Article ID: 1000 - 8152(2001)06 - 0882 - 05

The Comparison of Multi-reproduction Groups of Genetic Algorithms and Its Application in the Optimization Schedule

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Abstract: The comparison approach of genetic algorithms based on the multi-reproduction thinking is introduced, the judgement principle about the number of reproduction groups and its influence on the algorithm convergence speed are compared, and the genetic operator and the parameter of evaluation function that was built to slove the programming problem of hybrid system are designed. Compared with ordinary genetic algorithms, statistical calculation, and the simulation to the Shanghai Heavy Duty Tyre production process, the results of calculation indicate that this approach had a fast speed of convergence, and can optimize the production schedule of hybrid system in which there are continuous and discrete processes and it is broad in scale.

Key words: multi-reproductions transform; genetic operator; genetic algorithm; hybrid system schedule
Document code: A

多种群变换遗传算法及其在优化调度中的应用

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摘要: 提出了一种基于多种群思想的遗传算法,研究了种群数目对收敛速度的影响及确定原则,设计了适合连续离散规划问题求解的交叉与变异算子以及评价函数参数.通过与一般遗传算法比较、统计计算及对某载重轮胎厂生产调度系统仿真,表明该算法的收敛速度有很大提高,并能够很好解决连续与离散状态并存和规模较大的一类混合生产过程的调度问题.

关键词: 多种群变换; 遗传算子; 遗传算法; 混杂系统调度

1 Introduction

In recent years, the research on scheduling large scale system of production process has paid more attention to the description of complex process. The method of scheduling system, such as ISIS and YAMS, can not be used in hybrid schedule system.

The random optimizing method such as GA has been successfully applied to the solution to schedule problems. It is not necessary for this method to analyze the property of optimizing problem. It can be used in optimize scheduling discrete and continuous processes. But when there is a large scale or complex system, the conventional GA has some problems, such as a long time calculation, enclosed competition and super character strings. The conventional gene factor can't be used directly in hybrid system. In order to solve the above problems, we introduce the multi-reproduction group and investigate the influence of reproduction amounts on the search for schedule optimization. The comparison of different reproduction amount is shown.

Received date: 1999 - 06 - 28; Revised date: 2001 - 03 - 29.

2 Genetic algorithms based on multi-reproduction group

As we know, GA is a kind of calculation method based on natural selection and genetic mechanism. It is a kind of recursive algorithm from a group of solutions to a better group of solutions. The conventional GA calculated from a group of solutions can't be used in the complex system scheduling.

The result of our investigation indicated that the gene algorithm with multi-reproductions can solve the schedule problem of complex system such as the hybrid system of rubber tyre production. In fact, if the number of chromosomes is too small, the result of optimizing is not the best. If the number of chromosomes increases, it increases the time of search. The data overflows can be solved by means of multi-reproductions and the coherent processing ability of computer. This paper designed new operators of crossover mutation and calculated the schedule of hybrid system. The results of the calculation indicated that the methodology is correct.

2.1 Algorithm process and operator design

1) Gene coding and initial reproductions.

Considering the feature of hybrid process and large scale system, we use the sequence of machines and several kinds of products as the basic information of gene coding. Definition of code sequence:

$$V_i^{k1} = \begin{bmatrix} X \\ U \end{bmatrix}, \ X = \begin{bmatrix} x_1 \\ \vdots \\ x_m \end{bmatrix}, \ U = \begin{bmatrix} u_1 \\ \vdots \\ u_m \end{bmatrix},$$

$$x_k = \begin{bmatrix} x_{k1} \\ \vdots \\ x_{kn} \end{bmatrix}, \ u_k = \begin{bmatrix} u_{k1} \\ \vdots \\ u_{kn} \end{bmatrix},$$

in which, $k = 1, \cdots, m$ is the code of machine, $j = 1, \cdots, n$ is the code of product, $i = 1, \cdots, m_2$ is the code of chromosome, $k1 = 1, \cdots, n1$ is the code of reproductions.

