A K-Means Matheuristic Solution Approach for the Hub Location and Routing problem

Kassem Danach[1, 2], Rahimeh N. Monemi[3, 4]

[1] Department of Management Information System, Islamic University of Lebanon, Beirut, Lebanon
[2] Laboratoire de Génie Informatique et d'automatique de l'Artois (LGI2A), Université d'Artois, F-62400 Béthune, France
Kassem.danach@univ-artois.fr
[3] CRIStAL - Centre de Recherche en Informatique, Signal et Automatique de Lille - UMR 9189, Lille - 59491, France
Rahimeh.monemi@univ-lille.fr
[4] IT and Business Analytics Ltd, 20-22 Wenlock Road, London, England

Keywords: *Machine-learning, matheuristic, hyperheuristic, hub location, K-means.*

Abstract

The hub-and-spoke structures are present in almost all modes of transport (cross-docks in national level, major airports and container ports in continental and inter-continental level). The main motivation for deploying such a flow network structures is in exploiting economies of scale (in terms of time and/or cost) in transporting higher volumes on much more efficient corridors (connected hubs). In this paper, we work on a known problem in the literature, which considers a single allocation model, while there exist capacity constraint in terms of number of spokes per route, as well as a fixed number of hubs in every feasible solution. In order to solve this problem, we propose a combination of a K-means machine-learning method with a matheuristic approach. In solving the proposed problem, whether the mathematical programming techniques are in charge of solving the problem (and (meta)heuristics are to exploit the primal/dual information to generate better primal bounds); or mathematical programming techniques are employed within (meta)heuristics to solve the sub-problem after some variable being fixed (for example a capacitated flow problem, or a linear part of an initially non-linear model where part of variables are fixed by the (meta)heuristic); in any of the two cases, we are talking about the matheuristics. The role of K-means was in the construction of the solution from the scratch, than a partial solution was offered by a hyperheuristic (HH) followed by a matheuristic.

Problem Statement

The problem studied in (Rodríguez-Martín, & Salazar-Go, 2014), is described as following:

A set of nodes N is given and p hub nodes are to be selected, D_{ij} represents the demand to be transferred from i to j. The capacity is considered as a maximum number q of spoke nosdes that can be allocated to a hub. The cost of travel between avery two nodes i and j, defined as t_{ij} which represents, in this study, “the time” needed to travel between nodes i and j. A hub edge is defined as the edge connecting two hub nodes and s factor of economies of scale, α, is defined as the factor of travel time efficiency over hub edges. Moreover, β represents the factor of changing the relative weight of the cycle edges' costs in the objective function. The objective is to construct a fully connected graph representing the hub network level containing p nodes, and one or more (maximum p) feeder networks each of which allocated to a hub node, constructing local routs, where these local routes are considered as undirected cycles. The objective function of our problem consists in minimizing the global cost in terms of transportation time. To illustrate more the problem, Figure 1 presents a proportional solution for a problem with 14 nodes within 4hubs.

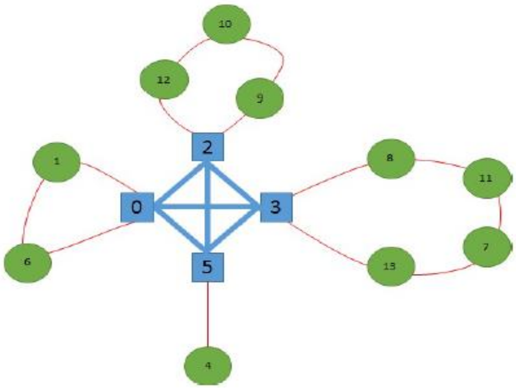

Figure 1: Proportional solution for an instance of 14 nodes within 4 hubs.

Solution Approach

Matheuristic optimization algorithms, proposed by (Bartolini, 2009), are a combination of (meta)heuristic approaches and different techniques of mathematical programming. Whether mathematical programming techniques are in charge of solving the problem at hand and (meta)heuristics exploit the primal/dual information to generate better primal bounds or mathematical programming techniques are employed within (meta)heuristics to solve a sub-problem after some variable being fixed; in bothe cases, we are talking about the matheuristics. Such techniques become very popular as MIP solvers or customized MIP codes have become more effective as primary solvers or as sub-procedures which is due to the advancements that were achieved in the research on mathematical programming, and in particular on discrete optimization. In order to solve this problem, we propose a combination with a K-means machine learning method with a matheuristic approach. K-means was in the construction of the solution from scratch, then a completed solution was offered by a hyperheuristic (HH) approach.From the HH solution we proposed, we only reserve the information about the allocation part of the problem (allocating spokes to hubs) and ignore all the spoke routes information obtained from the HH. Then, we inject all allocation information into the solver, which finds feeders' network, while all constraints related to the number of hubs and allocating spokes to hubs were ignored.

Conclusion

Our numerical results show that the proposed approach is capable of providing high quality solutions in cases where an ideal solution or a solution of known quality is known. In any case, such solutions are obtained in a very short amount of time on the CPU.

References

Rodríguez-Martín, , I., & Salazar-Go, J.-J. (2014). A branch-and-cut algorithm for the hub location and routing problem. *Computers and Operations Research*, 161–174.

Bartolini, E. a. (2009). Algorithms for the non-bifurcated network design problem. *Journal of Heuristics*, 259.