Toward a Smart Mobility System: Integrating Electric Vehicles Within Smart Cities

[Extended Abstract]

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ABSTRACT

Within the context of Smart Cities, Smart mobility aims at reducing road traffic, carbon emissions and total travel times of transportation tools. In this paper, we propose to investigate the capabilities of electric cars within the context of Smart Cities. We propose to reduce polluting gas emissions from road traffic in modern cities by integrating electric cars with other existent public transportation tools. Next, we focus on the related operational level of decision by studying a specific optimization problem which aims at reducing the total energy consumption of the proposed Smart mobility system. An iterated local search algorithm is proposed as a solution approach. The efficiency of our proposed Smart mobility option as well as our algorithmic approach is studied in a realistic Smart City context and is proven to yield good results.

CCS CONCEPTS

•Applied computing → Transportation; •Theory of computation → *Theory of randomized search heuristics;*

KEYWORDS

Smart city; Smart mobility; car-sharing; Electric car; iterated local search

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1 INTRODUCTION

Efficient transportation of goods and freight in urban areas represents an important aspect for economic and social activities happening in urban areas. For people living in urban areas, transporting goods supplies malls, stores, deliver merchandize at home, etc. For companies efficient goods transportation represents a vital link between its suppliers and its customers. That is why moving goods in urban areas is one of the most important features in urban life. All of these features have resulted on the increase in the concern and awareness of environmental issues as well as an urgent need to rethink how urban areas should be built and constructed. Consequently, these interlinked issues has resulted in the development of a new concept: Smart Cities.

In this paper and within the concept of Smart City, we focused in the relation between the reduction of carbon emissions in urban areas (Smart Environment), road traffic and travel time (Smart mobility) in order to improve the quality of life of urban areas inhabitant(Smart Living).

In our research, we focused on proposing an effective urban mobility option which will be capable of reducing total travel time as well as carbon emissions and energy consumption in urban areas. We are doing so by suggesting a new intermodal intelligent transportation option for urban areas. More specifically, we are proposing a systematic view of using electric car-sharing systems.

First, we propose a conceptual Smart mobility context where electric vehicle systems are implemented as a part of whole global integrated urban transportation system. We are doing so by proposing to integrate electric vehicle systems with bigger transportation systems such as train, subway, and so on. We are also proposing to use electric vehicle systems not only to move people but also small parcels of goods in urban areas. Second, the capabilities of such a solution is asserted by formulating a routing optimization problem related to our proposal. The studied optimization problem aims at reducing the total energy consumption of our smart mobility solution by satisfying a set of known transportation demand. Next, we propose an effective iterated local search (ILS) to solve the proposed optimization problem. Finally, we investigate the feasibility of our proposal by estimating its efficiency in term of energy consumption and transportation capabilities based on benchmarks from the literature as well as a realistic smart city context based on the Masdar City case in the United Arab Emirates.

The remainder of this paper is organized as follows. Section 2 presents the optimization problem related to our context. Section 3 details our solution approach. Section 4 present our computational results. Finally, future work and conclusions are exposed in Section 5.

2 THE PROPOSED ROUTING PROBLEM

The proposed routing problem could be defined as follow. Let us supposed to have a set of customers with known demand that need to be served using a set of homogeneous set of electric vehicles. Initially all the vehicles are located at the depot location. The depot location as well as customer locations are considered as recharging stations. Consequently, the electric vehicles could recharge their

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batteries in one of these locations. One should note that the vehicles charge their batteries at the customer location only if its current charge level is bellow a critical predefined value. The total recharging time depends closely on the current electric charge level of the vehicle. We should note that a penalty could occurs if a vehicle breaks the time window of the customer while charging its battery.

The objective is to find the set of least cost roads starting and ending at the depot while serving each customer once subject to time windows and capacity constraints.

Our problem definition is based on the following assumption: Let us define $G = \{N, A\}$. N is the set of nodes representing the customers, the charging stations as well as the depot node. $N = \{s \cup C \cup R \cup t\}$. C represents the set of customers. R represents the set of recharging station. s and t are two dummy nodes representing the depot. A represents the set of edges. $A = (i, j)||i, j \in N; i \neq j$. Each arc (i, j) has a related travel time t_{ij} travel distance d_{ij} and a related energy consumption e_{ij}. The set of vehicle is initially located at the depot location. Each vehicle has a battery capacity β and leaves the depot while being fully charged. Each customer i to be served in a predefined urban area has an associated demand q_i and a service time s_i

Based on this graph, we could note that our problem could be assimilated to the Electric Vehicle Routing Problem (EVRP), which is proven to be NP-hard [2].

3 SOLUTION APPROACH:ITERATIVE VARIABLE NEIGHBORHOOD LOCAL SEARCH

Iterative Local Search (ILS) is a local search procedure that uses iterations and perturbation to escape from local optima. This method use iteratively local search technique but it start each time from local optima This algorithm starts with an initial solution.It applies a perturbation technique to get an intermediate solution and then it applies a local search technique. An acceptance test is used. If the new solution passes this test then it will be the next starting solution otherwise the algorithm will start from the previous solution. This process is repeated for a relative number of iteration. Our proposed ILS is presented in Algorithm 1. The solutions are represented by a permutation of customers demand. The evaluation function is based on the Split function proposed by Prins for the vehicle routing problem [5]. We should note that C represents the evaluation function in our algorithm. The Perturbation operator is base on the double bridge operator from the literature [4].

Algorithm 1 ILS Algorithm()

$X_0 \longleftarrow$ Initialize-individual
$X^* \longleftarrow LocalSearch(X_0)$
while Not reach termination criterion **do**
  $X^{'} \longleftarrow Perturbation(X^*)$
  $X^{''} \longleftarrow Improve - Procedure1(X^{'})$
  $\Delta = C(X^{''}) - C(X^*)$
  if $\Delta \leq 0$ **then**
    $X^* \longleftarrow X^{''}$
  end if
end while
$X_{best} \longleftarrow X^*$

4 COMPUTATIONAL RESULTS

In this section, we present the results of applying the ILS algorithm to a set of instances from the literature related to a problem of routing electric vehicles in urban context[1]. The experiments described in this paper consider classes of electric vehicles problem that are parameterized by the number of travels. This number varies from 10 to 400 travels. We used a set of 1320 instances [1].

To evaluate the ILS algorithm, we use the GAP metric, which is defined as follows:

$$GAP = (\frac{(SOL_{heuristic} - LB)}{LB}) * 100,$$

where the lower bound(LB) is taken as the linear relaxation of the mathematical formulation of Kara [3] and $BestSOL^*$ represent the best solution found between our algorithm and the result of CPLEX.

The ILS algorithm finds the near optimal solution for the different-sized problems. The results indicate that our simple ILS algorithm can be considered as a very competitive approach. In fact, for the different problems, the average deviation from a lower bound is relatively as high as 4.328%, and for overall the average deviation is 1.497%.

5 CONCLUSIONS

This paper proposed to present an innovative application to artificial intelligence in the field of smart mobility and transportation. For this purpose, a new integrated application area of artificial intelligence is introduced. In fact, it were proposed to use electric vehicle jointly with mass transit tools in order to deliver parcel of goods in dense urban areas within the context of smart cities. Based on this context, this paper proposes to use artificial intelligence tools in order to optimize the proposed smart mobility context. More specifically, the present paper presents the integration of an ILS algorithm to provide a powerful tool for solving vehicle routing problem related to electric vehicles. The proposed ILS is designed in such a way to diversify its search by the integration of multiple neighborhood operators to reach good zones in the search space.

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