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Research on Parameter Calibration Method of Microscopic Traffic Simulation Model Based on Improved Genetic Algorithm

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Abstract

The parameter calibration of the micro-traffic simulation model is a prerequisite for the application of micro-traffic simulation technology. This paper aims at the average queuing length in the simulation model as an index to evaluate the advantages and disadvantages of the simulation model parameters, taking the evening peak signal intersection of Waijiang Road-Yongkang Road intersection in Yibin City, and an improved genetic algorithm is proposed to calibrate the parameters of the microscopic traffic simulation model, and analyzes the average queuing length in driving behavior using VISSIM software simulation. The actual traffic operation conditions are analyzed and compared, which proves the feasibility of the parameter calibration method of the micro-traffic simulation model based on the improved genetic algorithm.

Keywords

Microscopic Traffic Simulation Model; Improved Genetic Algorithm; VISSIM Simulation; Parameter Calibration.

1. Introduction

Compared with the traditional mathematical model, micro traffic simulation technology can track and describe various traffic phenomena such as simulated traffic flow and traffic accidents in time and space, and analyze the changeable and complex human, vehicle and road traffic characteristics and the temporal and spatial characteristics of traffic flow, overcoming the problem that existing mathematical models are difficult to accurately describe traffic laws. Microscopic traffic simulation model through a large number of independent parameters to describe traffic characteristics, etc., the use of foreign software development set by the default parameters of the traffic model simulation of China's traffic situation is still inappropriate, in order to improve the applicability of simulation software, reflect the most real traffic operation situation, establish a more realistic simulation model, so simulation model parameter correction is an extremely important step of micro traffic simulation. At present, a large number of research records have been carried out in domestic and foreign academic literature for the parameter calibration method of microscopic traffic simulation model, including Latin hypercube algorithm, simulated annealing algorithm (SA), orthogonal test algorithm, genetic algorithm (GA), synchronous perturbation stochastic approximation algorithm (SPSA), etc.

Yang [1, 2] proposed to use the Latin hypercube algorithm and the genetic simulation annealing heuristic algorithm to correct the simulation parameters of VISSIM, and selected intersections as examples to find the optimal solution of satisfactory parameter set. In order to verify the applicability of the orthogonal test method in the parameter calibration of the VISSIM simulation model at the intersection, Zhang and Niu [3] took the Shijiazhuang intersection as an example, selected five calibration level parameters, used the orthogonal experimental method to carry out orthogonal design experiments, and combined with range analysis to determine the validity of the proposed values of the parameters to be determined. AU Giuffre [4] proposed a microscopic traffic simulation model calibration method based on genetic algorithm, which aims to use genetic algorithm to assign optimal values to driver and vehicle simulation parameters in the microscopic traffic simulation software AIMSUN, taking two roundabouts as an example, the total random effect estimate is obtained by meta-analysis, and the empirical ability function is used as the basis for calibration parameters, defines the model objective function, and minimizes the difference between the empirical capability function and the simulated data. The results show that the GA optimization parameters are good and suitable for calibrating the parameters of the microscopic simulation model. Zhang [5] considered the problems of genetic algorithm, cumbersome decoding process and slow algorithm search speed, and proposed a parameter calibration method based on synchronous perturbation stochastic approximation (SPSA) algorithm, taking the West Third Ring Road section of Beijing as the research field, using GA and SPSA algorithms to calibrate 10 driver behavior parameters in the model, and the results showed that the SPSA algorithm was 1.7 times faster than the GA algorithm compared with the convergence speed. Mohammad [6] proposed a general parameter calibration tool VISCAL based on three heuristic optimization algorithms (genetic algorithm, synchronous perturbation random approximation algorithm and simulated annealing algorithm) for microscopic simulation parameters in the VISSIM simulation environment, and obtained the best estimate of parameters by performing sensitivity analysis on the parameter calibration pending value obtained in the multi-objective function.

The purpose of this paper is to improve the fitness function, selection, crossover, mutation, etc. in the traditional genetic algorithm, propose a microscopic traffic simulation model parameter calibration method based on the improved genetic algorithm, and carry out the simulation model parameter calibration optimization design, taking the intersection of Waijiang Road and Yongkang Road in Yibin City as an example, select the corrected model parameter set, and introduce the improved genetic algorithm to realize the VISSIM simulation model parameter calibration.

