A New Apprecd To Solve Multiple Traveling Salesmen Problem By Clonal Selection Algorithm

by Dr.ayi Purbasari. St.,mt. Turnitin Paper -publikasi 9

Submission date: 19-Oct-2021 11:50AM (UTC+0700)
Submission ID: 1677823258
File name: 9ANEWA_1.PDF (3.19M)
Word count: 4153
Character count: 23920

ISSN 0973-4562

Volume 9,
Number 21,
2014

International Journal *of*

APPLIED ENGINEERING RESEARCH

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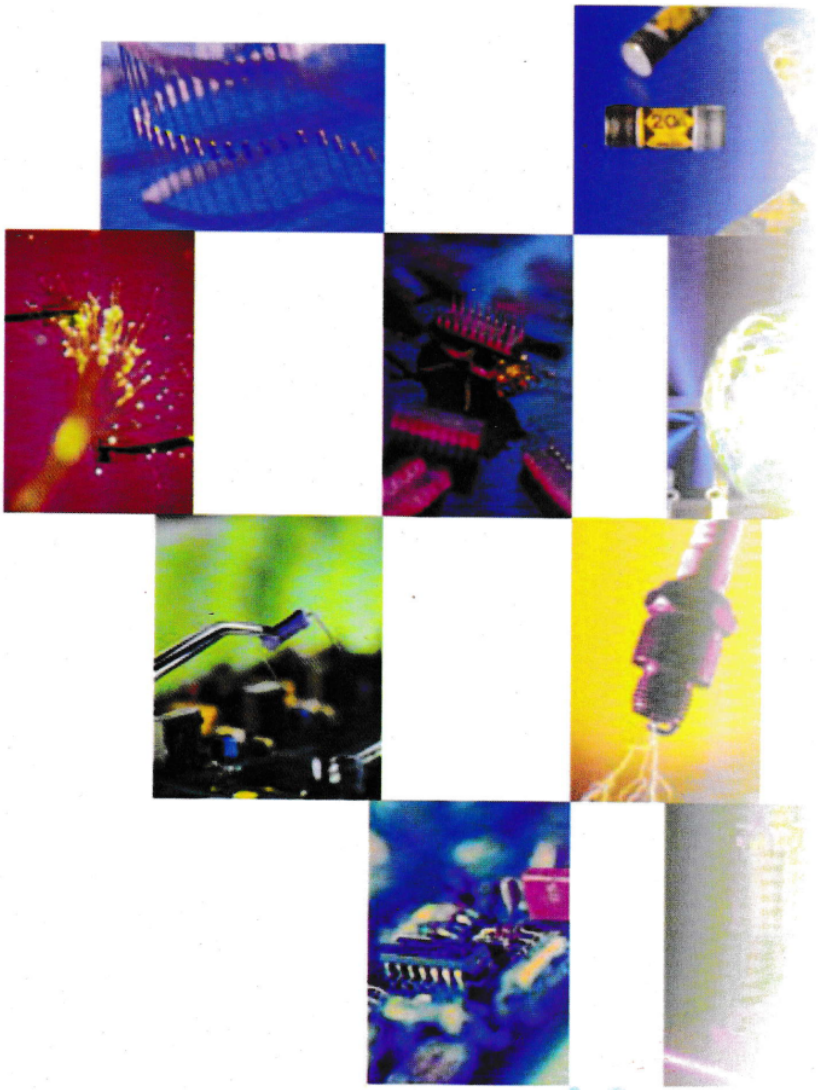

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International Journal of Applied Engineering Research
ISSN 0973-4562

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Tel No.: 91-11-65394240 Fax No.: +91-011-27297815
Website: www.ripublication.com E-mail: info@ripublication.com

International Journal of Applied Engineering Research

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Publisher: All business correspondence, enquires and subscription orders should be addressed to
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International Journal of Applied Engineering Research
Volume 9, Number 21 (2014)

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International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 9, Number 21 (2014) pp. 11005-11017
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A New Approach to Solve Multiple Traveling Salesmen Problem by Clonal Selection Algorithm

