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A proposal on a new efficient framework dedicated to large scale vehicle routing problems -FOCUS-

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Abstract—A new framework dedicated to large scale vehicle routing problems(VRPs) are proposed. The main characters of this framework are based on the way of divide and conquer strategy and to be aimed for producing an effect search in large scale problems. This framework using divide and conquer strategy has two contradictory mechanisms; problem decomposition and gradual restoration of decomposed ones. The former one is compatible with divide part and the latter is conquer part. In addition , we incorporated a circular partitioning scheme and a intensive search scheme around borderlines of partitionings. In this paper, the proposed framework is called "a framework based on divide and conquer strategy for very large scale VRPs -FOCUS-".

To investigate the effectiveness of FOCUS, some test problems of which features that are already-known were used and examined how these mechanisms of FOCUS works in search process.

1. Introduction

Vehicle Routing Problems (VRPs) which are called as delivery planning problems are well known as combinatorial optimization problems and have attracted a great deal of attention since 1970's due to their wide applicability and economic importance[1].

Although the objective of most VRPs' application is to minimize the total area distance, VRPs inherently have multi-objective aspects such as the number of vehicles or the degree of dispersion between the distances of each vehicle. Therefore, there have been many studies using evolutionary multi-criterion optimization (EMO) algorithm to optimize multi-objective VRPs [2, 3].

Recently, data size and problem size become larger scale according to technical advantages of storage performance and cloud technology. Since this trend cause a new formidable issue as the combinatorial explosion and the increased computational cost, previous approaches is difficult to obtain the solutions to fill required quality in real time.

Therefore, we proposed a new framework based on divide and conquer strategy for very large scale VRPs[4]. In here, abbreviated name of the proposed framework as FOCUS[1]. This paper presented a improved version of FOCUS and presented the efficiency of FOUCS through the numerical examples using some different instances.

2. The modification of FOCUS

The main feature of FOCUS is based on divide and conquer strategy, and FOCUS has two contradictory mechanisms; problem decomposition and gradual restoration of decomposed ones. The former one is compatible with divide part and the latter is conquer part.

In the FOCUS, firstly, the proposed approach tries to divide the whole area of original problem into some small areas as many as the number of depots. And then each small area is subdivided into sub-areas until the total number of sub-areas reaches to the pre-defined number. After finishing this area segmentation processing, gradual integration would be performed until every sub-area are integrated into the one (the original area).

However, FOCUS was difficult to form a route striding over a borderline because of the influence of area segmentation. In order to overcome this shortage, we implemented a circular partitioning scheme and a intensive search scheme around borderlines of segmentations.

The following is the specific flow of the proposed approach, and the flowchart figure of this process is shown in Fig. 1.

2.1. Proposed method in the past (FOCUS)

In this proposed method in the past, we proposed a new EMO approach for very large scale VRPs. The proposed approach has area segmentation and gradual area integration mechanisms.

Area segmentation

[1]FOCUS is abbreviated name of "a framework based on divide and conquer strategy for very large scale VRPs".

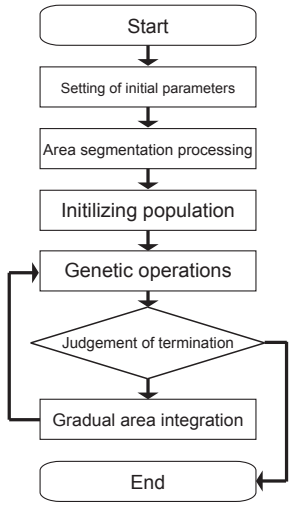

Figure 1: Flowchart of the proposed approach.

The important point of area segmentation in MDVRPs is to divide area so that each sub-area belongs to only one depot. Since this restriction enable to skip the decision of which depots customers in sub-area should belong, the divided sub-area could be treated as one of small size CVRPs with single depot.

Therefore, our segmentation mechanism is based on a multistep segmentation approach, namely, our segmentation firstly tries to divide the whole area of original problem into some areas as many as the number of depots, and then subdivides each area into sub-areas. Specifically, first step segmentation is implemented by assigning each customers to the nearest depots and in second step each area is subdivided according to the midpoint of line connecting points of two customers; one customer is farthest removed from depot and another is farthest removed from this customer.

Gradual area integration

Area integration mechanism tries to restore the segmentation sub-areas to original area by integrating each sub-areas. The key points of area integration are the timing of integration and the choices of integration sub-areas.

In our mechanism, this timing is when a best incumbent solution remains unchanged for a certain predefined generation and the choices of integration is selected in the inverse order of dividing area. This means that the last divided sub-areas are firstly integrated and the first divided ones are lastly integrated.

