a given input weighted undirected graph. The algorithm operates on the idea that every connected graph without any cycle is a tree. At successive iterations, the algorithm selects and tests if the highest degree vertex is a member of any cycle to remove the most expensive edge from the cycle associated with it. The iteration continues until all the cycles are eliminated to obtain the resultant minimal spanning tree. The simplicity of the algorithm makes it easier to understand and implement in any high-level languages. The proposed approach will be beneficial in analyzing certain class of problems in science and engineering.

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Keyword: Discrete Optimization; Minimal Spanning Tree; Greedy Algorithm; Cycle Detection; Graph Algorithm.

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1. Introduction

The minimal spanning tree problem (MSTP) is a notable problem of combinatorial optimization. It deals with the problem of obtaining a tree of minimum weight that spans all the vertices of a weighted, undirected and connected graph, where the weight of the tree corresponds to the sum of weights of its edges. It is widely applied in various fields of science and technology ranging from computer and communication networks, knowledge engineering, wiring connections, VLSI circuits design to a large class of optimization problems. Recent approaches in analyzing various biomedical problems like medical imaging, bio-terrorism, etc have made an extensive use of the concepts of minimal spanning tree (MST). In fact recent advances in clustering algorithms also deploy the concepts of MST.

Numerous systematized solution techniques exist for solving the MSTP. One of the first known solutions was given by Boruvka [11] in 1930. Two most popular MST algorithms are due to Kruskal [12] and Prim [13]. These three algorithms are often referred to as the classical algorithms for solving the MSTP.

The rich history of the MSTP is also well documented. Pierce [1] analyzed the details of all the classical algorithms related to the minimal spanning tree problem. Maffioli's [2] survey stressed on the asymptotical complexity of the methods used to solve different types of optimum undirected tree problem. The survey by Graham and Hell [3] gives an insight to the algorithmic technique for solving the minimal spanning tree problem, even tracing their independent sources/origin.

Researchers in recent past have focused on devising computationally faster algorithms. With the emergence of modern data structures and improved hardware support, efficient implementation techniques were also invented aiming to speed up these classical algorithms. In 1984, Haymond, Jarvis and Shier [5] elaborated various computational methods for MST algorithms. Non-greedy approaches for MSTP were also proposed [6]. A detailed survey of different computational experiments is also available [7]. Finally the first linear expected-time randomized, recursive algorithm for the MSTP was proposed by Karger [4] suitable for computational models of restricted random access type.

With the advent of parallel computing, different authors began to focus on parallelizing the so called classical algorithms. In 2014 Lončar [18] proposed a technique to parallelize the classical MST algorithms using distributed memory architecture. Osipov [19] presented the Filter-Kruskal algorithm that avoids sorting of edges that are obviously not in the MST. It also provided an equivalent parallelization best fitted for modern multi-core machines. Bader [20] gave several parallel minimal spanning tree algorithms (three variations of Boruvka and a new version) that can be easily implemented on irregular-structured graphs.

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In the next two sections, we present the problem definition and the general solution techniques. In section 4, we describe our proposed algorithm that can efficiently find the MST. In section 5, we illustrate the working of the proposed algorithm followed by drawing a conclusion in section 6.

2. Problem Definition

A spanning tree of a connected undirected graph G = (V, E), is defined as a tree T consisting of all the vertices of the graph G. If the graph G is disconnected then every connected component will have a spanning tree T_i, where 'i' is the number of connected component, the collection of which forms the spanning forest of