CONSTRUCTION OF A MATHEMATICAL MODEL BASED ON A GENETIC ALGORITHM FOR AN APTITUDE PROGRAM IN HIGH SCHOOL STUDENT OPTIMIZATION

CONSTRUÇÃO DE MODELO MATEMÁTICO BASEADO NO ALGORITMO GENÉTICO PARA OTIMIZAÇÃO DE UM PROGRAMA DE APTIDÃO EM ESTUDANTES DO ENSINO MEDIO

CONSTRUCCIÓN DE UN MODELO MATEMÁTICO BASADO EN UN ALGORITMO GENÉTICO PARA LA OPTIMIZACIÓN DE UN PROGRAMA DE APTITUDES EN ESTUDIANTES DE SECUNDARIA

Original Article
Artigo Original
Artículo Original

Yu Xiao[1]
(Sports Education Professional)

1. Changzhou Institute of Industry Technology, Changzhou, Jiangsu, China.

Correspondence:
Yu Xiao
Changzhou, Jiangsu, China.
212221.
czxiaoyu2019@126.com

ABSTRACT

Introduction: The genetic algorithm is one of the essential theoretical mathematical models for simulating biological development. It is widely used in many fields such as engineering, medicine, and economics. Objective: Use the genetic algorithm as a mathematical model basis for optimization in the high school students' aptitude program. Methods: The selection method by competition is adopted to elect the random crossover of male crossover probability with high similarity to generate a new population. A genetic algorithm was proposed to adjust the crossover probability and dynamic mutation according to fitness, aiming to solve the problem of dynamic changes. A comparative analysis is performed between the nonlinear differential equations and the Levenberg–Marquardt method algorithm. Results: The algorithm improvement was obtained after analyzing the operation process and structuring of the traditional genetic algorithm; the mathematical model application revealed improvement in the motion accuracy model established by the genetic algorithm. Conclusion: The physical enhancement optimization scheme was tested and verified by a genetic algorithm and proves the research results hold theoretical feasibility. ***Evidence Level II; Therapeutic Studies – Investigating the results.***

Keywords: Fitness; Process Optimization; Students.

RESUMO

Introdução: O algoritmo genético é um dos mais importantes modelos matemáticos teóricos para simulação de desenvolvimento biológico. É amplamente utilizado em muitos campos, tais como engenharia, medicina e economia. Objetivo: Utilizar o algoritmo genético como base de um modelo matemático para otimização no programa de aptidão nos estudantes do ensino médio. Método: Adota-se o método de seleção por competição para eleger o cruzamento aleatório da probabilidade de crossover masculino com grande semelhança para gerar uma nova população. Um algoritmo genético foi proposto para ajustar a probabilidade de crossover e mutação dinâmica de acordo com a aptidão física, visando resolver o problema das alterações dinâmicas. Efetua-se uma análise comparativa entre os resultados das equações diferenciais não-lineares e o algoritmo de Levenberg-Marquardt de quarta ordem. Resultados: O aperfeiçoamento do algoritmo foi obtido após a análise do processo de operação e estruturação do algoritmo genético tradicional, a aplicação do modelo matemático revelou melhora na precisão do modelo de movimento estabelecido pelo algoritmo genético. Conclusão: O esquema de otimização do aprimoramento físico foi testado e verificado por um algoritmo genético provando que os resultados da pesquisa possuem praticabilidade teórica. ***Nível de evidência II; Estudos Terapêuticos - Investigação de Resultados.***

Descritores: *Aptidão Física; Otimização de Processos; Estudantes.*

RESUMEN

Introducción: El algoritmo genético es uno de los modelos matemáticos teóricos más importantes para la simulación del desarrollo biológico. Se utiliza ampliamente en muchos campos como la ingeniería, la medicina y la economía. Objetivo: Utilizar el algoritmo genético como base de un modelo matemático de optimización en el programa de aptitud para estudiantes de secundaria. Método: Se adopta el método de selección por competencia para elegir el cruce aleatorio de probabilidad de crossover masculino con alta similitud para generar una nueva población. Se propuso un algoritmo genético para ajustar la probabilidad de cruce y la mutación dinámica en función de la aptitud, con el fin de resolver el problema de los cambios dinámicos. Se realiza un análisis comparativo entre los resultados de las ecuaciones diferenciales no lineales y el algoritmo de Levenberg-Marquardt de cuarto orden. Resultados: La mejora del algoritmo se obtuvo tras el análisis del proceso de funcionamiento y estructuración del algoritmo genético tradicional, la aplicación del modelo matemático reveló la mejora de la precisión del modelo de movimiento establecido por el algoritmo genético. Conclusión: El esquema de optimización de la mejora física se probó y verificó mediante un algoritmo genético, demostrando que los resultados de la investigación tienen viabilidad teórica. **Nivel de evidencia II; Estudios terapéuticos - Investigación de resultados.**