2. Simulate Model Parameter Calibration and Optimization Design

2.1 Section Headings

According to the research and analysis of the microscopic traffic simulation model parameter calibration process, the existing simulation calibration process framework is improved accordingly, as shown in Figure 1, the details are described below:

1) Establish a simulation model. After comparing, analyzing and preprocessing the obtained electronic police data with the actual data, the traffic operation status of the geometric intersection within the research scope is reproduced by using the VISSIM micro traffic simulation software to build a traffic simulation real scene model.

2) Initial parameter evaluation. Check whether the default model parameter set value is feasible, compare the operating traffic situation of the simulation model with the actual traffic situation, if the simulation results of the micro traffic simulation model are consistent with the field scenario, no further parameter calibration optimization is required, otherwise, parameter calibration optimization is required.

3) Check parameter index selection. The parameter set collected by the field data can be compared with the simulation model data as the calibration data, that is, the index basis for parameter calibration. According to the determination of parameters and the selection of benchmark parameter indicators, calibration parameter indicators need to meet the principles of practicality, sensitivity, consistency, comparability and effectiveness. Through the summary of a large number of literature, under the constraints of field investigation data and road geometric characteristics, the following parameters are usually selected: a. delay; b. Queue length; c. Travel time; d. Traffic flow; e. Driving speed. The field survey data was used as the parameter index, and the parameter calibration and optimization were carried out by comparing the parameter results of the micro traffic simulation model.

4) Select the optimization algorithm. At present, the parameter calibration optimization algorithm of the surrounding traffic simulation model is described in the frontier, and the combined optimization methods include linear interpolation algorithm, simplex search method, gradient search method and

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genetic algorithm. The genetic algorithm is a globally optimized probabilistic algorithm, which takes the objective function as the search information, and its population search characteristics can avoid falling into local problems; However, at the same time, genetic algorithms are inefficient and prone to premature convergence. Therefore, this paper calibrates parameters based on genetic algorithm, improves the algorithm, strengthens the search ability, improves the convergence speed and accuracy of the algorithm, and searches for the optimal solution in the given known objective function value.

5) Determine the objective function. The objective function is to find the optimal solution that is the least different between the actual survey traffic data and the simulation data of the micro traffic simulation model.

6) Simulation optimizes operating parameters. The calibrated parameter values are used to simulate microscopic traffic and obtain the simulation optimization parameter data.

7) Result verification. Compare the optimized traffic simulation results with the actual survey traffic data to evaluate whether the parameter calibration is reasonable, and if it is reasonable, end the parameter calibration; If it is not reasonable, proceed with parameter calibration.