And the main reason why we adopt 'gradual' integration is to reduce the magnitude between problem settings before and after applying our integration. If every sub-areas are integrated to one at a time, the magnitude of difference between before and after integrating sub-areas are so large that the obtained information is not able to effectively utilize subsequent search. Therefore our integration mechanism used to integrate partial sub-areas in stages and repeat this integration until all sub-areas are unified. We expected that this gradual approach leads to an efficiently search, because the small magnitude of problem change before and after would enable that the obtained information of prior problem is effective seeds in posterior search.

2.2. The modified parts

In order to decrease the influence of area segmentation, we incorporated two modifications; a circular partitioning scheme and a intensive search scheme around borderlines. The details of these schemes are shown as follows.

Circular partitioning scheme

Circular partitioning scheme is one of segmentation method that was proposed by Haimovitch-Rinnooy Kan[5]. This method is well known that is very effective for large scale problem.

Intensive search around borderlines

Gradual area integration of FOCUS searches while restoring sub-areas to original area size. However, when segmentation area size returned to original area size, formed routes are strongly influenced by area segmentation.

Therefore, when segmentation area size restore sub-areas to original area size by gradual area integration, we incorporated search mechanism near area segmentation lines. This search mechanism is known to create a route overlapping area segmentation lines.

The followins are the detail steps of this mechanism.

Step 1: Set the parameter *count* representing the generation of using intensive search around borderlines mechanism *count* = 0.

Step 2: In the case of two areas, find a perpendicular line from a line between each depots and draw a perpendicular line through each depots and select route(t) in random order between two perpendicular lines. In the case of over three areas, find gravity point from each depot and select route(t) in random order from circle centering on gravity point.

Step 3: To select route on limiting route, applying the following two methods, after that, increment *count*:

- According to the order distance between customer of route t and customer of route in limiting range.
- According to the order distance between gravity point of route S and gravity point of route in limiting range.

Step 4: If $count \neq T$, go back to Step2. However, in the case of $count = T$, terminate this mechanism.

3. Numerical experiments

We used two test problems of Cordeau's instances from VRP website[2]; p08, pr06. In addition, we used large scale

[2]VRP website
http://www.bernabe.dorronsoro.es/vrp/

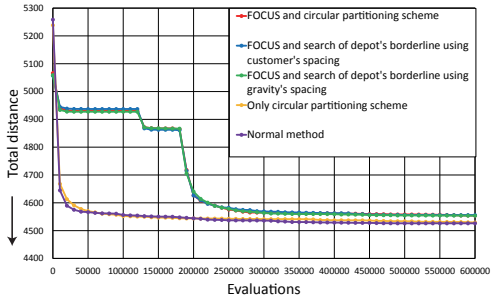

Figure 2: Transitions of F_{dist} at p08

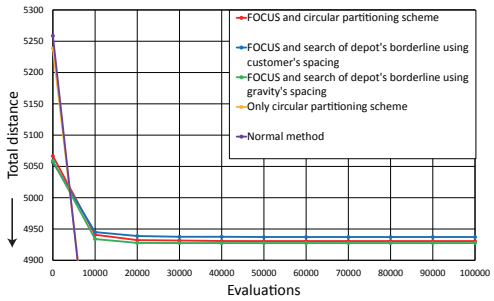

Figure 3: Expanded Fig. 2

problems (X-n1001-k43-D2 : XD2) that we originally created.The details of three test problems are shown in Table. 2.

In this experiment, we investigated the characteristics and effectiveness of the proposed approach by comparing the improved method to without FOCUS mechanisms(normal method) in p08.

3.1. Results and Analysis

The transitions of the total travel distance F_{dist} in p08 and XD2 are shown in from Fig. 2 to Fig. 4. And the distribution maps of the final results in three problems are shown in Fig. 5 respectively.

As shown in from Fig. 2 to Fig. 4, The improved methods have a better transition than the normal method in XD2 of large scale problem. However, the improved methods were comparable with the normal method in p08 of small scale problem.