A code sequence V defines a chromosome. Define m_2 as the number of chromosome. The initial reproduction is produced in a random method and define $n1$ as the number of initial reproduction.

2) Object function.

From goal function we sequence the individuals among reproductions according to minimum processing time.

3) Selection.

Design the evaluation function by adjusting scale of fitness. Define $f_1, f_2, \cdots, f_{m_2}$ (the criterion values of chromosomes $[V_1, V_2, \cdots, V_{m_2}]$) original fitness. By linear fitness scaling

$$f_i' = af_i + b, \ i = 1, 2, \cdots, m_2, \tag{2.1}$$

in which, f_i', $i = 1, 2, \cdots, m_2$ as new fitness, a and b are the parameters. The evaluation function is defined as:

$$\mathrm{eval}(V_i) = f_i' / \sum_{j=1}^{m_2} f_j', \ i = 1, 2, \cdots, m_2, \tag{2.2}$$

$i = 1$ means that the chromosome is the best. $i = m_2$ means that it is the worst. Choosing process is m_2 times as m_2 chromosomes in new reproductions.

4) Crossover.

Define P_{c1}, P_{c2}, P_{cn1} respectively as the probability of crossover operation for $n1$ reproductions. Producing random numbers $r_1^1, r_2^1, \cdots, r_{m_2}^1$ from $[0,1]$. if $r_i^1 < P_{c1}$, let V_i^1 be a father generation, we can obtain $V_i^2, V_i^3, \cdots, V_i^{n1}$ in the same ways, such as

$$V_{11}^1 \quad V_{13}^1 \quad V_{17}^1 \quad V_{19}^1$$

the father generation of the first initial reproduction;

$$V_{22}^2 \quad V_{24}^2 \quad V_{25}^2$$

the father generation of the second initial reproduction;

$$V_9^{n1} \quad V_{16}^{n1} \quad V_{20}^{n1}$$

the father generation of the $n1$ th initial reproduction.

Separate them randomly, such as: (V_{11}^1, V_{25}^1), (V_9^{n1}, V_{17}^1), (V_{16}^{n1}, V_{19}^1), (V_{24}^2, V_{13}^1), (V_{22}^2, V_{20}^{n1}), if the total number of father generations is odd. Take, for example, (V_{11}^1, V_{25}^1). The equations of crossover are:

Continuous variables

$$X_b = c_i X_{11}^1 + (1 - c_i) X_{25}^1, \tag{2.3}$$

$$X_c = (1 - c_i) X_{11}^1 + c_i X_{25}^1, \tag{2.4}$$

in which, c_i is the random number in $(0,1)$, $i = 1, 2, \cdots, m_2$.

Discrete variables

$$U_b = \mathrm{int}[(U_{11}^1 n' + U_{25}^1 m')/(n' + m')], \tag{2.5}$$

$$U_c = \mathrm{int}[(U_{11}^1 m' + U_{25}^1 n')/(n' + m')]. \tag{2.6}$$

Hybrid variables

$$V_b = [X_b \quad U_b], \tag{2.7}$$

$$V_c = [X_c \quad U_c], \tag{2.8}$$

in which, n' and m' are the random numbers in $(1, M)$. Checking probability of every new generation and decide new generation V_b, V_c instead of father generation.

5) Mutation.

Define $Pd_1, Pd_2, \cdots, Pd_{n1}$ as probability of every reproduction and operate chromosome to satisfy the condition of variation. Operate chromosomes to satisfy the condition by mutation operator (2.9) ~ (2.11).

Continuous process

$$X_i' = X_i + M_a d_1; \tag{2.9}$$

Discrete process

$$U_i' = U_i + \mathrm{int}(M_b d_2); \tag{2.10}$$

Hybrid process

$$V_i' = [X_i \quad U_i], \tag{2.11}$$

in which, d_1 and d_2 are the vectors of the n-dimensions super cube R^n.

6) The condition of end.

When the recursive number satisfies the given value, the calculation ends.