Descriptores: *Aptitud Física; Optimización de Procesos; Estudiantes.*

DOI: http://dx.doi.org/10.1590/1517-8692202228052021_0537 Article received on 12/12/2021 accepted on 01/20/2021

INTRODUCTION

The genetic algorithm has the characteristics of global random search for the best individual and the process of biological evolution. The use of genetic algorithm to optimize the construction of middle school students running optimization program has a good theoretical basis.[1] The most representative results of genetic algorithm are Darwin's evolutionism and Mendel's genetics. Genetic algorithm provides an intelligent model for human's work and life to find the internal law behind things by mathematical model.[2] In 1940s, the United States pioneered the adaptive optimization genetic algorithm that could effectively solve complex systems and complex computing in the world, which led the research.[3] Compared with other artificial intelligence algorithms, genetic algorithm has the advantages that it can search autonomously after determining parameters such as fixed coding scheme, fitness function and genetic operator. In the search, selection, crossover, mutation, and other operations can get a better sample of the next generation.[4] The algorithm can effectively overcome the limitations of other algorithms, and can only choose the initial point in the feasible solution space, which may fall into the local minimum. After the introduction of genetic factors, the genetic algorithm can search the global, so that the new generation of population always maintains the optimal structure, and find the global optimal solution.[5] Therefore, the fitness running program of middle school students based on genetic algorithm model is optimized in this paper.

According to the fitness value of individuals in different problem domains, a new approximate solution is found in the process of selection, crossover and optimization to simulate the process of population evolution in natural environment, so that new individuals can better adapt to environmental requirements than the old individuals. Genetic factors can optimize the population set, and maintain the good structure to the next generation.[6,7] Genetic factors can respond to changes in exercise content, route and mode of exercise. In the search process, we can actively acquire and accumulate all kinds of knowledge in the search space, and adaptively control the search process to get the best solution.[8] The research of fitness running scheme based on genetic algorithm can use mathematical model and mathematical logic. The qualitative analysis based on experience changes to the quantitative analysis by mathematical algorithm. If the program plan of fitness running cannot meet the students' moving goals and needs, it is necessary to redesign the mode and method of movement. Therefore, this paper is to optimize the fitness running program model based on genetic algorithm. The calculation of fitness degree of genetic algorithm is mainly based on the improvement of cross probability and mutation probability formula to enhance the adaptability of genetic algorithm, improve the global search ability, and make the local search ability better.[9] This basic search requires preprocessing of the original sample to adapt to the structure of the genetic algorithm, and it takes a lot of time to encode and decode. Therefore, it has a great impact on the efficiency and the cycle of the genetic algorithm.[10] Therefore, in this study, the author devotes to optimize the genetic algorithm, which is more suitable for the preparation of fitness program, and the improvement of the efficiency and quality of fitness program.

METHODOLOGY

Genetic algorithm

The main theoretical basis of genetic algorithm is to use mathematical model to simulate biological evolution process. The crossover and variation of chromosomes in the process of life evolution are used to achieve population evolution. Genetic factors are introduced into the sample population, and then a new generation of population is obtained after selection, crossover and mutation. In order to ensure the optimality of the population, the iterative search training is carried out for many times, and finally the individual with the maximum fitness is chosen as the optimal solution. The genetic algorithm uses binary encoding. In general, binary symbols with fixed lengths represent different individuals of the population, and their corresponding genes are also composed of symbol sets {0,1}. The individual tree encoding of the genetic algorithm is shown in Figure 1.