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Abstract

The Multiple Traveling Salesman Problem (m-TSP) is a generalization of the Traveling Salesman Problem (TSP) in which more than one salesman is allowed. Given a set of cities, one depot (where m salesmen are located), and a cost metric, the objective of the m-TSP is to determine a set of routes for m salesmen so as to minimize the total cost of the m routes. Clonal Selection Algorithm (CSA) is a popular algorithm from Artificial Immune System (AIS) that using population based and selection that is inspired from Clonal Selection Theory. In this paper, a clonal selection based algorithm was proposed for solving the m-TSP. This algorithm was implemented using Java language with dataset from TSP Lib and could show m-TSP solutions within various datasets. In particular, this paper shows representation for tour and salesmen, and also shows several techniques for cloning and hypermutation phase. The best technique is using mutation in tour representation, and also salesmen number. This paper also shows that best cost is obtained with lowest number of salesmen. Furthermore, using this proposed algorithm for all versions of the vehicle routing problem is suggested for future research.
Keywords: Clonal Selection Algorithm, Artificial Immune System, multi-Travelling Salesperson Problem (m-TSP).

INTRODUCTION

The multiple Traveling Salesman Problem (m-TSP) is a generalization of the well-known Traveling Salesman Problem (TSP)which is a combinatorial optimization problem. There are one or more salesmen can be used in the solution. The objective of the m-TSP is to determine a set of routes for m salesmen so as to minimize the total cost of the m routes in a set of cities, one depot (where m salesmen are located), and a

cost metric[1]. The cost metric represents distance, time, or cost. All of the routes must start and end at the (same) depot and each city must be visited exactly once by only one salesman.

The m-TSP is a generalization of the TSP; if the value of m is 1, then the m-TSP problem is the same as the TSP. Therefore, all of the formulations and solution approaches for the m-TSP are valid for the TSP.TSP is already a complex NP-complete problem, there are several heuristic optimization algorithms, like genetic algorithms (GAs) need to take into account[1]. GAs is known as bio-inspired algorithms. that are techniques to improve computational techniques by mimicking natural system and achieving similar desirable properties of the natural system.

Artificial immune systems (AIS) is a promising biological inspired computation based on metaphor and abstraction from theoretical of the vertebrate immune system[2]. The field of AIS encompasses a spectrum of algorithms that exist inspired by the behavior and properties of immunological cells, specifically B-cells, T-cells and dendritic cells (DCs). AIS became a class of computationally intelligent systems, bridging between immunology and engineering. There are three classes of AIS algorithms derived from more simplified models: clonal selection, negative selection, and immune networks. Clonal Selection Algorithms (CSA) is the popular algorithms from AIS that using population based and selection that is inspired from Clonal Selection Theory [3] This CSA are using for pattern recognition and optimization problem. Clonal Selection Algorithm (CSA) as heuristic optimization algorithm is promising to solve TSP problem[4].

To solve m-TSP problem, CSA requires special representation and interpretable encoding to ensure efficiency. The aim of this paper is to review how Clonal Selection Algorithms can be applied to solve m-TSP problem and propose a novel, easily interpretable representation based CSA.

The paper is organized as follows. Section II reviews literature consist of m-TSP and the clonal selection principle and algorithm. Section III contains implementation of clonal selection algorithms to solve m-TSP. Section IV briefly discusses the result of the algorithm implementation. Section V concludes the paper.

Literature Review

Multiple Traveling Salesmen Problem (M-Tsp)

The traveling salesman problem have various approaches to solve, from exact algorithms e.g use integer linear programming approaches with additional constraints, to near-optimal or approximate algorithms e.g. neural network or tabu search [5]. The m-TSP is much less studied like TSP. There are several exact algorithms of the m-TSP based on branch-and-bound algorithm or cutting planes [5],

The m-TSP problem is defined on a graph G = (V,A), where V is the set of n nodes (vertices) and A is the of arcs (edges). C = (c_{ij}) be a cost (distance) matrix associated with A. The matrix C is symmetric if $c_{ij} = c_{ji}, \forall (i, j) \in A$. Here $x_{ij} \in \{0,1\}$ is a binary variable used to represent that an arch is used on the tour and c_m represents the cost of the involvement of one salesman in the solution.