2.2 The comparison between multi-reproduction group algorithms and general algorithms

In the following calculation, define S_1 as an individual reproduction group, S_2 as two reproduction groups and S_3 as three reproduction groups. S is defined as the value of goal function and K is defined as the times of recursive calculation.

The programming of individual goal: considering optimization on convex set.

$\max f(x) = 0.1537$;

$$\max f(x) = \frac{x_1^2 x_2 x_3^2}{2x_1^3 x_3^2 + 3x_1^2 x_2^2 + 2x_2^2 x_3^3 + x_1^3 x_2^2 x_3^2},$$

$$\text{s.t.} \quad x_1^2 + x_2^2 + x_3^2 \geqslant 1,$$

$$x_1^2 + x_2^2 + x_3^2 \leqslant 4,$$

$$x_1, x_2, x_3 > 0.$$

The simulation of optimal schedule in a continuous production process:

G is defined as the recursive times. K is defined as the time of evaluation of 450 generations. Individual reproduction T_1 = 2min, two reproductions T_2 = 4min, three reproductions T_3 = 6min.

From Fig. 1 to Fig. 3, the calculation speed of most multiple reproductions is higher than the speed of individual reproduction. The calculation speed has a little difference when the number of reproductions is more than three.

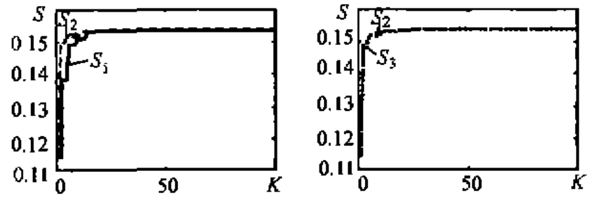

Fig. 1 The simulation of a single-goal programming

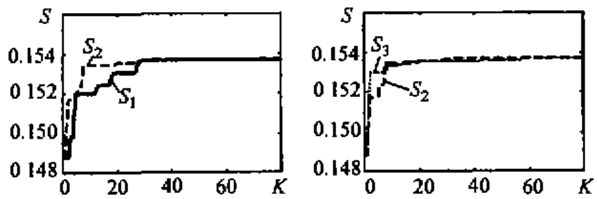

Fig. 2 The simulation of a single-goal programming

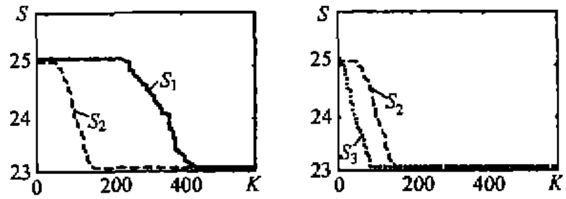

Fig. 3 The simulation of real optimization schedule process

From Fig.4, the optimal times of 50 generations is 8 times of individual reproduction, 25 times of two reproductions and 36 times of three reproductions.

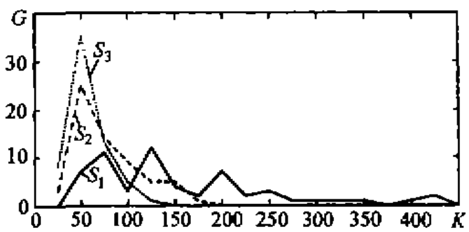

Fig. 4 The statistical figures after 62 times operation

3 The schedule simulation based on genetic algorithm of multi-reproduction group

The production of rubber tyre is a hybrid system shown in Fig.5. The key of technology is to schedule the continuous process of mixing rubber and rolling steel wires, and discrete process of processing triangle rubber and uncompleted product. The hybrid GA based multi-reproduction group obtained the satisfying results of scheduling.

