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A model for Mixed Orienteering problem: Case study

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***Abstract*— This papers introduces a new routing problem with profits known as the Mixed orienteering Problem. This problem aim to find an optimal subset that maximizes the total profits collected from the nodes and arcs minus travel costs under the constraint of time of tour. For the resolution of our model we used Cplex to get the results through the programming with Concert Technology.**
***Keywords*— Orienteering Problem, Arc Routing Problem with profit**

I. INTRODUCTION

Over the last decade and with the explosion of the logistics chain, several new problems have emerged in the transport sector. The Standard form is the traveling salesman problem (TSP) it's consists of delivering goods stored in a warehouse to a number of customers (warehouses, factories, factories, localities, etc.) at a lower cost. This distribution will be carried out by one vehicle placed in a warehouse.

In many real applications, there are constraints that force us to choose which customers to visit. The Mixed Orienteering Problem (MOP) models one of such situations. In this problem, each customer has a profit and the tour have a maximum duration T_{max}. So the decision to choose such a customer is tied to his profit and his contribution for the route duration.

Our problem represent a TSP with profits and its came from the hybridization of two problems depending on the position of profit including. The first problem is the orienteering problem (OP) where profit is located in the nodes and the Arc Routing Problem with profits (ARPPs) where it's shown in the links of the graph. It's the Mixed Orienteering Problem (MOP) a new routing problem with profits.

II. LITERATURE REVIEW

Vansteenwegen and al. [1], proposed for the first time the idea of the MOP. But no mathematical model has been formulated and no solutions for its resolution. In tourism MOP can be solved if not all attractions are associated with specific points, but also when walking along a beautiful street or river can be of a touristic interest or attraction.

In the framework of an application of the "Tourist Trip Design Problems: TTDP", Gavalas and al. [2] focused on the model of TTDP as a variant of MOP, where a set of roads can be of a touristic interest, in addition to other points of attractions. Two similar MOP problems were mentioned: the one-period Bus Touring Problem and the Outdoor Activity Tour Suggestion Problem. The first problem (BTP) aims to determine the optimal subset of tourist sites to be visited and scenic routes to be traversed between a start and end point that both coincide which maximizes the total attractiveness of the tour. The Outdoor Activity Tour Suggestion Problem (OATSP) presented by Maervoet et al. [3] which involves to finding a path of maximal attractiveness in a transportation network graph.

Many heuristics have been suggested in literature for solving a graph for a large number of nodes, the first is proposed by Tsiligrides [4] named the stochastic algorithm (S-algorithm) based on addition of Points to the path depending on this desirability and the deterministic heuristic algorithm (D-algorithm) based on dividing the area into sectors and routes are built up within the sector. Then, Golden et al. [5] developed a centre-of-gravity heuristic making use of a Euclidean metric.

A heuristic of four-phase considered by Ramesh and Brown [6] that proceeds as follows. An insertion phase for relaxing the time constraint and a cost, the 2-Opt and 3-Opt used to improve the initial solution and a reduction of the path length is achieved by deleting and inserting one node. The last step, introduce as many nodes as possible. Next approach proposed by Chao et al. [7] named the five-step heuristic, only considers vertices that can be reached. This heuristic clearly outperforms all above mentioned heuristic.

A genetic algorithm is presented by Tasgetiren [8], they results are competitive to the best then Chao's results but the computational time is relatively high.

The latest solution obtained by Schilde et al. [9], they developed a Pareto ant colony optimization algorithm and a multi-objective variable neighborhood search algorithm, both hybridized with path relinking.

The second part of literatures concerning the ARPPs where a demand the profit is allocate for each arc, the objective is visiting a maximum number of profitable arcs that satisfy the constraints of path length or travel time, while maximizing the sum of profits collected. Malandraki and Daskin [10] presented for the first arc routing problem, a benefit is collected each time the arc is served. This benefit decreases as the number of traversals increases.

The Prize-collecting Arc Routing Problems (PARPs) belongs also on the ARPPs, it's studied by Aráoz et al. [11] and solved by Aráoz et al. [12] where only a subset of edges have an associated profit and its collected only once, independently of the number of times the edge is traversed. Li and Tian [13] develop a two level self-adaptative variable neighborhood search algorithm for the prize-collecting vehicle routing problem.