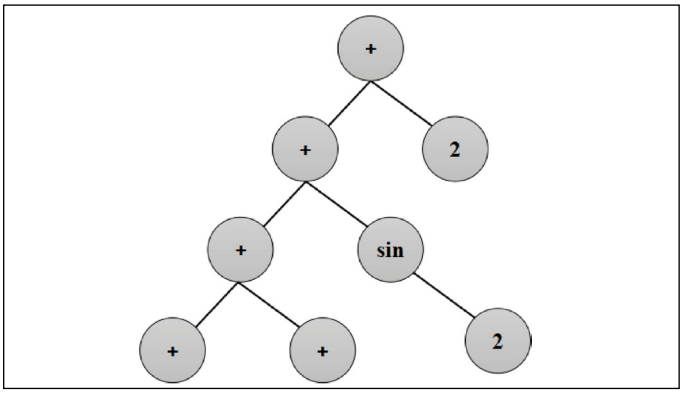

Figure 1. Individual tree structure coding graph of genetic algorithm.

In the selection of genetic algorithm, roulette is the main way, that is, the choice through the proportion. Crossover operation is to cross a single point, and set cross probability as a fixed value. The mutation operation is based on variation, and the crossover probability is also set as fixed value. Before entering the genetic algorithm, the required parameters are set. Population size (M) represents the number of individuals in the population, which is generally in the range of 20~100. The numerical range of termination of evolution in genetic operations is generally in the range of 100~500. The crossover probability p_c is within the range of (0.4, 0.9), and the variation probability p_m is in the range of (0, 0.1). These four operating parameters have a direct impact on the final solution, the solution period and the efficiency of the genetic algorithm. The population size is M, and the fitness value of individual i is expressed by f_1. The probability of the individual being selected is calculated by formula (1). The calculation process is that the fitness value f_1 for each individual of the population is calculated first, i =1, 2… M.

$$P_i = \frac{f_i}{\sum_{i=1}^{M} f_i} \quad (1)$$

The sum of fitness of all individuals in a population is calculated by formula (2).

$$F = \sum_{i=1}^{M} f_i \quad (2)$$

The probability of individual selection is calculated by formula (3).

$$P_k = \frac{f_k}{\sum_{i=1}^{M} f_i}, k = 1, 2, \cdots M \quad (3)$$

The above steps show the runner method. Selection process is the process of selecting M times of rotation. Each time the following method is selected, a new individual is added to the new population. The pseudorandom numbers *r* is uniformly distributed in the interval [0,1]. When $r \le q_1$, select the first individual. Otherwise, select the k individual ($2 \le k \le M$), so that $q_{k-1} \le r \le q_k$ is satisfied.

In this way, the selection process of M times is obtained, and the genetic operator is obtained. In practice, it is necessary to set up the reasonable range and size of the parameters of the genetic algorithm through many experiments. This paper mainly introduces the calculation process of roulette wheel selection for operator selection. Roulette is the most frequently used method in the selection of genetic algorithms.

The core operation of genetic algorithm is selection, crossover and mutation operation. Selection operation is carried out to ensure that individuals with better adaptation to the living environment can be inherited into a new generation to maintain the goodness of the population. Selection is mainly the process of survival of the fittest, and the standard of judgment is the applicability of the individual. Selection methods include optimal strategy, ranking selection and proportional selection. Crossover is analogous to the process of gene recombination between chromosomes in biological evolution. It is that the individuals with some defects in the previous generation are recombined according to the probability so as to form new individuals with excellent characteristics. The mutation operation is to avoid the omission of information that may occur in selection and crossover. Mutation is the random selection of an individual in a population, changing the gene value of a chromosome and forming a new individual. The advantage is that it can improve the local search ability of genetic algorithm, ensure the diversity of population, and avoid premature phenomenon. The basic operation steps of the genetic algorithm are shown in Figure 2.

Optimization of genetic algorithm model

Although the genetic algorithm has the advantages of other algorithms, there are some shortcomings. The genetic algorithm adopts the method of fixed policy parameters, and the optimization result is not good. There is no way to solve the problem of parameter variation and dynamics in genetic evolution, especially in the case that the crossover probability and mutation probability cannot be controlled. Therefore, the basic genetic algorithm cannot objectively reflect the individual evolution of the population in different periods of the state of change. The performance and efficiency of the algorithm are not high because of the constant parameters in the basic genetic algorithm. After analyzing the principle, advantages and disadvantages of the basic genetic algorithm, it is found that the performance of the genetic algorithm is greatly affected by the parameters.

