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Reliability Analysis of Vehicle Side Impact based on Wolf Pack Algorithm

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Abstract

Based on the Wolf Pack algorithm, this paper analyzes the reliability of a vehicle side impact model, builds the uncertainty mathematical model by introducing the parameter correlation, and transforms the constrained model into the unconstrained model by using the augmented Lagrangian multiplier method, based on which the reliability analysis of the vehicle side impact problem is carried out. It is found that the differential evolution algorithm can solve the reliability optimization problem with parameter correlation, and it also has high calculation efficiency and good convergence for the calculation of the limit state equation with high nonlinear degree, which verifies the feasibility of the present algorithm for the more complex reliability optimization problem.

Keywords

Wolf Pack Algorithm; Reliabilityanalysis; Augmented Lagrangian Multiplier Method.

1. Introduction

With the development of industry, automobile has become the main means of transportation. The increasing number of cars has also led to a large number of traffic accidents. In order to reduce traffic accidents and find traffic hidden dangers in advance, more and more scholars pay attention to the reliability analysis of vehicle collision. In reliability analysis, there are many uncertain factors, such as the properties of materials, splicing process and manufacturing accuracy. Traditional methods are difficult to solve these problems, so the research of intelligent algorithm is particularly important. In recent years, experts and scholars have conducted in-depth research on this issue [1-6]. Wang et al. combined BP neural network with particle swarm optimization algorithm, put forward a new reliability evaluation method of landslide [7]. Liu et al. put forward a unit commitment model, which considers economy and reliability, and used the most reliable index of system reliability to calculate. At the same time, the validity of the model was verified by using adaptive genetic algorithm [8]. Shen et al. put forward an improved artificial bee colony search algorithm to analyze the reliability of key parts of rolling stock and made a scientific plan for the maintenance cycle of rolling stock [9]. Xu et al. analyzed the non probabilistic reliability optimization problem of interval model by using the improved moth flame algorithm for the more complex reliability double nesting problem, which provided a new research idea for the non probabilistic reliability optimization of structure [10].

Through the research of the above scholars, this paper studies the vehicle side impact in the reliability optimization problem. The mathematical model of vehicle side impact is established and calculated by Wolf pack algorithm. The Wolf pack algorithm can solve the reliability

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problem of nonlinear equations to a certain extent. The effectiveness of the proposed method is verified by an example of vehicle side impact.

2. Introduction of Wolf Pack Algorithm and Establishment of Reliability Index

2.1. Introduction to Wolf Pack Algorithm

Wolf Pack Algorithm (WPA) is an intelligent algorithm based on the three behaviors of Wolf wandering, calling and siege. The algorithm adopts bottom-up design method based on artificial Wolf theme and cooperative search path structure based on division of responsibilities. The specific steps of Wolf pack algorithm are given as follows:

Step 1: Numerical initialization. Initialize the artificial Wolf position Xi and its number N, the maximum iteration number kmax, the scale factor α, the maximum migration number Tmax, the distance determination factor W, the step size factor S, and the update scale factor β.

Step 2: The optimal artificial Wolf is selected as the head Wolf, and the other artificial wolves is selected as scouts and carries out the migration behavior until the prey odor concentration Y_i detected by one scout is greater than the prey odor concentration Y_{lead} perceived by the head Wolf or reaches the maximum number of migration T_{max}, then go to Step 3.#

Step 3: The artificial fierce Wolf rushes to the prey. If the concentration of prey scent perceived by the fierce Wolf is $Y_i > Y_{lead}$, $Y_{lead} = Y_i$ will replace the head Wolf and initiate the call behavior. If $Y_i < Y_{lead}$, the artificial fierce Wolf continues to run until $D_{is} \le D_{near}$, then go to Step 4.

Step 4: Update the position of the artificial wolves involved in the siege and perform the siege.

Step 5: Update the position of rival Wolf according to the "winner takes all" rule of head Wolf generation; Then, according to the Wolf renewal mechanism of "survival of the strong", the population renewal is carried out.

Step 6: Judge whether the optimization accuracy requirements or the maximum number of iterations kmax are met. If so, output the position of the head Wolf, namely the optimal solution of the problem; otherwise, go to Step 2.

2.2. Reliability Index Establishment

It is assumed that the limit state equation of the actual engineering structure is expressed as $Z=g(X_1,X_2,\ldots\ldots,X_n)=0$, in which $X_1,X_2,\ldots\ldots,X_n$ is independent random variable with arbitrary distribution. R-F (lakowitz fissley method) is used to normalize the equivalent of non normal variables, and the normal distribution variables such as meanσ'_{x_i}, standard deviation μ'_{xi} and reliability index β are derived.

