Computers and Electrical Engineering 54 (2016) 53–67

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Anytime route planning with constrained devices

Marcus de L. Braga [a,c,*], Alyson de J. dos Santos [a,c], Aloysio C.P. Pedroza [a], Luís Henrique M.K. Costa [a], Marcelo Dias de Amorim [b], Yacine Ghamri-Doudane [c]

[a] *Universidade Federal do Rio de Janeiro, PEE/COPPE/GTA, Rio de Janeiro, Brazil*
[b] *LIP6/CNRS – UPMC Sorbonne Universités, Paris, France*
[c] *Université de La Rochelle, L3i, La Rochelle, France*

ARTICLE INFO

Article history:
Received 19 November 2015
Revised 15 July 2016
Accepted 18 July 2016
Available online 10 August 2016

Keywords:
Route planning
ARA*
Vehicular networks
Anytime algorithms

ABSTRACT

Urban mobility became a major challenge around the world, with frequent congestion and ever growing travel time. Albeit recent advances in the area of Intelligent Transportation Systems (ITS), it is still difficult to predict and manage the road infrastructure due to dynamics and instability of the traffic. One key issue is how, given some traffic monitoring information, a vehicle decides to dynamically change its route. In this paper, we analyze algorithms of the anytime class to make the route planning considering GPS traces of buses in Rio de Janeiro, as a measurement of traffic flows. Anytime algorithms inform, in a timely fashion, a sub-optimal response and progressively improves it as time goes by. We evaluate time and memory consumption, route length, arrival time, average velocity, distance traveled, and pathways on an experimental platform composed of Raspberry Pi nodes. For different time windows, the results show that ARA∗ allows finding alternative routes that, if used, help reduce traffic congestion.

1. Introduction

Urban mobility is a major challenge for managers of metropolises worldwide, significantly impaired by the constant traffic jams that cause economic, social, and environmental impacts. From the physical point of view, road traffic is an unbalanced system of particles (vehicles) that interact and influence each other, leading to instability caused by floating state valuations of these particles when they exceed a critical value [1]. Mechanical or electrical faults, works on roads, and abrupt lane changes are some factors that contribute to the imbalance of the road system. Driver and pedestrians, with their unpredictable behaviors, are susceptible to fatigue, distraction, and substances that cause the decrease of attention and reflexes. These variables are inherent to the system and cannot be ignored [2–4].

The extension of the road network and traffic interventions are widely used for increasing the efficiency of the flow of vehicles. However, such measures are time-limited, being efficient only until the next growth in demand [5]. The Traffic info and recommended itinerary, vehicle signage (electronic board) and, limited access warning are ITS applications that assist traffic management [6]. These initiatives have multiple goals, such as minimizing delays perceived by vehicle drivers, and improving the control and management of the road network reducing environmental impacts (e.g., air pollution).

* Corresponding author. Fax: +552139388628.
E-mail addresses: marcus@gta.ufrj.br (M. de L. Braga), alyson@gta.ufrj.br (A. de J. dos Santos), aloysio@gta.ufrj.br (A. C.P. Pedroza), luish@gta.ufrj.br (L.H. M.K. Costa), marcelo.amorim@lip6.fr (M. Dias de Amorim), yacine.ghamri@univ-lr.fr (Y. Ghamri-Doudane).

http://dx.doi.org/10.1016/j.compeleceng.2016.07.011

The use of alternative routes is a solution adopted by many drivers to escape traffic jams. However, this solution has no guarantee of success, if there is no information about current conditions of the chosen route. It is clear that despite the technology employed in traffic monitoring systems, there are no self-management techniques capable of acting in unexpected situations and providing proactive traffic management [7].

To help drivers find appropriate alternative routes, we propose to rely on advanced route planning techniques. Route planning consists in finding the shortest path based on the states of the edges with associated costs. The path is optimal if the sum of weights in the edges is minimal in all possible paths from the initial vertex to the goal vertex [8]. Path planning is also important in the mobile robotics area (for navigation and arm movement) and is a support system to decision making in autonomous vehicles, where the localization methods are based on GPS or DGPS[1] [9,10]. This work investigates the use of the search algorithm Anytime Repairing A* (ARA*) for route planning in a real road network, using a Raspberry Pi prototype as a proof of concept of the execution in resource-constrained devices.