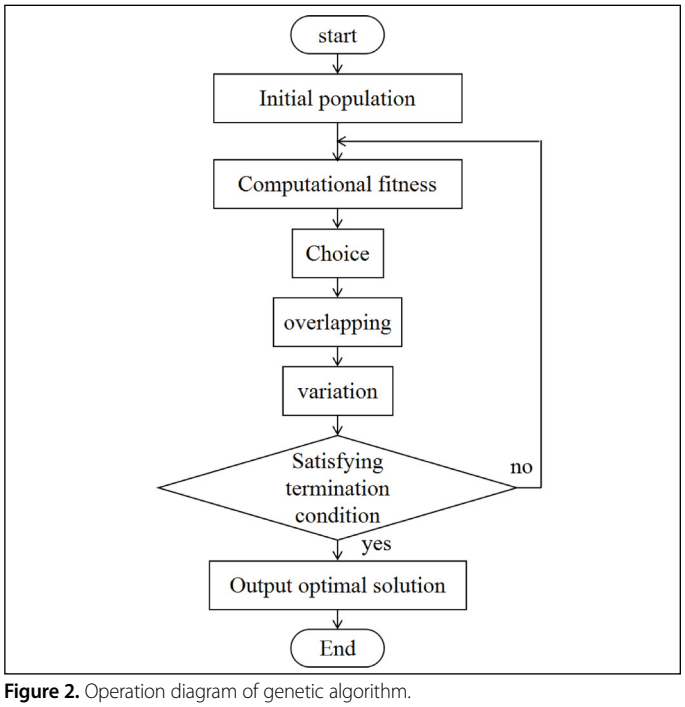

Figure 2. Operation diagram of genetic algorithm.

In genetic algorithm, the crossover operation is the core of the algorithm. Crossover operator is crossover in the current population by randomly selecting two male parents. How to choose a male parent is the key to genetic evolution. The representative strategies for selection of male parents are population improvement selection and competitive selection. In this paper, the competition selection method is adopted to select the random crossing of crossover probability of the male parent with large similarity to generate new population. The operation principle of the crossover operator is shown in Figure 3. In order to solve the problem that the crossover probability and mutation probability cannot be changed dynamically, a genetic algorithm is proposed to adjust the crossover probability and mutation probability dynamically according to the fitness value. In the formula (4), p_c represents the crossover probability; p_{c_max} represents the maximum crossover probability; p_{c_min} represents the minimum crossover probability; p_m represents the maximum variation probability; p_{m_max} represents the maximum variation probability; p_{c_min} represents the minimum variation probability. $it\ \max$ represents the largest evolutionary algebra; $iter$ represents the current evolution algebra; f_{avg} represents the mean fitness value of the population; f^1 stands for individual with greater fitness in two individuals who want to perform cross operation; f represents the fitness of individuals who need to perform mutation operations. With the optimized genetic algorithm, p_c and p_m can automatically change with the fitness value. However, when the fitness value of individuals is close to or equal to the maximum fitness, p_c and p_m will be in the state of near or equal to zero. If the algorithm is in the early stage of evolution, excellent individuals are almost in the same state, and the whole algorithm is going to find the local optimal solution.

$$p_c = \begin{cases} p_{c\_\max} - \left(\dfrac{p_{c\_\max} - p_{c\_\min}}{it\ \max}\right) * iter & f^1 \geq f_{avg} \\ p_{c\_\max} & f^1 < f_{avg} \end{cases} \quad (4)$$

$$p_c = \begin{cases} p_{c\_\min} + \left(\dfrac{p_{m\_\max} - p_{m\_\min}}{it\ \max}\right) * iter & f^1 \geq f_{avg} \\ p_{c\_\min} & f^1 < f_{avg} \end{cases} \quad (5)$$

The improved genetic algorithm is to make the crossover probability and mutation probability of the individuals of the population change linearly with the average fitness and maximum fitness according to