Here are the mathematical formulation for m-TSP problem[5]:

$$min \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} + mc_m$$

$$\sum_{j=2}^{n} x_{1j} = m$$

$$\sum_{j=2}^{n} x_{j1} = m$$

$$\sum_{i=1}^{n} x_{ij} = 1, \mathrm{j} = 2,.., \mathrm{n}$$

$$\sum_{j=1}^{n} x_{ij} = 1, \mathrm{i} = 2,.., \mathrm{n}$$

$$X_{ij} \in \{0,1\} \forall (i,j) \in A$$

Here is the example of m-TSP with 3 salesmen and one depot:

Király and Abonyi stated many approaches applied to find solution, including heuristic approaches published by Russel, Potvin et all, and Hsu et all [5]. Zhang et all using GAs for the solution of m-TSP. Lately GAs is used for the solution of m-TSP too[5]. The first result can be bound to Zhang et al. converts the m-TSP into a single TSP and apply a modified GA to solve the problem. It was used for hot rolling scheduling[5].

When using GAs techniques, there are several representations of m-TSP, like one chromosome technique, the two chromosome technique and the latest two-part chromosome technique[1]. Each of the previous approaches has used only a single chromosome to represent the whole problem, although salesmen are physically separated from each other. Some research use GA with modified [6][7]. Both of them improved the best known solution. [5] proposed new representation of chormosome and review how genetic algorithms can be applied to solve these problems and propose a novel, easily interpretable representation based GA.

The Proposed Clonal Selection algorithm (CSA)-Based Approach to Solve the M-TSP

Clonal Selection Algorithms

Over the last few years, there has been an ever-increasing interest in the area of artificial immune systems (AIS) and their applications [8] [9]. AIS uses ideas gleaned from immunology in order to develop adaptive systems capable of performing a wide range of tasks in various areas of research. AIS algorithms are inspired from acquired immune response[2]. The clonal selection theory is a theory used to describe the functioning of acquired immunity, specifically the diversity of antibodies used to defend the organism from invasion[4]. This theory postulated by Burnet (1957), stated that antibodies production is the selection process triggered by antigens as their

enemies. The theory specifies that the organism have a pre-existing pool of heterogeneous antibodies that can recognize all antigens with some level of specificity[4]. An antibody then chemically binds to the antigen if its receptors matched to an antigen. This chemically binding causes the cell to clone, replicate and produce more cells with the same receptor. During the cloning stage, cells genetic mutations occur and promote the match or affinity with the antigen. This allows the binding ability of the cells to improve with time and exposure to the antigen. The clonal selection theory has been inspiring deCastro and Von Zuben to create clonal selection algorithms name ClonalG[4].

ClonalG is used to find solution for TSP problem. This approached is used by M. Bakhouya and J. Gaber to improve solution for TSP problem[9]. Chingtham[10] using this algorithm to find new solution for TSP problem.

Due successful to solve TSP problem, this paper will review how CSA algorithms can be applied to solve these problems and propose a novel, easily interpretable representation based CSA.

The proposed algorithms

This figure below show the workflow of the Clonal Selection Algorithm technique:

The theory specifies that the organism have a pre-existing pool of heterogeneous antibodies that can recognize all antigens with some level of specificity[4] [8] An antibody then chemically binds to the antigen if its receptors matched to an antigen. This chemically binding causes the cell to clone, replicate and produce more cells with the same receptor. During the cloning stage, cells genetic mutations occur and promote the match or affinity with the antigen. This allows the binding ability of the cells to improve with time and exposure to the antigen.

CSA starts from a group of initial solutions called the initial population[11] [4]. Furthermore, affinity maturation is used to evaluate the performance of the solutions. Each time best solutions are chosen from the population according to the selection probability which is proportional to their affinity value. The best solutions are cloned and then hypermutated to produces new solutions of the next generation. These new solutions will replace the old solutions if they have better affinity. This procedure continues until reached a stop condition.

Immune Engineering

Immune engineering is the process mapping between the immune system and the problem[9]. Here is the mapping between TSP problems with the CSA algorithm as follows:

- Population initiated randomly of all possible solutions in form TSP tours and its cost (there are n!/2 Hamiltonian circuit, with n is vertices number). Total population defined as initial variable.
- There is a function to select affinity which represented as minimum tour's cost. High affinity presented as low cost. Number of selections is defined as initial variable.
- There is a function of cloning and hypermutation, to clone a number of

selected population and then hypermutate the population. The number of copies defined as initial variable. Hypermutation of population copies done in accordance to affinity value. The higher value will give lower possibility to undergo mutation. Then cloned and mutated population added to the initial

- Population for further selection process. The population with the best cost will be chosen while the rest are ignored.
- The steps above will be repeated until stopping criterion is satisfied. Stopping criterion can be: a maximum iteration number, selection results were converged, or all of the tour had been finished evaluated.

