International Journal of Soft Computing and Engineering (IJSCE)
ISSN: 2231-2307, Volume-3, Issue-4, September 2013

Optimization of Warranty Cost using Genetic Algorithm: A Case Study in Fleet Vehicle

Hairudin Abdul Majid, Nur Hayati Kasim, Azurah A. Samah

Abstract— Optimization is a process of making something better. Genetic Algorithm (GA) has been widely used in many applications specifically in optimization problem. This paper describes GA and its application to warranty problem in optimizing total cost of warranty. A detail procedure of GA process is provided in this paper. Initial point were created randomly and the survival are depends on fitness criterion. Improvement in every generation of GA process gives the fittest solution which is the most optimum. The results of GA give small error of parameter values while comparing with estimated values by using Maximum Likelihood Estimation (MLE).

Index Terms— Fleet vehicle, Genetic Algorithm, Optimization, Warranty

I. INTRODUCTION

A warranty is a manufacturer assurance to a buyer that a product is or shall be as represented (Murthy *et. al*) [1]. Generally, reducing warranty cost is an interesting issue in warranty area. In automobile industry, the manufacturer incurs additional costs when an item fails under warranty. Thus, it becomes an important thing for manufacturers to obtain an accurate prediction of warranty cost and period. Reducing warranty cost is an interesting issue in warranty studies and the literature on warranty cost model has been a very active research.

Recently, some researchers do not deal with conventional techniques anymore. Verma and Lakshminarayanan [5] stated that many optimization problems are complex and difficult to solve by conventional optimization techniques. Thus, we applied GA technique in warranty area as an alternative to conventional techniques. The advantages of GA in optimization are common in previous research.

Therefore, the purpose of this paper is to obtain optimum warranty cost by optimizing parameters in warranty cost model using GA. This paper is organized as follows. Section 2 presents some review of previous research regarding the implementation of GA in solving optimization problem. Section 3 describes a flowchart of GA approach. Then, the warranty cost model which considering distribution of delay time is presented in section 4. Section 5 describes a detail procedure of GA in obtaining optimal solution followed by section 6 which presenting experimental results and some discussion. The results of GA will be compared with other method. Section 7 provides the conclusions drawn from this paper.

Manuscript received September, 2013.

Hairudin Abdul Majid, Department of Modeling and Industrial Computing, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.

Nur Hayati Kasim, Department of Modeling and Industrial Computing, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.

Azurah A. Samah, Department of Modeling and Industrial Computing, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.

II. PREVIOUS RESEARCH

GA is one of the useful techniques in Artificial Intelligence which is based on the natural evolution to solve search and optimization problem. In early 1970s, the idea of GA was first introduced by John Holland which was inspired by natural process of evolution. The application of GA has been widely use and the benefits of using GA technique are clear and well-known. GA is a simple method yet effective in finding a reasonable solution to a complex problem. Genetic Algorithm can also produce solutions close to optimal solutions. In 1996, Gen and Cheng proved that GA gives better results than the traditional optimization method in solving real life problem.

Based on previous findings, the application of GA has been studied in many different areas. For instance, Chaudhry and Luo [6] reviewed the application of GA in twenty-one major production and operations management journals during the period of 1990 to 2001. Their findings show that most researchers implementing GA in scheduling and facility layout topics. Besides, Hairudin *et. al* [3] reviewed the application of soft computing methods in warranty problem during the period of 2003 to 2012. In literature, there have been few reviews regarding the application of GA in warranty areas. For example, Jin and Ozalp [3] proposed a stochastic reliability model to minimize warranty cost through design for reliability. GA was applied in the model for optimization process.

In the same year, Sohn, Moon and Seok [7] proposed a dynamic pricing model for mobile phone in order to find an optimal pricing policy by implementing genetic algorithm method. They found that GA gives high profit in a series of optimal price for mobile phone. GA also has been applied in many different fields. For example, Verma and Lakshminarayanan [5] applied GA for optimization of engine parameters specifically in selecting a simple speed-dependent injection timer for a diesel engine. Besides, in 2007, Woods clarified that Genetic algorithms are well suited in optimizing complex problems such as image segmentation. The paper discusses the feasibility and issues involved in image segmentation.

GA is robust in producing near-optimal solutions even it takes plenty of time to provide a good result. It can also handle varieties of objective function and constraint. The capability of GA in optimization problem becomes famous in many research areas. Thus, this paper is carried out to obtain optimum warranty cost by optimizing the parameters in warranty cost model using GA approach.