We consider the definition of a resource-constrained device as devices with limited CPU, memory, and energy capability. Those devices range from embedded sensing systems such as the Arduino to expensive smartphones, where the limitation is not the CPU, but energy starvation still is. Therefore, the motivation for investigating route planning in resource-constrained devices is twofold. First, for almost every mobile device energy is an issue and saving CPU clocks preserves energy. Second, one may argue that offloading the program execution to the cloud is an alternative solution to reducing the program execution complexity. The problem is, even if computation offloading is an elegant solution, it is not always feasible. First, certain tasks can be offloaded to the cloud, others not, such as tasks which depend on reading variables that are local to the device, such as a sensor or the GPS. Those are not available in the remote system in the cloud. Second, the device can find itself in an area without Internet access. In that case offloading to the cloud is not possible.

We have implemented anytime ARA* algorithm and a proposed and implemented a code-optimized version of ARA*, therefore decreasing the execution time. We use the implementation of classical search algorithms, A* and Dijkstra, in order to perform a comparative study among them.

In this paper, we make a comparative study of algorithms to choose the short path, given the points of source and destination selected randomly. We simulate real traffic of vehicles, using real GPS data of public transportation buses and the Rio de Janeiro city map. The Raspberry Pi platform was used in the tests and the short path is found in terms of distance and travel time. On the other hand, runtime and the memory consumed were measured, as well the quantities of nodes composing the paths found, the distance traveled, the average velocity, the arrival time and pathway's frequency used by algorithms. In summary, our main contributions in this work are:

- We need, besides short paths, also efficient alternative routes. We analyze alternative routes generated from robotic algorithm (ARA*), using real road map and traffic flow from a Brazilian metropolis, Rio de Janeiro.
- We propose the use of path planning algorithms in a constrained device.
- We propose an improvement in ARA* implementation, where the gain computation on average was 3% in the results.
- We describe and evaluate the algorithms, in relation to distance and travel time, using three performance metrics in the three time windows: a) from the algorithm; b) from the routes; and c) from the graph.

Nowadays, the Rio de Janeiro city has third worst traffic of 146 cities in the world, with 51% in the congestion level [11]. Rio de Janeiro city has recently hosted major events such as Soccer World Cup (2014), Rock in Rio festival (2015), as well as the Olympics (2016), suffering with many work sites and traffic jams. Thus, it was the chosen the scenario for testing the route planning algorithms. Raspberry Pi was the computing platform chosen for tests, due to its portability and limited CPU resources. We used two metrics to find the short path: distance and travel time. The execution time and memory consumption, the number in the path, the distance traveled, the average velocity, the travel time are evaluated in the results.

This paper is organized as follows. Section 2 presents related work. Section 3 presents the ARA* algorithm and proposes an optimization called ITS-ARA*. Section 4 describes the experiments, results and analyses with a real implementation on a resource-constrained device. Section 5 concludes the paper and discusses future work directions.

2. Finding paths: shortest and near-shortest approaches

A major problem in graph theory is the shortest-path problem, i.e., how to find the shortest route, if any, between two nodes of a graph. Formally speaking, a graph is a pair $G = (V, E)$, where V is a non-empty set of nodes and E a set of edges. Although the shortest-path problem is generally studied in static structures, many problems involving graphs are dynamic by nature. The vehicular scenarios that we consider in this paper are typical examples of dynamic graphs; thus, algorithms such as Dijkstra, Bellman-Ford, and Breadth-first, which were conceived for static topologies, do not work well.

In Faez and Khanjary [6] Dijkstra's algorithm is used to find the shortest path based on traffic conditions collected by Wireless Sensor Networks (WSN) and ITS (optical, inductive, magnetic and video cameras). The optimized routes are simply sent to vehicles by messages in the basic mode. In advanced mode, vehicles are with transponders to provide direct and interactive communication.

[1] The Differential Global Positioning System has an accuracy of 10 cm.