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WINDY RURAL COLLABORATIVE POSTMEN PROBLEM USING ROS AS MULTI-AGENT SYSTEM ARCHITECTURE

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Abstract: In the last decades the urban areas have grown and as a result the transportation has become an important problem. We are exploring a potential solution for the last mile delivery problem in urban areas in a similar way that internet solves the delivery of information problem.

Keywords: Last Mile Problem; Multi-Agent System; ROS; Graph Theory; Routing Tables; Postman Problem.

1 Introduction

In the last decades, the number of people living in urban areas has grown dramatically throughout the world and this trend continues to grow. According to data from The World Bank, in 1960, 61% of people in the European Union lived in urban areas and in 2015 this number increased to 75%. In Spain, where industrialization has taken place later than in other countries, this increase is even more pronounced, from 57% to 80%.

The increase in urban population has led to a drastic rise in transportation necessities [1-15]. As a result, traffic and environmental problems (CO_2 emissions, air pollution, noise, etc.) have increased, and such problems have a direct impact on the quality of life in cities. Among the main challenges that big cities face nowadays is that of managing the mobility of both people and goods.

The «classic» way of dealing with these problems has been the encouragement of public transport and placement of restrictions on the use of private vehicles. Although these measures have helped to ease these problems, traffic and pollution due to transport, continue to persist. There are several reasons for which these measures have not provided real solutions to traffic and pollution. On the one hand, modern life requires us to get to places «anytime» and «anywhere» [16-24]. The ability to travel to any place at any time has become a basic necessity and traditional public transport systems have some limitations in this regard. Perhaps, this is the reason for which private vehicles have become the main means of urban transport in many countries in Europe and North America, while public transport finds it increasingly difficult to attract and retain passengers [25-31]. On the other hand, the emergence of e-businesses has triggered a change in the habits of consumers: globalized purchasing services provided by technological platforms allow consumers to acquire goods and services from both, the local and international markets and the public and private spheres. This change entails increased freight transport and the need for new freight transport methods, since this aspect affects urban mobility and in which traditional public transport systems are not very helpful.

The way citizens demand services, as well as the way services are established, offered and executed has changed with the evolving environment. Technological advances have contributed to this change, especially the increase in connectivity, between both «things» and people. Along with an increase in connectivity, areas such as the Internet of Things, Cloud Computing or Artificial Intelligence facilitate new ways of offering, distributing and regulating existing services or generating new services, also in the field of urban mobility [32-40].

This article aims to define and develop the ICT services that will facilitate the transition to a more sustainable and individual-centered mobility model. Such a model will reduce the global costs related to mobility but will satisfy the transportation needs of today's society. The term cost here is rather general. It refers to the energy costs, the costs of the infrastructure (streets, parking spaces, etc.), the «environmental costs», the cost derived from occupying or using public space, etc. In our opinion, in order to achieve more sustainable mobility, the system should be based on I) an efficient coordination of shared infrastructure resources II) prioritization of the use of transportation infrastructure resources to favor and thereby encourage the use of more sustainable means of transport III) collaborative transport solutions [41-49], based on transport sharing or perform several transportation tasks on a single trip. A proposal for an integrated solution will be developed, as well as techniques, methods and tools to proceed in this direction.

This article main approach is to solve the last mile delivery problem in a cooperative environment. The last mile delivery problem is a problem known in math and graph theory as the rural postman problem (which is a variation of the classic postman problem where the postman just needs to travel certain places, not everyplace). The rural postman problem is about finding the optimal route inside a graph to pass by every connection inside the graph [50-59]. However if we consider the fact that the delivery will be affected by traffic and that traffic asymmetrically affects routs (A route may have lots of traffic in a direction but few in the opposite direction) and the fact that streets may or may not be bidirectional, we are dealing with the «windy» version of the problem. In summary the last mile delivery problem may also be referred in the academia as the «windy rural postman problem». In this particular case, it is intended to solve the problem where collaboration may exist among several postmen. It is also important to note that the postmen problem and every other variant here described are NP-problems, so the approach is going to be mainly in reduce the complexity of the problem as much as possible to get efficient results (not necessarily optimum) in affordable time [60-67].

Since this thesis work started two months ago, everything mentioned here are non-proven ideas, conjectures and results can not be provided.

2 Proposal

The proposal presented is propound the graph as a multi-agent system where each node of the graph is an individual agent that communicates with the adjacent nodes and uses Routing tables in a similar manner as internet routers (which are designed to manage graphs with 4,294,967,296 nodes which are graphs bigger than any city graph).

The routing tables algorithm is about each node has a list of the nodes that it can reach, the edge that must be taken to reach that node, the associated cost. when a node gets connected with another node (or the connection information change), this nodes exchange information of their routing tables and update the information (if necessary) and the new information. The routing tables algorithm has advantages and disadvantages that will be exposed below [68-71].

The fist advantage is that since each node only depends on the node it is communicating with the algorithm may run in parallel (even if two nodes are connected, if this are not communicating, the execution is independent). This allow to consider cluster systems to accelerate the computing process in certain cases.

In contrast, a disadvantage of this algorithm may not be run in GPU technology since each node needs to execute different parts of the algorithm at the same time.

Another disadvantage of this algorithm is that the system initialization may be computationally expensive. This disadvantage only suppose a problem in the first initialization since once the initialization is done the configuration may be saved in disc.

The main advantage of this algorithm in this particular problem is that once each node have knowledge of the best route to the other nodes, you may just ask any node about how to reach another node and get the optimal direction in an instant time (technically is in a logarithm time since the search inside a table is logarithmic at best).

Once the graph is initialized with this system the next proposed step is to make an agent to represent each postman (In the multi-agent system) and assume the postmen are not collaborating so each postman should form the best route [72-80].

To generate the best route each postman will list all the nodes that it should attend and will ask every node in that list about how much does it cost to go to the other nodes in the list and from there the postman will generate a reduced graph in which the postman should travel every node transforming this problem into the Hamiltonian Traveling Salesman Problem (TSP). The TSP is also a NP-Problem

This problem conversion can be seen in the figure \ref{graph} where we have a 10 city with 10 nodes where we need to deliver packages to the nodes 1, 7, 9 and 10 so the graph get transformed into a graph with just 4 nodes. In this example the reduction may seems small, but in real examples a city may have ~ 5,000 nodes and a very busy postman may have ~100 packages so the reduction is quite significant [81].

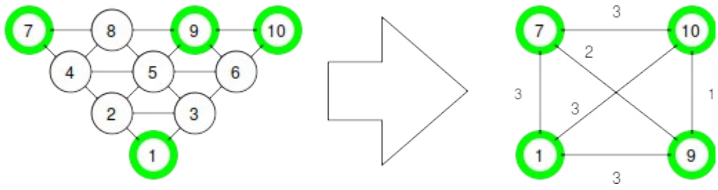

Figure 2. Transformation from Postman problem to Traveller problem.

The way to solve this problem is still to be analyzed since we may find a way to merge the graphs of each traveller in order to make a collaborative solution or to solve each graph in an independent way and then try to merge each path to generate a collaborative solution.

The way to implement this will be using the ROS framework. Robot Operating System (ROS) is a development framework (not an operating system despite the name) made to communicate multiple process developed to make reusable software independent of programming language. ROS currently fully supports C++ and python and have as a main advantage that makes the communication transparent to the network so once a development is working in a computer, migrate the multi-agent system to a cluster where the process run in different computers should be trivial. Furthermore, given the fact that the delivery task is gradually becoming a robot driven task, ROS also represents an advantage since ROS Have become the standard of development in the robotic development field.

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