3.1 The schedule model of rubber tyre hybrid production process

The production process shown in Fig. 5 can be described as the following model.

$$\min E = \min \sum_{j} \Delta t_j = \min \max_{i \in I} \sum_{j} \Delta t_{ij}. \quad (3.1)$$

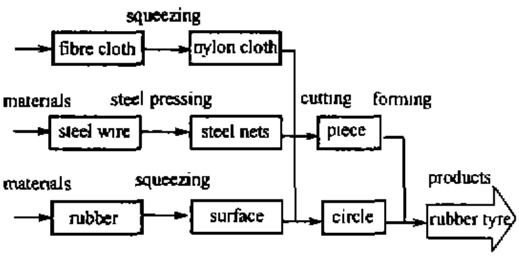

Fig. 5 The flow chart of tyre production process

The equation presents the minimum criterion of production process period of considering the longest process time:

$$\Delta t_{ij} \geqslant \Delta t_{ij\,\min},\ i \in I = \{1,2,3,\cdots,m\},\ j \in \Sigma = \{1,2,3,\cdots,n\}. \quad (3.2)$$

The equation presents the restriction of jth kind of products that is larger than the minimum process time.

$$\int_0^t x_j'(\tau)\mathrm{d}\tau = \sum_j \int_0^{\Delta t_{ij}} x_{ij}(\tau)\mathrm{d}\tau,\ \Delta t_{ij} \leqslant t. \quad (3.3)$$

The equation is the restriction of production plan that the production output of jth kind of products in every machine per unit time satisfies the requirement of products.

$$\begin{cases} \sum_j c_{ij} x_{\min} \leqslant \sum_j x_{ij}(t) \leqslant \sum c_{ij} x_{i\,\max}, \\ x_{ij}(t) \geqslant 0. \end{cases} \quad (3.4)$$

The equation presents the restriction of maximum ability of machine processing.

$$x_{ij}(t) \leqslant \min_h (a_{ijh} z_{ijh}(t)),\ a_{ijh} \neq 0. \quad (3.5)$$

The equation presents the restriction of materials.

$$\begin{cases} \sum_j c'_{ij} u_{i\,\min} \leqslant \sum_j u_{ijk} \leqslant \sum_j c'_{ij} u_{i\,\max}, \\ u_{ijk} \geqslant 0. \end{cases} \quad (3.6)$$

The equation presents the restriction of the maximum ability of production about unfinished products.

$$\sum_k \sum_i u_{ijk} = u'_j,\ j \in \Sigma. \quad (3.7)$$

The equation presents the restriction of unfinished products.

$$u'_j = \min_h \left(b_{jh} \int x'_h(\tau)\mathrm{d}\tau \right). \quad (3.8)$$

The equation presents the restriction of mixed rubber for next process of unfinished products.

$$y_l = \min_j (d_{lj} u'_j). \quad (3.9)$$

The equation presents the restriction of product plan. In equations 3.1 ~ 3.9:

$x_{ij}(t)$, u_{ijk} are the amounts of jth kind of rubber and unfinished product made by ith machine.

$x_{i\,\min}$, $x_{i\,\max}$ are minimum and maximum amounts of rubber made by ith machine

$u_{i\,\min}$, $u_{i\,\max}$ are minimum and maximum amounts of unfinished product by ith machine.

Δt_{ij} is the processing period of jth kind of product made by ith machine.

$\Delta t_{ij\,\min}$ is the minimum processing period of jth kind of product made by ith machine.

y_l is the amount of order products.

$c_{ij}, c_{ij}' = \{0,1\}$ are the ability of production equipments;

$x_j'(t)$ is the amount of rubber production in unit period;

$z_{ijh}(t)$ is the amount of materials to mix rubber, H is the kinds of materials;

a_{ijh}, b_{jh}, d_{lj} are the parameters of manufacture.

3.2 The production schedule simulation based on multi-reproduction group genetic algorithms

Table 1 shows the products of factory in one day. Table 2 and Table 3 show the sources, abilities and production state.