CSA for Solving m-TSP

According to example of TSP dataset in TSP Lib [11], CSA using initial population with this representation:

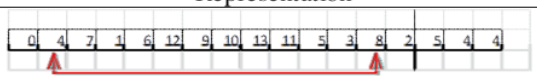
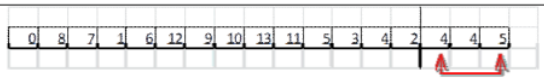
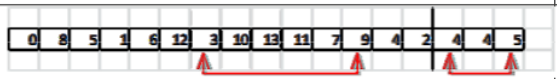
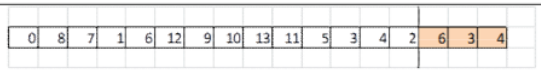
In m-TSP, we will use two-part representation Part one is representation of tour and part two is representation of salesmen as figure 3. The tour for TSP and m-TSP above can be seen below:

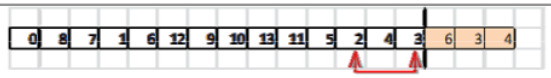
After population initialization, next step is evaluation and selection. Evaluation function that used in m-TSP is same as evaluation function in TSP e.g a total minimum tour's cost from each subtour's cost. The best cost then selected for cloning and hypermutation phase. This phase is using the same principle with TSP. The best cost from cloning and hypermutation phase then replace the population. This procedure is repeated until stop condition. Further mathematical formulation for evaluation function and cloning phase can be found in[4].

When cloning procedure is taken, here's an example of a population cloned:

After that, hypermutation is taken by swapping nodes in a population. In this paper, we will present five techniques to do hypermutation as follows:

Table 1 Five techniques for hypermutation phase

No	Representation	Description
1		Hypermutation is taken by swapping nodes in a tour population.
2		Hypermutation is taken by swapping salesmen's number of node.
3		Hypermutation is taken by swapping nodes in a tour population and salesmen's number of node.
4		Hypermutation is taken by re-randomized salesmen's number of node.

5		Hypermutation is taken by swapping nodes in a tour population and re-randomized salesmen's number of node

Implementation and Experiment Design

Implementation

This section describes the implementation of CSA for m-TSP problem. We used Java and the program is developed using Toshiba Portege Z935, Processor Intel® Core™ i5-3317* CPU@1.70GHz. Using memory 4GB, 64-bit Operating System and Windows 7, The m-TSP datasets are taken from TSPLIB [11]. This research is using burma14.tsp and vrp64.vrp dataset.

Experimental Design

Experiments performed with the following steps: 1) Determination of the parameters, 2) Determination of the dataset, 3) Determination of the analysis of experimental results. In this experiment, set the value of the static parameters: 1) Population size (N) = 50; 2) The size of the selection (n) = 10; 3) The value of cloning factor (β) = 0.1; 4) The value of the mutation factor (rho) 2.5; 5) Random size for replacement (d) = 5.

Stopping criteria consisted of: the number of generations, convergence, achieving optimum value. In implementation, the stopping criteria are the number of generations and set statically, ie 1000 generations. We set number of generation from 10. 100, and 1000 generations.

With the parameters that have been set, this result is using vrp64.vrp dataset. We determine number of salesmen, from 2 until 34 salesmen. After the experiments performed, taken to the analysis: 1) Best cost for each dataset for numerous cloning and hypermutation technique. We use static number of salesmen and a maximum number of nodes that a salesman can visit;2) Best cost for each dataset for various number of salesmen and various number of nodes that a salesman can visit.

Result and Discussion

This section provides the result of experiment:

Experiment for numerous hypermutation techniques:

In the following graph, we can see that a best cost of the best tour is obtained by clone and hypermuation technique number 5. The hypermutation is taken by swapping some nodes and the salesmen's number of nodes are re-randomized. The worst best cost is taken by swapping or re-randomized salesmen's number of nodes, without tour mutation.

Using vrp64.vrp dataset, we gain a different result. The best cost is obtained by tour mutation without mutation for salesmen's number of nodes or re-randomized.

The worst best cost is obtained by swapping or re-randomized salesmen's number of nodes, without tour mutation.