III. FRAMEWORK

Fig. 1 shows a simple flowchart of GA process. An initial population is randomly created where the survival depends on the fitness criterion. In order to find near-optimization of the problem, selection, crossover, and mutation are the three main operators that were used in GA process. The fittest individual will survive more frequently and have high chances for reproduction.

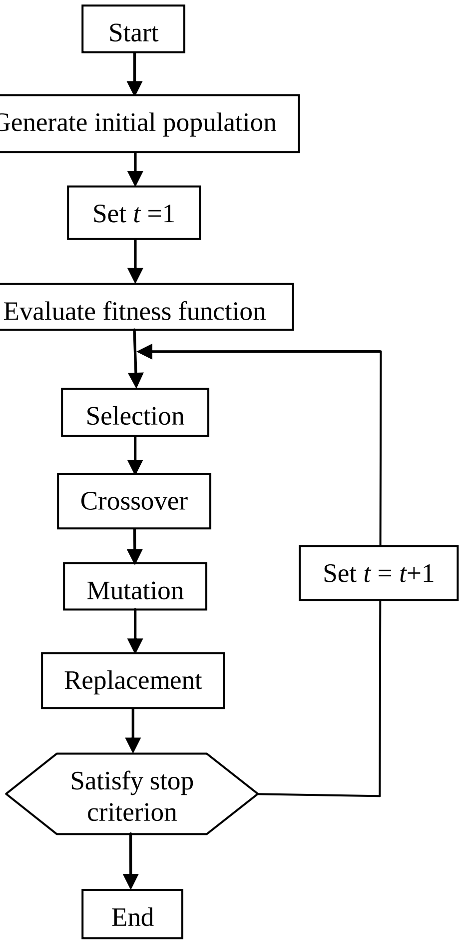

Fig. 1: Flowchart of GA process.

IV. WARRANTY COST MODEL

In this paper, the modeling of warranty cost is based on real data which cover five-year period that is from 1998 to 2002. We employ the model proposed by Hairudin and Scarf [4] which consider a Non-Homogeneous Poisson Process (NHPP) model with asymptotically defect arrivals, $\lambda(u)$ and mixed exponential distribution, $f(h)$. The equation of asymptotically defect arrivals is as follows:

$$\lambda(u) = \frac{\lambda_0 + \lambda_1 u}{1+u}$$

where

$\lambda_0 =$ Initial value of failure rate at time zero

$\lambda_1 =$ Steady state defect rate

Basically, there are several types of delay time distribution such as weibull distribution, exponential distribution and mixed exponential distribution. Hairudin and Scarf [4] introduce the mixed exponential distribution since zero delay time may occur in some defects. As a result, they found that the result with mixed exponential models is more reasonable. The probability density function (pdf) of mixed exponential distribution is

$$f(x) = \begin{cases} p & x = 0 \\ (1-p)\beta e^{-\beta x} & x > 0 \end{cases}$$

where *p* is the probability of failure with zero delay time and β is mean of delay time. Therefore, the final model of total warranty cost is as follows:

$$TC = \int_0^w \lambda(u).F(w-u)du.C_f + \int_0^w \lambda(u).\big(1 - F(w-u)\big)du.C_i + n_s.C_s$$

where

C_f = Cost of failure
C_i =Cost of inspection
C_s = Cost of service
n_s = Number of free service

V. GENETIC ALGORITHM

In this section, a procedure of GA method with description is presented. GA is proposed in order to obtain optimal value of parameters in the warranty cost model. GA is selected based on its computational efficiency with less mathematical calculation and the capabilities of handling large search space.

The objective of the optimization process in this study is to determine the optimal values of the parameters that lead to the minimum value of warranty cost. The information of the model was extracted from a research made by Hairudin and Scarf [4]. The total warranty cost model is proposed as the fitness function for optimization solution of GA which is expressed as follows:

$$TC = \int_0^w \lambda(u).F(w-u)du.C_f + \int_0^w \lambda(u).\big(1 - F(w-u)\big)du.C_i + n_s.C_s$$

The minimization of the fitness function value of the above equation is subjected to limitation constraints. The limitation constraints are as follows:

$$0 < \lambda < 0.2$$
$$0 < p < 1$$
$$0 < \beta < 1$$

Generally, some GA operator must be considered by GA algorithm as shown in Table I below.

Table I:Value of GA operator

GA operator	Setting Value
Initial Population	100
Number of Iteration	100
Probability of Crossover	0.8
Probability of Mutation	0.1

A. Initial Population

At first generation (iteration) where *t* = 1, a population which contains 100 chromosomes is generated randomly. The random numbers ranged based on the limitation constraints for each variable. Each chromosome has 4 genes which represent the unknown parameters.