Other related problem under the Clustered Prize-collecting Arc Routing Problem (CPARP) was considered by Aráoz et al. [12] for undirected graphs and by Corberán et al. [14] for the case of windy graphs.

Feillet et al. [15] presented the Profitable Arc Tour Problem (PATP) where the goal is to maximize the difference between the collected profit and the travel costs of a set of cycles constraint of limit length.

We also interest of the differ combination between problems with profits. Benavent et al. [16] presented the Mixed Capacitated arc routing Problems with profits, it's hybridization between ARPPs with a model of fuzzy variables where a feasible solution is a single tour. In fact, the visit of a set of nodes is obligatory but for some others it remains an option while satisfying the constraint of capacity as affirmed by Gouveia et al. [17]. The Profitable mixed capacitated arc routing problem (PMP) introduced by Benavent et al. [18]. This problem obtained by the hybridization of PTP and CARP. A profit is associated with each arc in addition to demand and a service time, we look for the set that maximizes the total profit collected minus the costs. The profit will be available on the arches only once and collected by a single vehicle while complying with the capacity constraint. The tour begins and ends at the depot.

III. DESCRIPTION PROBLEM

The MOP is very interesting in the context of tourism applications, Vansteenwegen et al. [1] mentioned tourism applications. When traveling to a tourist town, tourists aim to visit as many as possible of the pleasant places known as points of interest which constitute specific localities. But not just specific sites representing attractions in sightseeing tours, a stroll along a river or during a beautiful street can also be considered attraction. Profit in this case is considered a satisfaction or a pleasure. Then, Gavalas et al. [2] discusses the interest of adapting the model of MOP in context of tourist trip planning

The objective of the MOP is to maximize total collected profit while associated to nodes and arcs of graph under the constraint of time of the tour. The characteristic of the MOP did not necessary to visited all vertices. We can limit our problem on mainly objective: maximize the collected profits in nodes and arcs for the visited subset.

The subset visited must provide maximum profit constraint of limit time of tour.

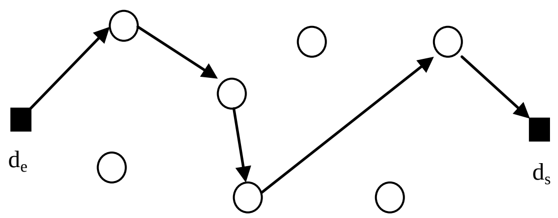

Fig. 1 Illustration of the MOP

Given a directed graph G (V, A) such that $V= C \cup D$ is the set of costumer C and the depot $(D=\{d_e, d_s\})$ where de is the initial depot and ds is the final depot. A be the set of arcs such that: $A = \{(i, j) \backslash\ i \in C \cup \{d_e\}, j \in C \cup \{d_s\}, i \neq j\}$.
Each arc $(i, j) \in A$ has a travel cost c_{ij} and a travel time t_{ij} between node *i* and *j*, it's symmetrically between vertices. Let E be the set of profitable arcs with $\mathbf{E} \subset \mathbf{A}$.

A profit p_{ij} is associated for each profitable arc $(i, j) \in E$ will be visited only once and a service time s_{ij} considered only for the profitable arc. Each point *i*, except for the starting and the finishing point, is associated with a profit $(p_i > 0)$ and a service time s_i. It is assumed that each point can be visited at most once.

Making use of the notation introduced above, the MOP can be formulated as an integer problem. The following decision variables are used:

$y_i = \begin{cases} 1 \text{ if the vertex } i \text{ is visited in the tour ,} \\ 0 \text{ otherwise.} \end{cases}$

$x_{ij} = \begin{cases} 1 \text{ if the arc } (i, j) \text{ is included in the tour ,} \\ 0 \text{ otherwise.} \end{cases}$