This is following graph is showing the best cost of the best tour:

Using hypermutation technique number 5, we obtained a route for each salesman. Figures below show nodes represent cities and five routes for each salesmen:

This is the resume for vrp64 experiments. Best cost obtained is 2497 with five salesmen and five routes for each salesmen. The tour can be seen in figure 8:

Experiment for numerous number of salesmen:

The pictures below show best cost obtained for Burma14.tsp and vrp64vrp datasets, with several number of salesmen:

As we can see, both graphs above show that best cost obtained with lowest number of salesmen. Greater number of salesmen will improve best cost achieved.

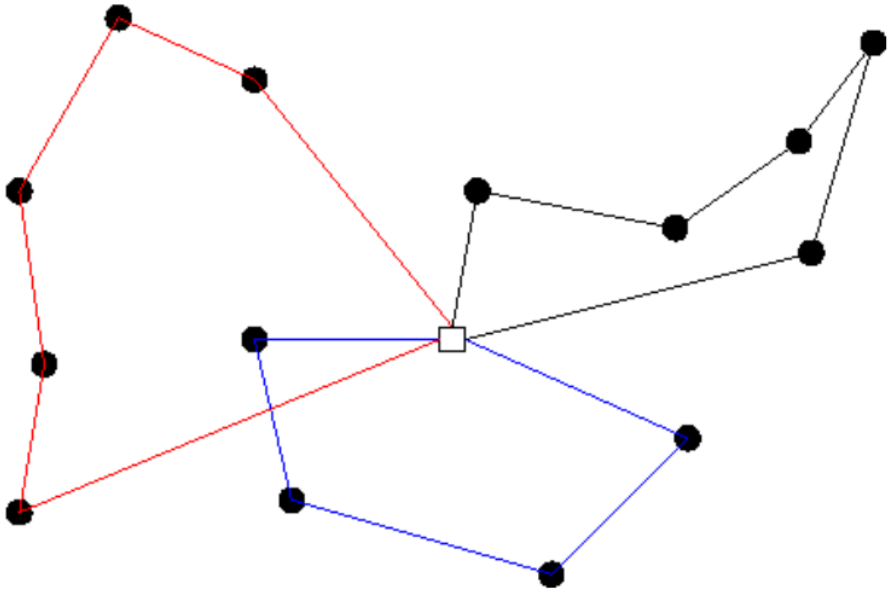


Figure 1Solving m-TSP with 3 salesmen