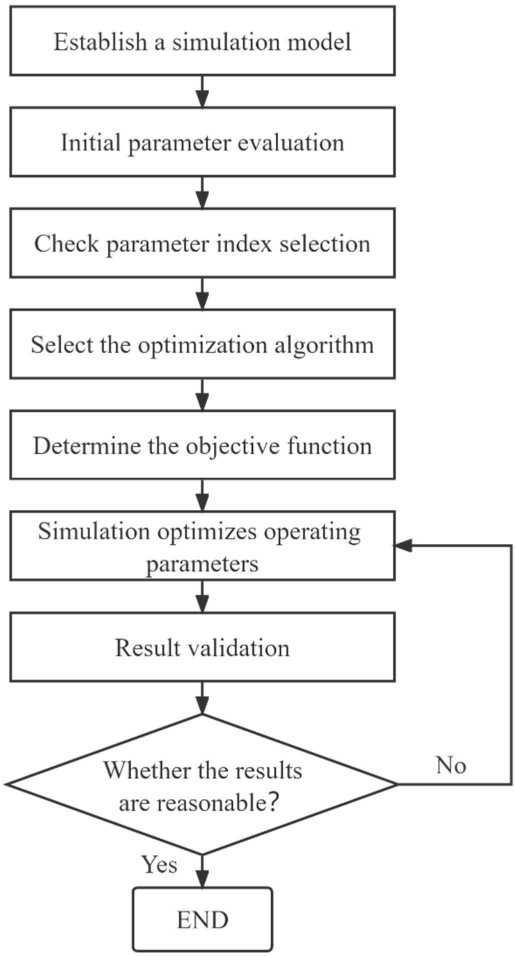

Fig 1. Microscopic simulation model calibration process

3. Model

Genetic algorithm (GA, Genetic Algorithm) originated from the computer simulation research of biological systems, also known as evolutionary algorithms, borrowing from biological evolution theory and proposed a heuristic algorithm, its essence is an efficient, parallel, global search method, its iterative search process is to the biological "survival of the fittest" concept of the population in the highly adaptive individuals to continuously select, cross and mutate operations, can automatically obtain and accumulate knowledge about the search space in the search process and adaptively control

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the search process to find the best solution [7]. The optimization iterative process based on genetic algorithm is shown in figure 2:

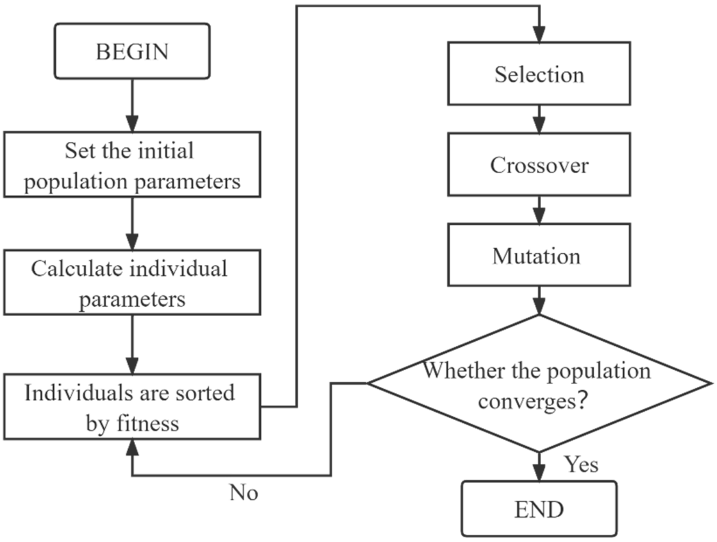

Fig 2. Genetic algorithm optimization iterative process

3.1 Fitness Function Design

The design of the fitness function is crucial to the optimization search process of genetic algorithms. Improper selection and design of fitness function may affect global optimization due to abnormal fitness of an individual in the population in the early stage of genetic algorithm optimization. Or in the later stage of genetic algorithm optimization, because the individual fitness in the population is not much different, it is impossible to continue the optimization iteration and it is easy to fall into the situation of local optimization. Therefore, in different optimization problems, the fitness function used will be set according to the specific optimization goal, and the fitness function is formed by the change of the objective function.

In this paper, the average queuing length of the intersection is taken as the evaluation index for the calibration of the parameters of the traffic simulation model, and the three parameters of Y (the average vehicle spacing when parking), bx_{add} (the safety distance sum item) and bx_{mult} (the safety distance multiplier item) are selected as the calibration set according to the Wiedemann74[8] Car-following model, and the model form is as follows:

$$Y = ax + bx \tag{1}$$

$$bx = (bx_{add} + bx_{mult} \times z) \times \sqrt{v} \tag{2}$$

where z is an immediate factor between 0 and 1 that follows a normal distribution and v represents vehicle speed. The average queuing length in the simulation is compared with the actual average queuing length, and the root rmse index of mean squared deviation in the regression model is used as the fitness function, and the objective function f(x) to be solved can be converted into the fitness function Fit(f(x)):

$$F = \frac{1}{RMSE} = \sqrt{\frac{n}{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}} \tag{3}$$

where F is the fitness function, which is equal to F is the fitness function, which is equal to the reciprocal of the rms error of y_i (the actual average queuing length) and $\hat{y}_i$ (the simulated average queuing length).

3.2 Improved Genetic Algorithm Process

This paper improves the traditional genetic algorithm, and the basic process of improved genetic algorithm is as follows:

1) Encode. By analyzing the parameter characteristics of the microscopic traffic simulation model proposed in this paper, each parameter can be encoded by real numbers, and the parameters can be coded and described with intuitive and simple real numbers, and it is easy to convert real numbers back to actual parameter values in the algorithm. Table 1 describes the encoding information of the parameters.