B. Fitness Function

All chromosomes in the population are evaluated through fitness function. Fitness function is a function to be optimized. In this paper, the fitness function is warranty cost model which was minimized to give optimal solution of parameter values.

C. Selection

Selection process is performed in which some chromosomes are chosen from the population to be parents. The selection operator is implemented in a number of ways. In this paper, we use Roulette-wheel selection method where a chromosome is selected from the population with a probability proportional to the fitness, *F*. The probability of the i^{th} selected string is

$$p_i = \frac{F_i}{\sum_{j=1}^{n} F_j}$$

where *n* is the population size. Then, cumulative probability is required by adding the individual probabilities from the top of the list. In order to choose *n* chromosomes, *n* random numbers are created at random. Thus, the chromosomes that represent the random number lie between the ranges of cumulative probability are copied to the population. The chromosome with higher fitness value has a higher probability of being copied into the population.

D. Crossover

A crossover operation starts with selection of two random individuals from the population to produce an offspring. In this paper, one-point crossover method is used which select the cut point randomly and exchanges the right parts of two parents to generate an offspring. The number of pairs to be performed in crossover process is depends on the probability of crossover. According to previous studies, the probability of crossover is varied from 0.5 to 0.8.

E. Mutation

In order to prevent the algorithm to be trapped in local minimum, mutation operator is performed in GA process. Probability of mutation determines the number of mutations occurred in the population. We kept the probability of mutation at 0.1. A small percentage of the population is allowed to mutate. Then, old generation will be replaced by new generation.

F. Termination Criterion

We consider maximum generation as the termination criterion which was set at 100. The old generation will be replaced by the new generation if the generation is more or equal to 100. Otherwise, breeding process is repeated until the termination criterion is fulfilled. When the termination criterion is fulfilled, the process has to be terminated and new generation is produced to give optimal values of parameter. Therefore, individual with the best fitness in 100 generations is taken as the best solution.

VI. EXPERIMENTAL RESULTS

An experiment of a case study of selecting the best parameter values of warranty cost model are described in this section. This paper attempts to optimize the parameters of warranty cost model using GA approach. The process of GA was carried out using Matlab software to minimize the objective function.

Table II: Results of parameter values of warranty cost model

Parameters	Estimated Value	Genetic Algorithm	Errors
λ_0	0.0164	0.0026	0.0138
λ_1	0.0071	0.0004	0.0067
p	0.0291	0.0164	0.0127
β	0.0089	0.0089	0.0000

By referring to Table II, the results of parameter values by using GA which lead to minimum warranty cost are 0.0026 for initial value of failure rate, 0.0004 for steady state defect rate, 0.0164 for probability of failure with zero delay time and 0.0089 for mean delay time. The time unit is 1 day. This implies that the initial value of failure rate is 0.95 which means the defect arrive on average once a year. Based on the probability of failure with zero delay time, *p*, approximately 2% occur defect immediately failure. Besides, the mean delay time is approximately 112 days since the calculation interval for mean delay time is $1/\beta = 1/0.0089 \approx 112.35$. Thus, the performance of GA is good since the parameter values of GA and the estimated values using MLE do not differ significantly.

Table III: Best Solution of Warranty Cost

Experiment number, (i)	Best Solution of Warranty Cost, WC(i)	Errors
1	158.75	0.0122
2	241.82	0.0131
3	191.64	0.0140
4	185.57	0.0083
5	167.66	0.0132

Table III shows best solution of warranty cost in five times of running program. These results were the product of 100 generations with population size of 100, and a probability of crossover and mutation of 0.8 and 0.1 respectively. From the five experiments, we choose 185.57 as the best solution for warranty cost which selected based on smallest error. This is the result of warranty cost value incurred by manufacturer at the first free service.

The value of fitness function is plotted against number of iteration as illustrated in Fig. 2. It shows the value of the best fitness function of GA which means the optimum warranty cost is RM185.57. According to the figure, the optimal solution is obtained at the 56^{th} iteration.

