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A Quasi-optimal Restaurant Work Scheduling Based-on Genetic Algorithm with Fuzzy Logic

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Abstract - **A quasi-optimization algorithm for generating a chain restaurant work scheduling (WS) is proposed based on Genetic Algorithm with fuzzy logic, where the whole weekly chain restaurant WS problem is decomposed to 7 daily WS problems and a combined weekly WS problem. Experimental result shows that a weekly schedule for 15 workers and 24 hours in a chain restaurant is produced in 6 minutes using the proposed algorithm implemented with C++ and executed on a PC (Athlon XP 1900+), where the quality of WS is satisfactorily evaluated by professional experts.**

I. INTRODUCTION

Work Schedule (WS) for chain restaurants in Japan is made by experts (a special regular member of a chain restaurant). It takes the expert for about five hours to make a schedule of the shifts for seven days. There is growing needs of a practical automatic system that generates the WS for chain restaurants. The conventional scheduling technologies used for Nurse Scheduling Problem (NSP[1][2]) may not be applied to the restaurant WS, due to the various difficult characteristics of the restaurant WS compared with that of NSP, e.g., working time zones of NSP are relatively simple such as day time zone (7:00-15:30), evening time zone (15:00-23:30), night time zone (23:00-7:30), most of the members of NSP are regular members whereas the main body in the restaurant WS problem consists of part time job members and they request many complicated and selfish issues.

In this paper, a quasi-optimization algorithm for the WS problem of a chain restaurant is proposed based on Genetic Algorithm[3] with fuzzy logic, and the system based on the proposed algorithm is developed and implemented by using C++ language and executed on a PC (Athlon XP 1900+). The constraints associated with the WS problem are divided into daily WS constraints and weekly WS constraints, that are mutually independent. The proposed method deals with the WS problem for a whole week by fuzzily decomposing it into 7 daily WS problems. The weekly WS problem is solved by searching a quasi-optimized solution within the solution space created by the combinations of the daily WS solutions. By using the fuzzy division of the problem constrains and the evaluation factors, the search space of the proposed method can be decreased. The proposed algorithm can produce a quasi-optimization solution for the partitioned problem, based on Genetic Algorithm with fuzzy logic.

In Sec. 2, the chain restaurant work schedule optimization problem is formalized. In Sec. 3, an algorithm for generating work schedules for chain restaurants is proposed. Experimental results are shown in Sec. 4.

II. CHAIN RESTAURANT WORK SCHEDULE PROBLEM

The chain restaurant WS optimization problem is defined as follows.

[Def. 1] Time, Date, Member Set

Whole time set : $\mathbf{T} = [0, 24)$, (1)

Section time : $T_s \subset \mathbf{T}$, (2)

Time : $t \in T_s$, (3)

Time class : $2^{\mathbf{T}}$, (4)

Date set : $\mathbf{D}$, (5)

Date : $d \in \mathbf{D}$, (6)

Member set : $\mathbf{M}$, (7)

Member m : $m \in \mathbf{M}$. (8)

[Def. 2] Schedule Functions

The schedule function

$$S:\mathbf{D}\rightarrow 2^{\mathbf{T}}$$
$$\Downarrow \quad \Downarrow$$
$$d\mapsto T_s. \tag{9}$$

is a mapping from date set to time class.

Required members function S_{N_i} (where n_i is the necessary number of members), requested work time function S_{R_m}, and work time function S_{W_m} related with Def. 2 are defined as:

$$S_{N_i}, S_{R_m}, S_{W_m}:\mathbf{D}\rightarrow 2^{\mathbf{T}}$$
$$\Downarrow \quad \Downarrow$$
$$d\mapsto T_s. \tag{10}$$

Functions S_{R_m} and S_{W_m} must satisfy:

$$S_{R_m}(d)\supset S_{W_m}(d) \text{ for } \forall d\in\mathbf{D}. \tag{11}$$

[Def. 4] Restaurant WS Problem

Restaurant WS problem is solved by changing the work time function S_{W_m} under the condition:

$$\forall n_i\in\mathbf{N},\forall d\in\mathbf{D}, \Big(\bigcup_{\{m_1,m_2,\dots,m_{n_i}\}\subset \mathrm{M}}\ \bigcap_{l=1}^{n_i} S_{W_{m_l}}(d)\Big)\supset S_{N_{n_i}}(d), \tag{12}$$

where $\mathbf{N}$ is the set of natural numbers.