Table 1. Relevant parameter encoding information

Parameter name	The range of independent variables$[U_{min}, U_{max}]$	Default value	Gene length l	Search precision δ
Average parking distance (m)	[1, 4]	2	4	0.20
Safety distance sum item	[1, 4]	2	4	0.20
Safety distance multiplier item	[2, 5]	3	4	0.20

The binary encoding and decoding formula are as follows [9]:

$$\delta = \frac{(U_{\max} - U_{\min})}{(2^l - 1)} \tag{4}$$

$$x_i = \delta_i \times A \times B + U_{i\min} \tag{5}$$

$$A = (\alpha_1, \alpha_2, \cdots, \alpha_{n_j}) \tag{6}$$

$$B = (2^{n_j - 1}, \cdots, 2, 1)^T \tag{7}$$

Where x_i represents the ith calibration parameter (i=1, 2, 3). δ is the coding accuracy of the ith calibration parameter and n_i is gene length for the ith calibration parameter.

2) Initial group setting. The process mainly includes two aspects, the first is the generation of the initial population, this paper adopts random sampling, first randomly generate a certain number of individuals, and then select the best individuals to join the initial population, through the algorithm for continuous iteration, until the number of individuals in the group reaches a set size. The second is the determination of population size, and the key link in the process is how to "jump" out of the local optimal and find the global optimal solution. In order to analyze in more detail, the degree of influence of each parameter on the simulation results, set the maximum and minimum values for each parameter separately, combined with the default values of other parameters as the initial population of the algorithm.

3) Fitness assessment. To determine the advantages and disadvantages of the parameter combination corresponding to an individual, one is to see whether the parameter value meets the value range given by the constraint condition; The second is to look at the size of its fitness function value. In this paper, the reciprocal of rms error between the actual queuing length of the intersection and the average queuing length output by the simulation model is used as the fitness function, and the larger F, the smaller the error between the actual value and the simulated value. Therefore, the larger the value of the function, the higher the individual fitness and the better the individual.

4) Genetic algorithms have three basic operations: selection, crossover, and mutation.

Selection refers to the selection of individuals from the previous generation of the population according to probabilities until a new generation is formed. For the probability of the parent generation being selected by the parent generation with relatively good degree of freedom function, the elite (superior individual) retention strategy is implemented for the population before and after the crossover, and the probability calculation formula of the parent individual being selected into the next generation is as follows by normalizing the individual fitness:

$$P(x_i) = \frac{F(x_i)}{\sum_{i=1}^{M} F(x_i)} \tag{8}$$

Crossover operation, understood in genetic algorithms as the process of selection, that is, copying parent individuals to form offspring individuals, using a single-point crossover method, setting the cross-probability bit 0.7. The cross-operation flow is shown in Figure 3.

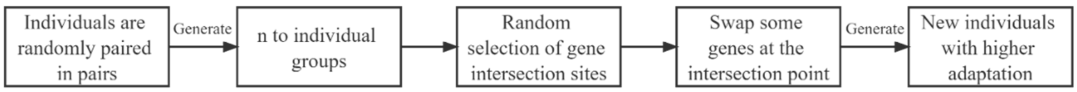

Fig 3. Cross-operation flowchart

In the mutation operation, the DNA is cut at the same location of the two chromosomes, and the two strings are crossed and combined to form two new chromosomes, that is, gene recombination or hybridization.

3.3 Result Test

The simulation results are tested by visual comparison and fitness function values. Firstly, the simulation is carried out according to the calibration parameter values, and the microscopic traffic simulation status is observed and compared with the observable data of the actual traffic situation, and whether the calibration parameters are preliminarily judged whether the calibration parameters are valid. Secondly, according to the fitness function value, whether the final calibration parameter value meets the calibration index.

