A OnLine Genetic Algorithm for Dynamic Steiner Tree Problem

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1 Introduction

In network, it is necessary to tranmission multiple copies of a message from a source to a set of destination nodes for example at internet. This is called Steiner minimal tree problem(SMT) on graphs. In SMT problem, there is a set of special vertices called Steiner vertices which must be contained by Steiner minimal tree. Dynamic Steiner tree problem is motivated by multipoint routing in communcation networks, where the set of nodes and the set of Steiner vertexes in the connection is change over time. In the dynamic Steiner tree problem, the online algorithm sees a sequence of requests of the form $(u_i v_i, r(u_i, v_i))$ where u_i,v_i are vertices in the underlying network N, which is assumed to be known a priori.

This problem was proposed by M.Imase and B.M.Waxman [1]. They considered the problem as a restricted case of generalized Steiner problem(GSP), where nodes in G are revealed online and goal is to maintain a Steiner tree that contains all of the revealed nodes. They have presented the polynomial time algorithm with worst-case performance within two times optimal of any fixed cost model.

The paper [2] was extended the problem by considering the problem of constructing a d-connected subgraph of the revealed nodes in the monotone model. They showed that the greedy algorithm is the best online algorithm for such problem.

Although the greedy algorithm is the best online algorithm for such problem, But under parallel condition, the genetic algorithm is good algorithm too. In this paper, we propose a online genetic algorithm(OLGA) to solve the dynamic Steiner tree problem. The dynamic Steiner tree problem, which has its basis in the Steiner tree problem on graphs, can be solve as "static" Steiner tree problem if we see add nodes as destination nodes. The difference between an OLGA and standard genetic algorithm is that OLGA is retain the a series of training examples one at a time, but isn't presented with the entire set for training. In order to prove our GA and OLGA is efficient and precise, we use a heuristics algorithm [4] to calculate the dynamic Steiner tree problem as a static Steiner tree problem. and use offline genetic algorithm(GA) and OLGA to calculate the tree's minimal cost. the conclusion is that the OLGA is robust which can be used in in reality.

2 Problem Description

Let G=(V, E) be an undirected and connected graph with a finite set of vertices V and an edge set E. Associated with each graph G is a cost function cost:$E \to \gamma^+$ (positive reals). An instance of DST consists of the graph with a cost function and a sequence of requests $R = \{r_0, r_1, \cdots, r_k\}$ when each r_i is a pair (v_i, ρ_i) or (e_i, ρ_i), when $v_i \in V$, $\rho_i \in \{add, remove\}$ when $e_i \in E$,ρ_i is the change edge weight opteration. Request r_i be viewed as a call of the form add(v_i) or remove(v_i). or call of the form change weight change(e_i).

The set S_i, called the terminal set at step i, is simply the collection of nodes which are to be connected weith a Steiner tree after request r_i.

The objective of DST is to find a minumum cost tree connecting each terminal set S_i without knowledge of request r_j for any $j > i$.

3 The Genetic Algorithm for DST problem

Facing the DST problem, we base on the following components to construct the GA. First, how to coding the graph to be representated by individuatls. Second, select the adapted fitness function. Next, design of the genetic operators. Final, how to probabilities controlling the genetic operators. In this section, we propose our GA for solving DST problem.

Next, we will introduced offline GA and OLGA in detailed.

3.1 offline GA

The dynamic Steiner tree problem, which has its basis in the Steiner tree problem on graphs, can be solve as "static" Steiner tree problem if we see added nodes as destination nodes. We developed the offline GA as following:

Coding undirected connected graph In the follwing, binary strings of length $|V|$ are employed to represent a graph into genes. When the node is destination node, it alway is one. When the node is nondestination node, it can be change into zero or one.

Evaluation When nondestination of gene of individual is one which means that this node is selected as one node at graph. The fitness value of different cost functions is assigned to the cost of the graph's Steiner minimal tree. We use Prim algorithm to calculate the cost of the graph's Steiner minimal tree. The individual fitness value is the average vaule of different cost functions's fitness value.

Selection This part is similar as in paper [5].

Mutation There are two kinds of Mutations in our algorithm the chang mutaion and exchang mutation.

The result of the DST problem The result of the DST problem is top of individual in the last generation.

3.2 Online genetic algorithm

Online GA's initialization generation use the last instance's last generation's individual as the first generation. But the instance include the change edge weight, so it is necessary to evaluatethe first generation again. The other is small as standard genetic algorithm.

4 Experimental

In this section, we introduce the experimental method and results that in order to prove that the GAs-based method is effective.

4.1 Method of Simulation

In order to prove our method is effective, we first has been tested on the B-problem set from Beasley with offline GA and online GA.

5 The Results of Simulation and Conclusion

The table 1 is the result of the second simulation test. $|V_{max}|$,$|E_{max}|$, and $|S_{max}|$ represent the maximal number of graphs's vertices, edges and destination nodes respectively. Fast is expressed fast algorithm which was proposed by paper [4]. We use comparison method as paper [3]. If we treat the offline GA's optimal cost as the optimal cost, there are expressed the average solution-qulity criterion of dynamic Steiner tree. The difference between an OLGA and standard genetic algorithm is that OLGA is retain the a series of training examples one at a time, but isn't presented with the entire set for training. Just because this, we can adapt online GA into dynamic Steiner tree problem. From the experimental results, we can say that ours GA is robust and can obtain optimal solution of a given problem and it is can be used enough to real application.

Problem *No.*	$\|V_{max}\|$	$\|S_{max}\|$	fast (% dev)	GA_{online} (% dev)	$GA_{offline}$ (% dev)
1	50	9	0	0	0
2	50	13	3.61	0	0
3	50	25	0.16	0	0
4	50	9	1.54	-0.02	0
5	50	13	2.81	0	0
6	50	25	2.63	0	0
7	75	13	0.25	0	0
8	75	19	4.10	0	0
9	75	38	0	0	0
10	75	13	1.62	0	0
11	75	19	1.55	0	0
12	75	38	0.74	0	0
13	100	17	0.77	0	0
14	100	25	2.14	0.03	0
15	100	50	1.14	0.04	0
16	100	17	2.55	0.02	0
17	100	25	3.25	-0.02	0
18	100	50	0.06	0	0

Table 1:Comparison of online GA and offline GA with fast Algorithm

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