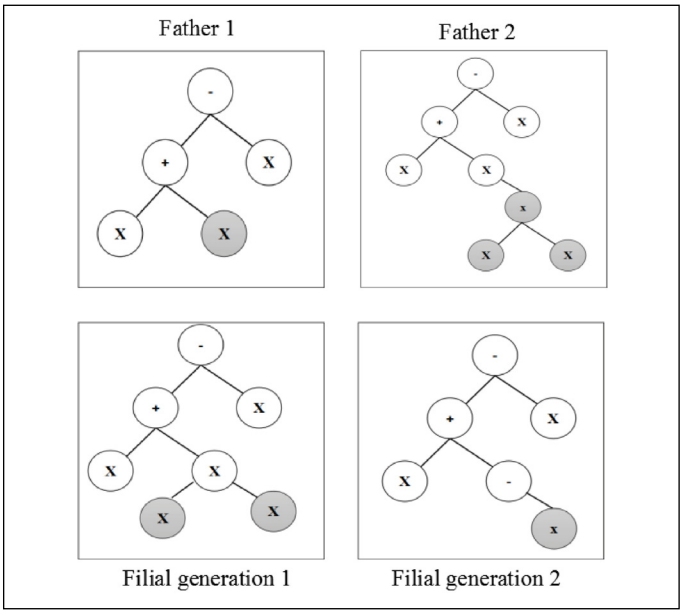

Figure 3. Schematic diagram of cross operator operation.

the fitness of the individual. Therefore, the adaptive genetic algorithm is an important mathematical model to improve the algorithm. The basic principle of adaptive genetic algorithm is that the crossover probability p_c and mutation probability p_m can dynamically change. When the individual fitness of the population becomes consistent, or when the local optimal state appears, p_c and p_m will increase. When population fitness is not concentrated, p_c and p_m are reduced. For those individuals whose fitness is better than the average fitness, let the solution go into the next generation of sequences for lower p_c and p_m. If the fitness is less than the average fitness of individuals, the deletion of the individual is directly eliminated in the case of higher p_c and p_m. So the adaptive degree of p_c and p_m here is p_c and p_m that can provide the best state relative to a solution. Thus, the adaptive heritage algorithm achieves global convergence on the basis of maintaining the diversity of the population.

RESULT ANALYSIS AND DISCUSSION

The movement model of middle school students' running fitness program is to obtain safety heart rate, heart rate and other indicators when achieving certain exercise time and effective exercise. In this paper, various parameters of fitness running program are abstracted as mathematical problems. The improved genetic algorithm is used in the experiment. In other words, the simulation test of the fitness running program is carried out to determine whether the motion model can achieve the goal of improving the exercise effect and avoiding the transition movement. Firstly, the motion model is established based on genetic algorithm. The experimental code uses the real coded, and the individual length is set to 6. Crossover operator is a single point crossover method, and mutation operator is also a single point mutation model. Roulette wheel selection method for retained elitist selection is used. Based on the conditional choice, the optimal solution and the global optimal solution of the current generation are compared. If it is better than the global optimal solution, the global optimal solution will be used to update the population. If the current optimal solution is good, the individual will be directly inherited into the next generation to ensure the excellent population.

In the parameter optimization of motion model, considering the characteristics of fitness running, the residual square of heart rate and heart rate measured by the model is used as fitness function. The nonlinear differential equations are used to estimate heart rate values. In order to improve the accuracy of the equations, the fourth order Levenberg-Marquardt algorithm is used to solve the equations. In order to verify the effectiveness of the algorithm, the fitness running data of 10 middle school students are selected for comparative analysis. Of the 10 students, 6 are boys and 4 are girls. Each person provides 10 minutes of running data, and 1 minute is a cycle. Based on the collected data, LM and GA algorithm are used respectively for motion modeling. The relevant basic data parameters are obtained as shown in Table 1.

On the basis of the statistics of basic data, the error of each student's psychological estimation is analyzed. The mean square error of the rate error of the motion modeling center is obtained by using the two algorithms. Finally, the specific distribution range diagram of students' heart rate error value is obtained as shown in Figure 4 and Figure 5.

Through the comparative analysis of the two algorithms, the results of this study can be obtained. The improved genetic algorithm and Levenberg-Marquardt algorithm are validated by learning the collected data of construction and running. The results show that the motion model established by the improved genetic algorithm has better accuracy than the LM algorithm in the prediction of heart rate estimation.

Table 1. Comparison of data tables between LM algorithm and GA algorithm.