4. Case Study

4.1 Data Collection and Simulation Model Building

In order to verify the applicability of the improved genetic algorithm proposed in this paper to the calibration of microscopic traffic anyway model parameters, the traffic operation at the intersection of Waijiang Road and Yongkang Road in Yibin City was used as the calibration object, and the field investigation content mainly included: 1) road geometric characteristics; 2) Signal timing control; 3) Traffic conditions, etc. Combined with the obtained electronic police data for preprocessing, comparing the morning and evening peak traffic flow and road characteristics, finally using the evening peak (17:30-18:30) as the road simulation data, the preliminary collation results of the road data are shown in Table 2:

According to the actual survey data, the two import roads in the east-west direction are set up consistently: 3 import roads (straight ahead, straight right, left turn), width 3.5 meters, 2 exit roads with a width of 3.5 meters, with non-motorized lanes; the two north-south import roads are set up the same: 3 import roads (straight, right turn, left turn), width 3 meters, 2 exit roads with a width of 3.5 meters, with non-motorized lanes. The east, west, south, and north entrance roads are equipped with green separation belts, and non-motorized lanes are equipped to build traffic simulation scenarios, and the road CAD base map and traffic simulation scene diagram are shown in Figures 4 and 5.

Table 2. Hourly traffic volume of each entrance (pcu/h)

Direction		Number of lanes	Single lane width (m)	Traffic Flow (pcu/h)	Total traffic (pcu/h)
	Left	1	3.5	101	
North import	Straight	1	3.5	259	452
	Right	1	3.5	92	
	Left	1	3.5	112	
East import	Straight	1	3.5	448	920
	Right	1	3.5	360	
	Left	1	3	92	
South import	Straight	1	3	234	430
	Right	1	3	104	
	Left	1	3	44	
West import	Straight	1	3	427	805
	Right	1	3	334	

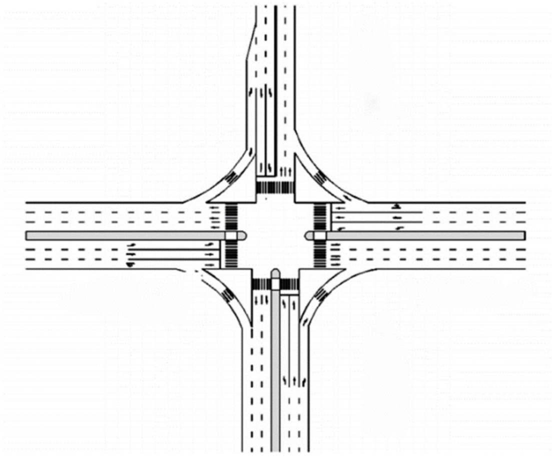

Fig 4. CAD effect of intersection

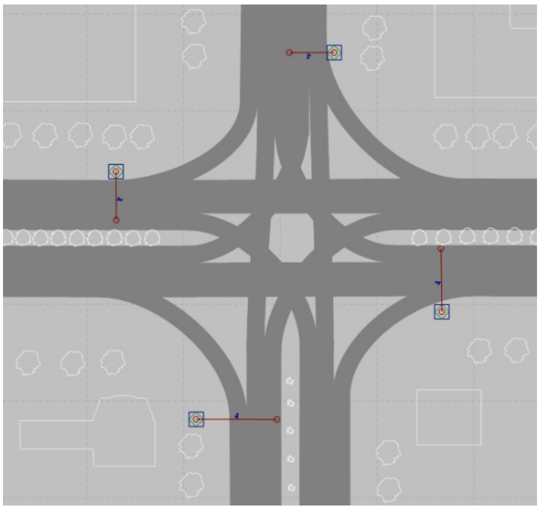

Fig 5. Simulation scene of signalized intersection

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The intersection of Waijiang Road and Yongkang Road in Yibin City is the peak hour of weekdays during the actual investigation period, and the signal timing is selected as a peak green wave scheme, with a total signal period of 135s, including 4 phases of east-west straight (straight right turn), east-west left turn, north-south straight and north-south left turn, and the specific duration scheme of each phase is shown in Figure 6.