The mathematical model of the MOP is presented as follows:

$$Max \left(\sum_{i=2}^{N-1} P_i . y_i + \sum_{i=1}^{N-1} \sum_{j=2}^{N} P_{ij} . x_{ij} \right) \quad (1)$$

s / t

$$\sum_{i=1}^{N-1} x_{ij} = \sum_{k=2}^{N} x_{jk} = y_j \quad ; \forall j = 2,..., N-1 \quad (2)$$

$$\sum_{j=2}^{N} x_{d_e j} = \sum_{j=1}^{N-1} x_{j d_s} = 1 \quad (3)$$

$$(4)$$

$$\sum_{i=2}^{N-1} s_i y_i + \sum_{i=1}^{N-1} \sum_{j=2}^{N} x_{ij} (t_{ij} + s_{ij}) \le T_{\max} \quad (5)$$

$$2 \le u_i \le N \quad ; i = 2,..., N \quad (6)$$

$$u_i - u_j + 1 \le (N-1)(1 - x_{ij}); i, j = 2,..., N; i \ne \quad (7)$$

$$x_{ij} \in \{0,1\} \quad ; i, j = 1,..., N \quad (8)$$

$$y_i \in \{0,1\} \quad ; i = 2,..., N$$

The objective function (1) is to maximize the total profit collected in the nodes and arcs of tour. Constraints (2) enable connectivity between the nodes and that each is visited only once. The tour starts by the deposit d_e and finished in deposit d_s which are guaranteed by the constraints (3). Constraints (4) you cannot exceed the time limit T_{max}. Constraints (5) and (6) are necessary for the elimination of sub-tours with u_i the position of vertex i in the path. Finally, (7) and (8) are the binary constraints.

VI. Resolution by Concert Technology

As first method of resolution of the MOP we use programming by the Concert Technology.

A. *Description of method*

ILOG Concert Technology provides a set of lightweight C++ objects for representing optimization problems. It is included as part of ILOG Solver and ILOG CPLEX.

Different steps must be followed to make the resolution presented as follows: Create the environment (IloEnv) and create the model (IloModel), next we must translate problem data and constrained variables into appropriate ILOG Concert Technology types. Then, added constraint and objective of model. After that, solving the model by the solver (`IloSolver`).

B. *Case study*

In practice, the presence of a model dealing the case of distribution can solve several problems for a company. The MOP can remain the solution since it gives the clear plan of order customer's visits. On the one hand, the distribution of orders on more than one tour can guarantee the satisfaction of customers in terms of respecting delivery times. On the other hand, it can be a source to save expenses since each vehicle will serve a well-defined area so the geographic extent will be reduced.

Our model is applied to a case of Tunisian commercial Company"SVI". As it can be adapted for any company to optimally organize the orders of customer's visits, maximize profits, improve the visibility of sales teams and facilitate their orientation on site.

The data are taken from accounting folder of a Company, we grouped the data into Excel files containing principally sales realized to customers, distribution costs such as diesel consumption and other data necessary for the resolution of the problem.

The tests we have carried out are to increase the number of customers to visit and in parallel the T_{max} to determine the optimal tour for each test. Noting that the data for each test are not identical and they are subdivided into two groups. For the test (10), (20) and test (30) are related to local customers. For test (50) and (100) are the customers located in different cities. It was also mentioned that the test number reflects the number of customers for test (10) and so forth for other tests.

TABLE I. Carried tests

Test N°	**T_{max} (in minutes)**
Test (10)	240
Test (14)	300
Test (20)	400
Test (30)	450
Test (50)	480
Test (100)	650

IV. RESULT AND DISCUSSION

Table (II) summarizes the different results for all the tests obtained by Cplex using programming by Concert Technology.

TABLE II. EXPERIMENTAL RESULTS

	Value of F(x)	**Best tour**
Test (10)	1280.77	0-6- 4-7- 8-9
Test (20)	3417.20	0-2-7-9-12-1-6-19
Test (30)	4167.21	0-6-14-5-1-9-26-21-18-23-29
Test (50)	11026.12	0-4-11-27-15-9-22-7-10-35-24-3-21-49
Test (100)	14974.29	0-6-12-77-85-80-63-48-41-69-97-35-51-87-99

The solution represents the performed tours by a single vehicle through the initial depot that takes the order 0, then the visiting order for clients until the final depot corresponding to (N-1). For each tour, we calculated the value F(x) and the time for visiting to this subset of customers must be always less than T_{max}.

V. CONCLUSION

In this paper we developed the first model, according to our knowledge, of the Mixed Orienteering Problem which the goal is to maximize the total profits subject to differ constraint. The difficulty consists in the coordination between the maximum profits in the nodes and arcs. For the resolution of our model we used Cplex by programming of Concert Technology. As future research, we will use the heuristics and Metaheuristics to solve the MOP.

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