Model parameter		a1	a2	a3	a4	a5
Schoolboy 1	LM algorithm	1.5221	1.2651	1.4951	0.8765	4.7394
	GA algorithm	1.2759	1.0362	1.3261	0.8231	2.0357
Schoolboy 2	LM algorithm	0.6481	0.6325	2.4581	2.7623	0.3014
	GA algorithm	2.4151	2.3652	1.1723	0.0368	1.6239
Schoolboy 3	LM algorithm	1.9328	1.8425	1.5362	0.1524	2.968
	GA algorithm	1.4162	1.3498	0.5369	0.3521	1.1421
Schoolboy 4	LM algorithm	0.6989	0.6964	0.1896	0.3420	1.1539
	GA algorithm	1.2351	0.8217	0.1823	0.1956	3.5934
Schoolboy 5	LM algorithm	2.6124	1.7213	1.1856	0.1235	3.9272
	GA algorithm	1.3652	0.4251	0.5426	1.1873	4.4692
Schoolboy 6	LM algorithm	2.1663	1.9381	2.1623	0.1759	4.5629
	GA algorithm	1.5365	1.0932	0.0198	0.0176	4.5463
Girl student 1	LM algorithm	2.3856	2.7753	1.9362	0.1125	3.0687
	GA algorithm	1.9653	1.2398	2.2156	0.1589	4.0036
Girl student 2	LM algorithm	1.6325	1.1526	2.4561	0.2365	0.7459
	GA algorithm	2.3658	3.2651	2.1561	0.0899	4.9597
Girl student 3	LM algorithm	1.4962	0.7382	0.6653	0.1625	3.2637
	GA algorithm	2.0132	1.2936	2.5624	0.1625	3.1859
Girl student 4	LM algorithm	1.9625	1.2653	1.0256	0.6524	3.2657
	GA algorithm	1.1056	0.9651	2.1624	1.1923	0.7953

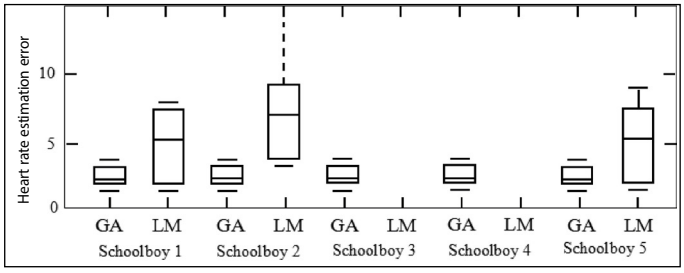

Figure 4. Comparison of two algorithms for modeling data.

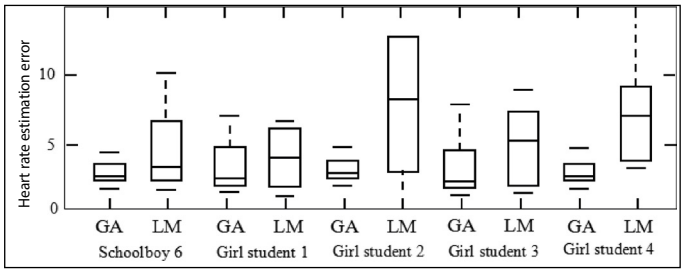

Figure 5. LM algorithm and GA algorithm modeling data contrast map.

CONCLUSIONS

Genetic algorithms learn biological evolution and genetic advantages, so that the problems need to be solved to get the best solution, give the best prediction and judgment, and make a positive contribution to people's life and work. Although the genetic algorithm has some shortcomings such as falling into local minimum, the improved algorithm has achieved remarkable results. Therefore, the genetic algorithm model was optimized and applied in the optimization program of fitness running for middle school students. After analyzing the operation process and model structure of the traditional genetic algorithm, the optimization and improvement of the algorithm were given, and the new formula of crossover probability and mutation probability in the adaptive state was obtained. Then the improved genetic algorithm mathematical model was applied to the fitness program optimization of

middle school students in the application of verification. The students' fitness running data was selected to establish the motion model. The samples were selected to compare the improved genetic algorithm motion model and the traditional Levenberg-Marquardt algorithm motion model. From the test results, the accuracy of the motion model established by the improved genetic algorithm is improved, which proves that the work is successful.

The author declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: The author has completed the writing of the article and the critical review of its knowledge content. This paper can be used as the final draft of the manuscript. YX: writing and execution.

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