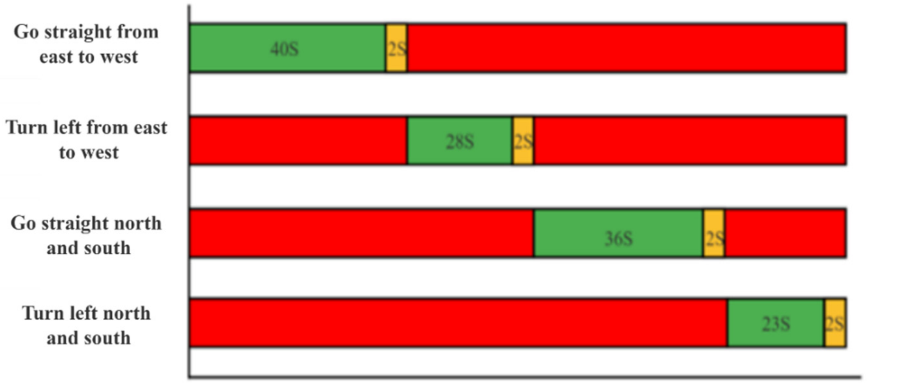

Fig 6. Timing scheme of signalized intersection

The actual measurement data of the average queue length of each entrance straight lane at the intersection of Waijiang Road and Yongkang Road is shown in Figure 7. According to the historical data of the intersection, the average queuing length of each straight entry lane of the intersection is obtained, the intersection measurement point is determined, and the actual average queuing length of each straight lane of each entrance road in the measurement period is obtained through manual measurement.

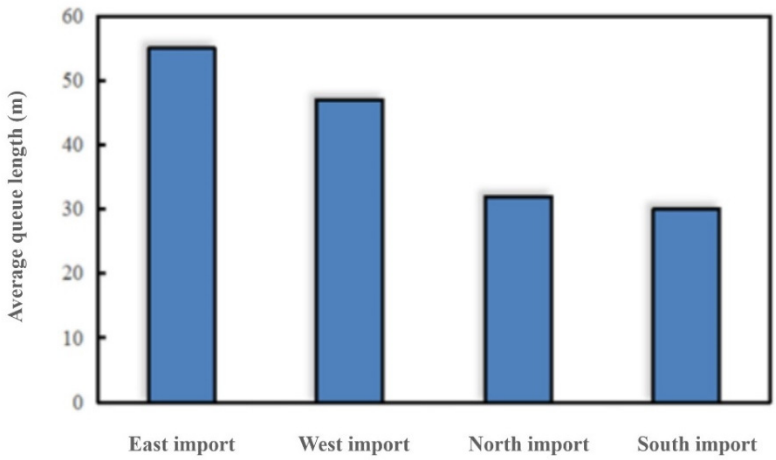

Fig 7. The actual average length of queues for each entrance lane

4.2 Microscopic Simulation Model Parameter Correction and Results

Table 3. Pending parameter optimization results

Parameter name	The range of independent variables$[U_{min}, U_{max}]$	Default value	Calibration results
Average parking distance (m)	[1, 4]	2	2.60
Safety distance sum item	[1, 4]	2	1.90
Safety distance multiplier item	[2, 5]	3	3.40

Based on the above improved genetic algorithm, the parameters to be determined in the microscopic traffic simulation model are calibrated and optimized, and the optimization results of the pending parameters are shown in Table 3.

By comparing the actual survey values, the default parameter environment and the simulation results after parameter calibration, the validity of parameter calibration is verified, and the analysis results of the average queuing length of each straight entry lane at the intersection are shown in Table 4. Compared with the actual survey data analysis, the average queuing length of each straight entry lane at the intersection has improved the accuracy rate.

Table 4. Analysis of the average queue length of each straight-line entrance lane

Direction of the entrance road	Survey data	Default value	Calibration results	Lift rate
East import	55.8	52.92	53.12	0.36%
West import	49.5	44.57	47.75	6.42%
North import	34.6	28.80	31.78	8.62%
South import	35.1	33.93	37.75	10.83%

5. Conclusion

This paper takes the average queuing length as the evaluation target, the sum of the average stopping distance, the sum of the safety distance and the multiplier of the safety distance as the calibration set, and combines the actual intersection as the case analysis to verify the feasibility of the parameter calibration method of the micro traffic simulation model based on the improved genetic algorithm, and compares the simulation results with the default parameter values and optimized parameter values with the actual traffic operation data, which fully confirms the operability of the improved genetic algorithm proposed in this paper in the parameter calibration of the micro traffic simulation model.

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