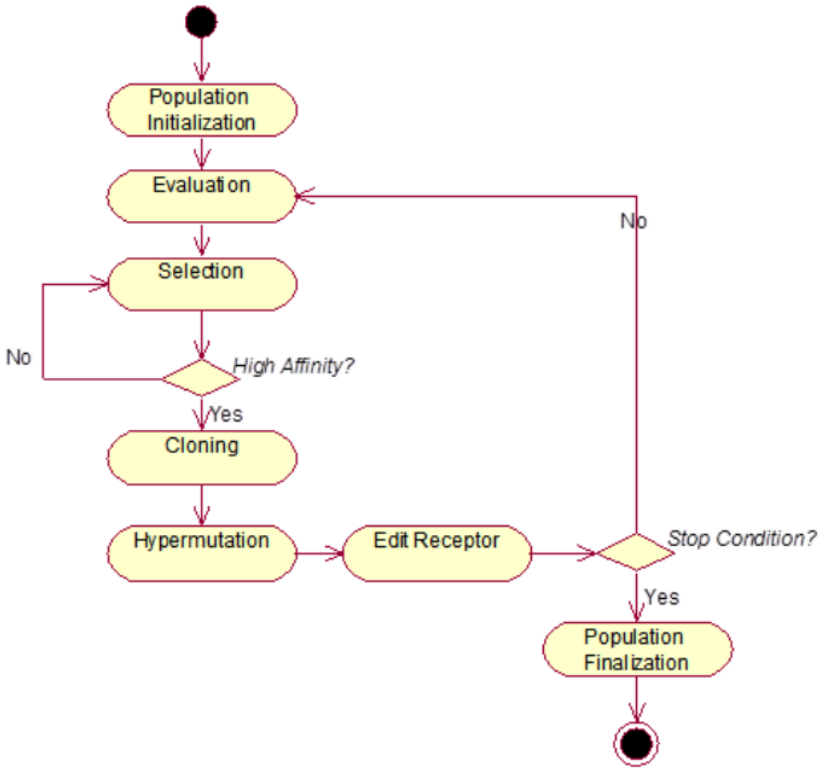


Figure 2 Clonal Selectin Algorithm

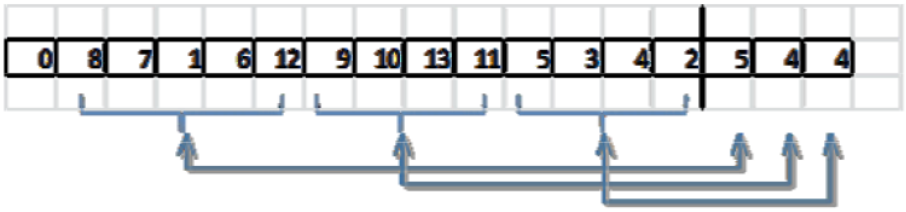


Figure 3Example of two-part representation with 14 nodes and three salesmen

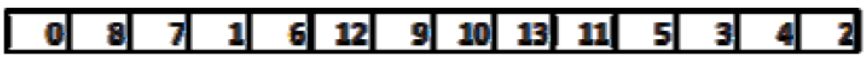


Figure 4Example of a population with 14 nodes and node #0 as depot

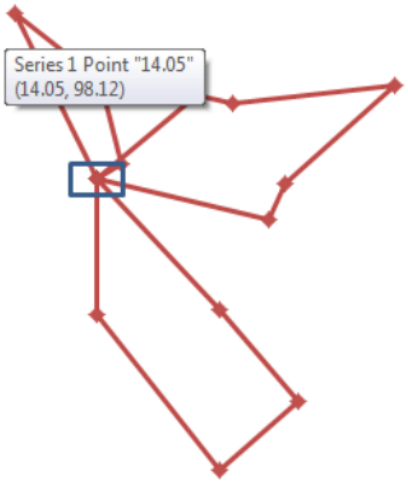


Figure 5 Figure 5 Tour optimal for mTSP with Burma14.tsp dataset

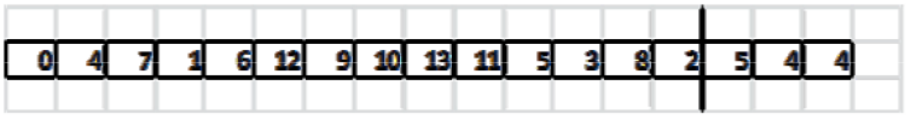


Figure 5An example of a population cloned

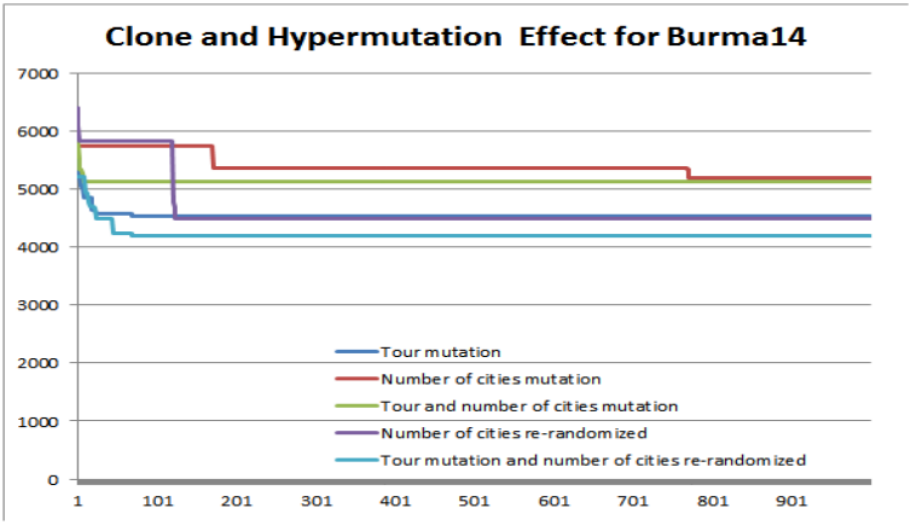


Figure 6 Clone and Hypermutation for Burma14 dataset

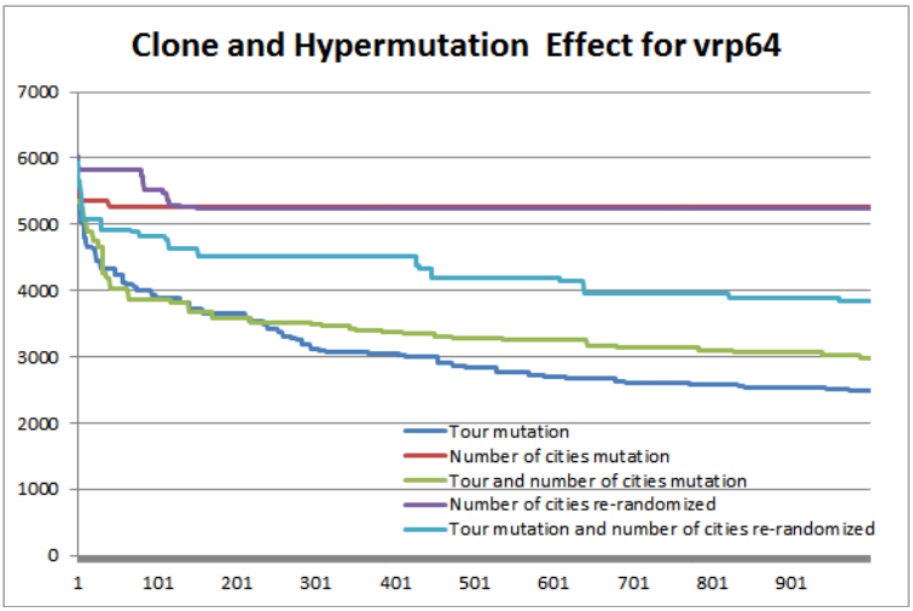


Figure 7 Clone and Hypermutation for vrp64

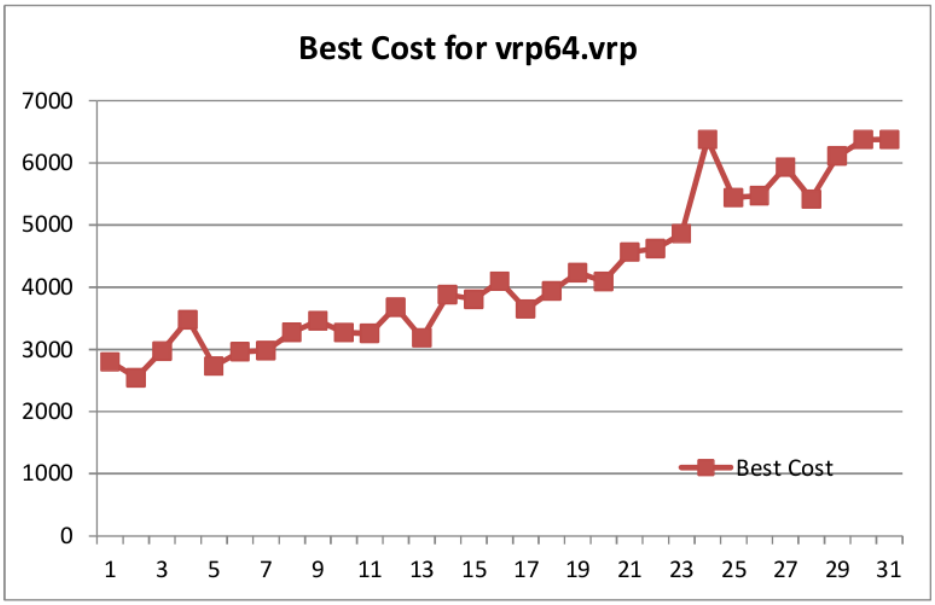


Figure 8best cost for vrp64.vrp for various number of salesmen

