A Novel Path Planning to Provide Real-Time Backup Paths for Vehicle Navigation Systems

Shih-Lin Wu, Department of Computer Science and Information Engineering, Chang Gung University, Taoyuan, Taiwan

Jhe-yu Jhou, Department of Computer Science and Information Engineering, Chang Gung University, Taoyuan, Taiwan

Yi-Chun Lin, Department of Computer Science and Information Engineering, Chang Gung University, Taoyuan, Taiwan

ABSTRACT
The rapid progress of wireless technologies has made the information of real-time traffic available to vehicles. In this paper, the authors propose a dynamic path planning algorithm for vehicle navigation system which can adapt to changeable traffic and replan a better path with good travelling time for drivers within a reasonable computation time for large-scale road networks. Based on the hierarchical model of road networks, we use source-directed A* to save the path planning time, to create a good travelling time path, and to construct a backup path tree. When a traffic condition of a link in the driving path becomes worse, the replanning of a new partial path for a certain part of the backup path tree reflected by the link is calculated. The system has been tested on Taiwan road network. Through experiment results, the system presents a good efficiency for planning/replanning a path in terms of planning time and travelling time.

Keywords: Dynamic Path Planning, Road Networks, Vehicle Navigation, Vehicular Ad-Hoc Networks, Wireless Ad Hoc Sensor Networks

1. INTRODUCTION
Thanks to the advancement of Global Positioning System (GPS) and Geographic Information System (GIS) technology, Vehicle Navigation System (VNS) becomes one of the most popular applications in our daily life. The key technology in VNS is the path planning performed on large-scale road networks. There are two models used in the system. One is the static model where the travelling time of every road link fixes and the other is the dynamic model where the travelling time of every road link changes over time. Most of known path planning algorithms are efficient in static environment but cannot work well in dynamic environment (Delling, Sanders, Schultes, & Wangner, 2009). In real road networks, the DOI: 10.4018/jghpc.2013070103
static path planning may guide vehicles to roads just incurred by traffic jam because the system cannot catch the real-time traffic condition of roads. Lee (1994) suggests that the static VNS may incur a hunting phenomenon (path overload) because the guidance to some main roads with the high prevalence of navigated vehicles. Recently, the rapid progress of wireless technologies has made the information of real-time traffic available to vehicles. The great progress motivates a new research direction on the development of dynamic path planning algorithms to avoid hunting phenomenon by using real-time traffic information.

In this paper, we propose a dynamic path planning algorithm for vehicle navigation system, which can adapt to changeable traffic and replan a better path with a good travelling time for drivers within a reasonable path planning time for large-scale road networks. Based on the hierarchical model of road networks, we mainly use source-directed A* to create a driving path and a backup path tree by considering the geographical position of destination and the current travelling time of road links. Whenever a traffic condition of a link in the driving path becomes worse, the replanning of a new partial path from a certain part of the tree reflected by the link is performed. Thus, our algorithm can always navigate vehicles to the better path with a good travelling time by avoiding traffic jam roads. As a result, the condition of traffic jam roads can be further alleviated. In a word, our algorithm has two main contributions. Firstly, the algorithm provides the tradeoff between the computation time and the travelling time. Secondly, the replanning is efficient because the process only focuses on a certain changing part of the tree instead of recomputing from the scratch. The system has been implemented and tested on Taiwan road network. Through testing results, we demonstrate that the system presents a good efficiency for planning/replanning a path in terms of planning time and travelling time.

The rest of this paper is organized as follows. Section 2 related works are introduced. Section 3 presents our dynamic path planning. Performance results are given in Section 4. Conclusions are drawn in Section 5.

2. MOTIVATION AND PROBLEM DEFINITION

A good design of vehicle navigation systems should use the real-time traffic to avoid traffic jam. The advancement of wireless technologies has made the information of real-time traffic available to vehicles. VNS can receive real-time traffic information by means of wireless sensor networks (WSN) (Yick, Mukherjee, & Ghosal, 2008), vehicle ad hoc networks (VANET) (Hartenstein & Laberteaux, 2008), and radio data system - traffic massage channel (RDS-TMC). Below, we give the brief review of related works. The detailed survey of literature can be found in reference (Delling, Sanders, Schultes, & Wangner, 2009; Fu, Sun, & Rilett, 2006).

Dijkstra (1959) is one of the most important algorithms for solving the single-source shortest path problem on a graph with nonnegative link costs. From an initial tree containing the source node only, the algorithm finds a neighbor node with the shortest cost to the source node and adds the neighbor to the tree. The process will repeat until the destination node is reached and then the tree, i.e. the shortest path tree, is outputted. The computation time of Dijkstra is too long because many unnecessary neighbor nodes are visited and the shortest tree sprawls on all directions. To accelerate the process time, the algorithm A* (Hart, Nilsson, & Raphael, 1968) is proposed. The main idea of A* is that the shortest path should be constructed toward the direction of the destination nodes. To implement this idea, a heuristic function is added to evaluate the distance from the current visit node to the destination node. The reference (Hart, Nilsson, & Raphael, 1968) proves that A* can find the shortest path if an admissible condition is satisfied. Figure 1 shows the difference search space between Dijkstra and A*.

Shortest path algorithms cannot work well as the network size grows larger because of the scalability problem on links and nodes.
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