In p08, we got the different result from the cases of only using circular partitioning scheme and the case of others. In other words, we considered that area segmentation had a

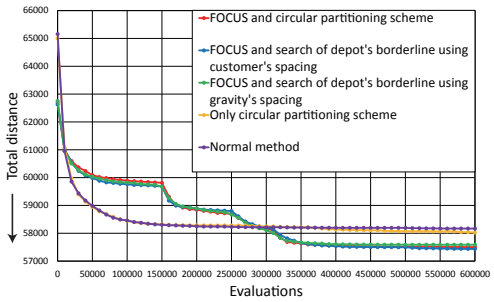

Figure 4: Transitions of F_{dist} at XD2

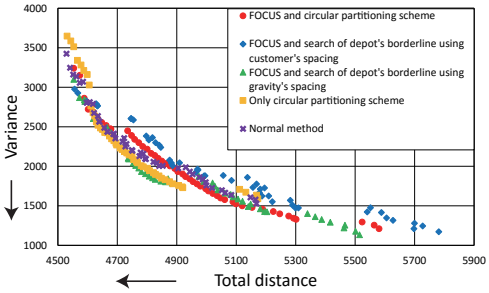

Figure 5: The distribution map of the obtained solutions at p08

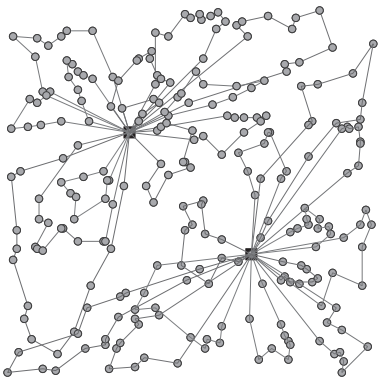

Figure 6: The optimal route relevant to F_{dist} in p08

bad effect on search in the case of using circular partitioning scheme. However, at the beginning of search, FOCUS with circular partitioning scheme could obtain better solutions than that of normal method(Fig. 3).

From these results, in the case of small scale problems, this segmentation scheme can work well on original problem environment. Therefore, when to use this scheme, it is necessary to restore sub-areas to a original area in the early stages.

Here, we compared the result of original FOCUS(Fig. 9) to those of others methods(Fig. 7 - Fig. 8). From these figures, in the case of original FOCUS, can not form a route overlapping area segmentation lines. However, by

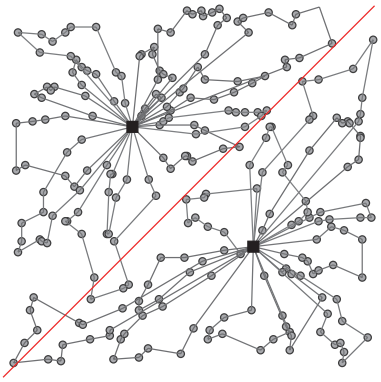

Figure 7: Actual route of the final solution obtained by the determinate search method using customer's spacing

Table 1: Used Parameters.

Parameter	p08	pr06	XD2
The number of population N	50		
Archive size A	250		
The number of area division P	8		
The upper period of the search stagnation G_S	5000		10000
The upper period of intensive search around borderlines T	50		

Table 2: Problem Instance.

Problem	p08	pr06	XD2
The number of customers	249	288	1000
The number of depots	2	4	2

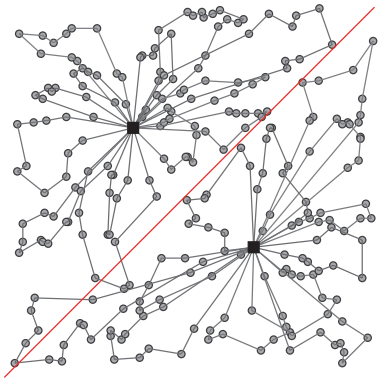

Figure 8: Actual route of the final solution obtained by the determinate search method using gravity's spacing

intensive search around borderlines, we could mitigate the influence caused by intensive search around borderlines can succeed in decreasing, the influence of area segmentation. On the other hand, in comparison with the optimal route(Fig. 6), same route did not exist. Therefore, it doesn't need to call intensive search around borderlines heavily.

4. Conclusions

In this paper, we proposed "a framework based on divide and conquer strategy for very large scale VRPs -FOCUS-", and incorporated circular partitioning scheme and presented two new mechanisms; intensive search around borderlines for large scale vehicle routing problems (VRPs).

We investigated the effectiveness of the improved approach by comparison of its performance with that of original FOCUS method. In the numerical experiments, the incorporated methods have a better transition than the normal method in a large scale problem.

As future works, we want to implement mechanisms to avoid the influence of partial solutions in sub-area. Specifically, we would like to implement mechanisms of alternating between area segmentation and area integration without returning to the original area size.

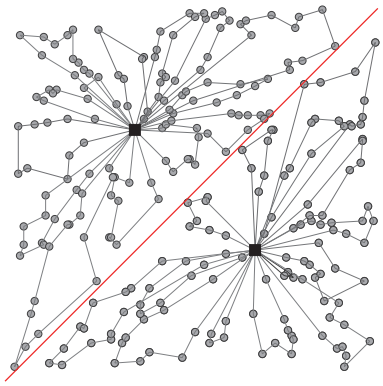

Figure 9: Actual route of the using only FOCUS method in p08

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