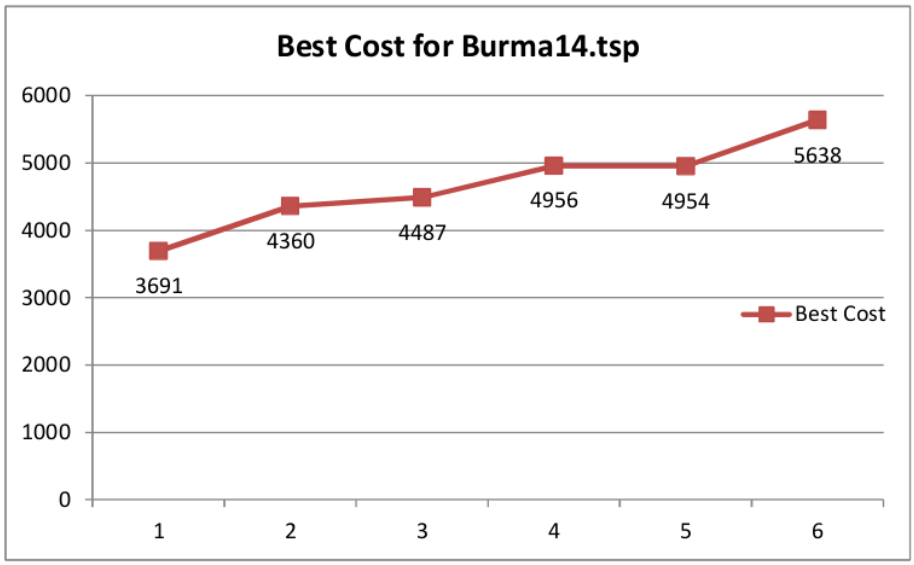
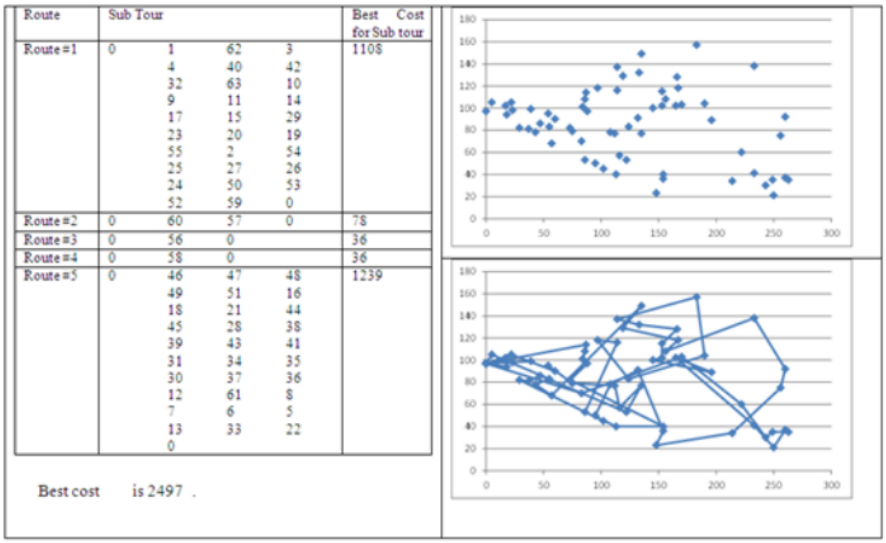


Figure 9best cost for burma14.tsp with various number of salesmen



Route	Sub Tour				Best Cost for Sub tour
Route #1	0	1	62	3	1108
		4	40	42	
		32	63	10	
		9	11	14	
		17	15	29	
		23	20	19	
		55	2	54	
		25	27	26	
		24	50	53	
		52	59	0	
Route #2	0	60	57	0	78
Route #3	0	56	0		36
Route #4	0	58	0		36
Route #5	0	46	47	48	1239
		49	51	16	
		18	21	44	
		45	28	38	
		39	43	41	
		31	34	35	
		30	37	36	
		12	61	8	
		7	6	5	
		13	33	22	
		0			

Best cost is 2497 .

Figure 10 Best Tour for Vrp64 dataset with 5 salesmen

Discussion

In this paper, a clonal selection based algorithm was proposed for solving the M-TSP. This algorithm is can show solution for M-TSP in various datasets. In particular, this paper shows representation for tour and salesmen, and also shows several techiniques for cloning and hypermutation phase. The best technique is using mutation in tour representation, and also salesmen number. This paper also show that best cost obtained with lowest number of salesmen. Furthermore, using this proposed algorithm for all versions of the vehicle routing problem is suggested for future research.

Acknowledgment

I would like to thank Dr. IpingSuwardi, Dr. dr. Oerip Santoso, Dr. Rila Mandala from School of Electrical and Informatics(STEI) InstitutTeknologi Bandung (ITB) forhelping the research. I would like to thank Department of Informatics and Technical Faculty of Universitas Pasundan (Unpas) Bandung for all support.

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