Table 1 The product of factory in one day kg

kinds	product	kinds	product	kinds	product	kinds	product
Q67	12000	Q12	600	207	19000	217	4000
600	16000	P92	21000	Q74	17000	S14	20000
320	16000	Q97	15000	P39	29000.	Tf	500piece
500	37000	800	1400	T72	9000	Tc	200piece
Q92	600	700	55000	300	4000	Tt	300piece

Table 2 The period of rubber mixing

mixing	1#	2#	3#	4#	5#	6#
mixing period/s	288	247	250	260	230	280
production/kg	220	240	250	220	200	240

Table 3 The production ability of cut-machine and rubber mixing machine ("1" = yes, "0" = no.)

	M1	M2	M3	M4	M5	M6	C1	C2
Q67	1	0	0	0	0	0	0	0
Q92	1	1	0	0	0	0	0	0
800	1	1	0	0	0	0	0	0
P39	1	1	0	0	0	0	0	0
217	1	1	0	0	0	0	0	0
600	1	1	0	0	0	0	0	0
P92	1	1	0	0	0	0	0	0
S41	1	1	0	0	0	0	0	0
T72	0	1	0	0	0	0	0	0
300	0	1	0	0	0	0	0	0
320	0	0	1	1	0	1	0	0
Q12	0	0	1	1	0	0	0	0
207	0	0	1	1	0	1	0	0
700	0	0	1	1	1	1	0	0
500	0	0	1	1	1	1	0	0
Q97	0	0	1	1	0	1	0	0
Q74	0	0	1	1	1	1	0	0
Tri rub-ber	0	0	1	1	1	1	0	1
Tread	0	0	1	1	1	1	1	1
Side tyre	0	0	1	1	1	1	1	1

The calculation used MATLAB in computer AIC PII. Assuming the scale of reproductions $m_2 = 20$, the parameter of evaluation function. The parameters of function $a = 0.05$, $b = 2.78$, crossover probability $P_{c_1} = 0.2$, $P_{c_2} = 0.25$, $P_{c_3} = 0.3$, mutation probability $P_{d_1} = 0.45$, $P_{d_2} = 0.5$, $P_{d_3} = 0.55$, $M_a = 100$, $M_b = 120$, the results of calculation is shown in Fig.6 and Table 4.

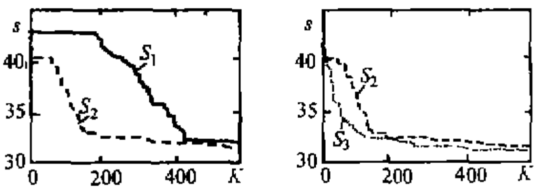

Fig. 6 The digital simulation of the real processes

4 Conclusion

Because the gene algorithm with multi-reproductions avoids the growth of close relations and the bad generations are replaced, its convergence speed is higher. The operations of crossover can not only break points of local optimization but avoid producing super character strings. The results of calculation indicated that it is available for scheduling hybrid system of production process. In the calculation of schedule, the number of reproductions is larger than three. This paper can not only solve the hybrid schedule of rubber tyre production, but also deal with other hybrid system by proper computers.

Table 4 The three-reproduction genetics algorithm schedule result of the tyre hybrid production process

	Morn shift	Noon shift	Eve shift
M1	Q67 800 217 600	P39 Q92	P92 S41
ton	12 3.7 3.3 2.9	18.2 0.6	14.6 8.6
M2	217 P92 S41 300	800 P39	600 T72
ton	0.7 6.4 11.4 4	10.3 10.8	13.1 9
M3	320 207 500 Q97 Q74	700	
ton	2.4 7.4 6.2 3.8 4	22	
M4	320 Q12 207 700 500 Q74	Q97	
ton	1.5 0.6 2.9 6.8 13.1 3.9	3.3	
M5	700 500 Q74		
ton	16 12.7 2.6		
M6	500 Q97	320 Q74	700 207
ton	5 7.9	12.1 6.5	10.2 8.7
C1	Tread Side	Tread Side	Tread Side
pc	130 40	204 84	52 129
C2	Tread Side Tri rub-ber	Tri rub-ber	Tri rub-ber
pc	24 37 117	103	80

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韩 兵 见本刊 2001 年第 5 期第 685 页.