$$\sigma'_{xi} = \phi\{\Phi^{-1}[F_{xi}(xi^*)]\} / f_{xi}(X_i^*) \tag{1}$$

$$\mu'_{xi} = X_i^* - \Phi^{-1}[F_{xi}(xi^*)] / \sigma'_{xi} \tag{2}$$

$$\beta = (\sum[(X_i^* - \mu'_{xi}) / \sigma'_{xi}]^2)^{1/2} \tag{3}$$

The initial design point is unknown. If the minimum reliability index value β is required, β should be regarded as a function of the point $P(X_1,X_2,\ldots\ldots,X_n)$ on the surface of the limit state equation. The design point P and the minimum reliability index β are derived. The mathematical model of reliability index is established as follows:

$$Min\beta^2 = \sum_{i=1}^{n}[(X_i^* - \mu_{xi}^{'}) / \sigma_{xi}^{'}]^2 \tag{4}$$

$$s.t.Z = g(X_1^*, X_2^*, ..., X_n^*) = 0 \tag{5}$$

3. An Example of Vehicle Side Impact Reliability

The reliability analysis is carried out for an example of vehicle side impact, and the finite element model is shown in the Figure 1. The limit state equation can be expressed as:

$$g(x) = -0.75 + 0.489x_1x_4 + R(x_2, x_3) - R(x_5, x_6) + 0.0556x_5x_7 + 0.000786x_7^2$$

Fig 1. Finite element model of vehicle side impact

Among them

$$i = \begin{cases} 1 \sim 4, \ldots x_i \sim N(1.0, 0.005) \\ 5, \ldots\ldots\ldots x_i \sim N(0.3, 0.006) \\ 6 \sim 7, \ldots x_i \sim N(0.0, 10.00) \end{cases}$$

where, g(x) is the vehicle response surface equation; R(x2,x3) represents vehicle side collision avoidance amount; $R(x_5,x_6)$ represents the amount of guardrail collision avoidance, and the corresponding relationship of each variable is shown in Table 1.

Table 1. Relationship of random variables

variable	name	distribution type
x_1	The inside of the floor	Normal distribution
x_2	Door bumper	Normal distribution
x_3	Door waist line reinforcement plate	Normal distribution
x_4	The roof	Normal distribution
x_5	The floor	Normal distribution
x_6	Barrier height	Normal distribution
x_7	Height position of guardrail	Normal distribution

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The Wolf pack algorithm is used to calculate the reliability index of the example in this paper, and the results are compared with the Monte Carlo method, as shown in Table 2. The fitness curve of the example calculated by the Wolf pack algorithm is shown in Figure 2.

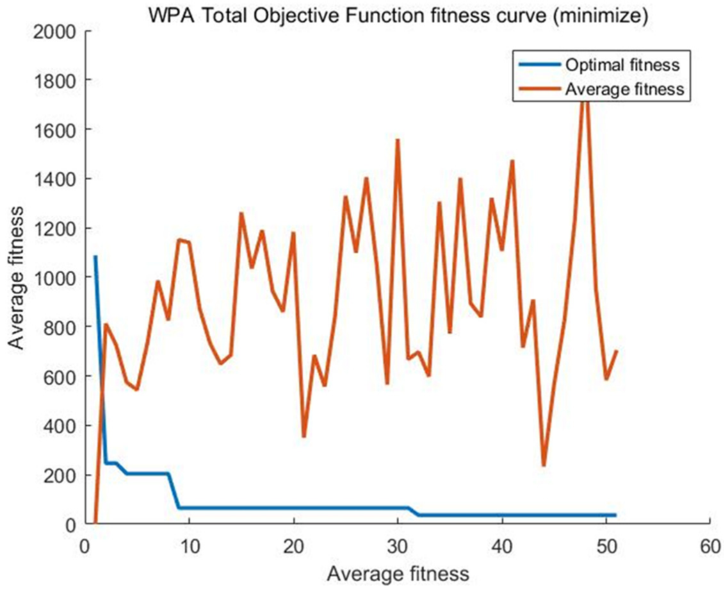

Fig 2. Fitness curve of Wolf Pack Algorithm

Table 2. Calculation results

Method	Reliability index	Failure probability	Iteration times
MC	4.1645	1.5600e-05	-
WPA	3.7304	9.5596e-05	31

As can be seen from Table 2, the reliability index β= 4.1645 and failure probability Pf=1.5600E-05 calculated by Monte Carlo method. After Wolf algorithm optimization, the stable reliability index β= 3.2562 and failure probability Pf= 5.6457E-04 are obtained in 31 steps. The stability value is obtained, and the obtained reliability index is better than monte Carlo method, which verifies the feasibility of the present algorithm for reliability index calculation.

4. Conclusion

In this paper, Wolf Pack optimization Algorithm is studied and an example of vehicle side impact is analyzed by using the present algorithm. The reliability index value is obtained. The reliability index calculated by the proposed method is compared with that calculated by monte Carlo method, and it is found that the calculated results of the proposed method are better than those of Monte Carlo method. It shows that the Wolf pack algorithm can solve the problem with certain nonlinear limit state equation. In practical engineering structures, Wolf pack optimization algorithm has a certain guiding significance for the reliability calculation of structures.

Acknowledgments

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