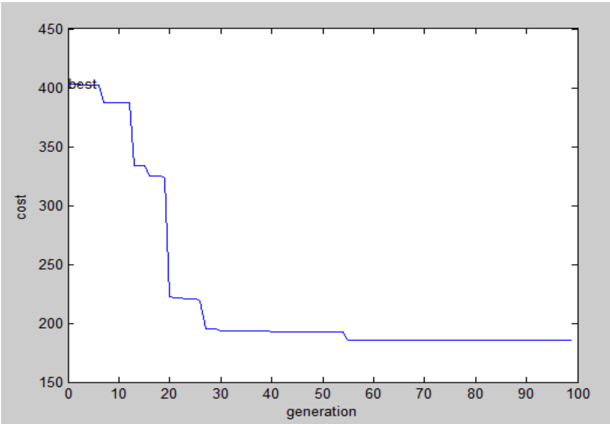

Figure 2: Fitness Function plot of GA

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

VII. CONCLUSION

In this paper, GA approach is implemented for optimizing parameters of warranty cost model. The results of GA were analyzed and compared with exact values based on error. Small error indicates a good result. Our findings show that GA is able to produce good results with small errors and need only function value which makes it easy to apply in real problem.

GA was found advantageous in finding global solution since it is a probabilistic search method. As a conclusion, the implementation of GA approach in optimizing the parameters of warranty cost model has been successfully applied. This technique can also be applied to many other optimization cases.

ACKNOWLEDGMENT

We are pleased to thank Ministry of Higher Education (MOHE), Research Management Center (RMC) and Universiti Teknologi Malaysia (UTM) for the support in making this project success. This work was funded by GUP Universiti Teknologi Malaysia (vot number: 02J30).

REFERENCES

[1] D. N. P. Murthy, O. Solem and T. Roren, “Product warranty logistics: Issues and challenges,” *European Journal of Operational Research*, Vol. 156, 2004, pp. 110–126.

[2] H. A. Majid, N. H. Kasim, N. I. Jamahir and A. A. Samah, “Soft computing methods in warranty problems: review and recent application (2003-2012),” International Journal of Computer Science Issues, Vol. 9, Issue 4, No. 3, July 2012, pp. 190-196.

[3] Jin, T. and Ozalp, Y., “Minimizing Warranty Cost by Design for Reliability in Product Development Phase,” *International Journal of Six Sigma and Competitive Advantage*.5, 2009, pp. 42-58.

[4] P. A. Scarf and H. A. Majid, “Modelling warranty extensions: a case study in the automotive industry,” *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, 2011, pp. 225- 251.

[5] R. Verma and P. A. Lakshminarayanan, “A case study on the application of genetic algorithm for optimization of engine parameters,” Proceeding of Automobile Engineering, Vol. 220, 2006, pp. 471-479.

[6] S. S. Chaudhry and W. Luo, “Application of Genetic Algorithms in Production and Operations Management: A Review,” *International Journal of Production Research.* 43, 2005, pp. 4083-4101.

[7] S. Y. Sohn, T. H. Moon, and K. J. Seok, “Optimal pricing for mobile manufacturers in competitive market using genetic algorithm,” *Expert Systems with Applications.* 36, 2009, pp. 3448-3453.

Hairudin Abdul Majid has received Diploma and Bachelor of Science in Computer Science-majoring Industrial Computing from Universiti Teknologi Malaysia in 1993 and 1995 respectively. In 1998, he obtained his M.Sc. in Operational Research and Applied Statistic from University of Salford, UK. Currently, he is a lecturer in Faculty of Computer Science and Information System, Universiti Teknologi Malaysia. His research interests focused on Image Processing, Operations Management and Warranty and Maintenance. Mr. Hairudin received Excellent Service Award by Universiti Teknologi Malaysia in 2004 and Excellent Staff Award by ISS Service in Manchester UK in 2006. Mr. Hairudin is the author of about 19 papers, 1 book chapter entitled ‘Recent Operations Research Modelling and Applications (Warranty Modelling)’ (UTM, 2009) and 1 text book entitled ‘Permodelan Simulasi’ (UTM, 2000). He has been a member of UK Operational Research Society and an active member of Operations and Business Intelligence (OBI) Research Group.

Nur Hayati Kasim has received Bachelor of Science (major in mathematics) from Universiti Teknologi Malaysia in 2011. Currently, she is doing her M. Sc. in Computer Science from Universiti Teknologi Malaysia and has two paper publications.

Azurah A. Samah has received the Diploma and Bachelor from Universiti Teknologi Malaysia in 1991and 1993 respectively. In 1996, she obtained her M.Sc. from the University of Southampton, UK and recently in 2010, she received her Ph.D from Salford university, UK. Currently, she is a lecturer in Faculty of Computer Science and Information System, Universiti Teknologi Malaysia. Her research interests encompass Image Processing, Soft Computing Techniques and Operational and Simulation Modeling.