There are multiple values of S_{W_m} that satisfies Eq. (12). On a real scheduling problem the objectives to be considered are continuity of working time (making the working time of members as continuous as possible while satisfying other constrains).

Ⅲ. QUASI-OPTIMAL RESTAURANT WORK SCHEDULING

A. Perspective strategy

The proposed method uses Genetic Algorithm (GA) in [3] that generates various quasi-optimization solutions. The size of the solution space of the optimization problem for one week schedules is: (under the condition of 20 members and 24-hours operation)

$$2^{\overset{\text{time}}{24}\times\overset{\text{member}}{20}\times\overset{\text{day}}{7}}=2^{3360}. \tag{13}$$

On the other hand, the size of the solution space for one day schedule is:

$$2^{\overset{\text{time}}{24}\times\overset{\text{member}}{20}}=2^{480}. \tag{14}$$

The size of the solution space for one day allows to solve the problem in reasonable time.

In the case of restaurant WS, the constraints of the problem can be treated as independent and can be divided into two categories, i.e., daily WS constraints and weekly WS constraints. On the other hand, the evaluation factors of the problem are not independent between Daily WS evaluations and Weakly WS evaluations. In this paper such non independent evaluations are fuzzily divided by using membership functions given by part time job members' opinions.

The proposed method divides the problems as shown in Fig. 1. Daily WS problem uses only a one day schedule. Weekly WS problem finds quasi-optimization solutions of restaurant WS problem based on some of the elements of the daily WS problem solutions. In daily WS problem, solutions are obtained by the proposed quasi-optimization method from the solution space of a single day. In the weekly WS problem, combinations of solutions of daily problem are used by quasi-optimization method to solve the restaurant WS problem.

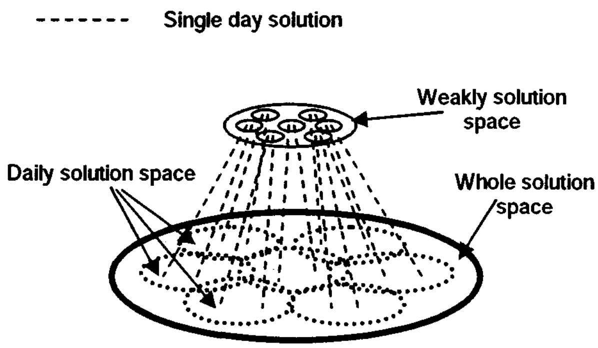

Figure 1: Fuzzy division of solution space

B. Daily WS problem

Figure 2 shows the quasi-optimization strategy of daily WS problem

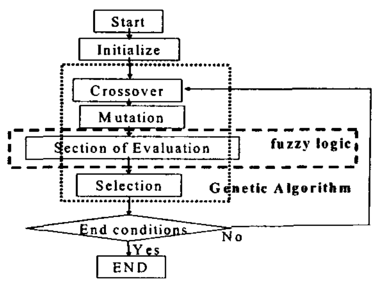

Figure 2: Quasi-optimization strategy of daily WS problem

The algorithm based on GA with fuzzy logic obtains quasi-optimized solution as shown in Fig. 2.

The formulation of the daily WS problem is presented as follows.

[Def. 5] Time, Date, Member Set

Daily whole time set : $\mathbf{T}' = \{0,1,..,23\}$, (15)

Section time : $T_s' \subset \mathbf{T}'$, (16)

Time : $t' \in T_s'$. (17)

[Def. 6] Membership Functions

Partial work time membership function P_m indicates the working time for member *m*, time request membership function R_m represents the request of working time for member *m*, and total working time request membership function G_m shows the total working time for member *m*

$$P_m, R_m, G_m : \mathbf{T}' \to [0,1]$$
$$t' \mapsto P_m(t'), R_m(t'), G_m(t'). \quad (18)$$

Daily total working time request membership function L_m is the total working time requested by member *m* for a single day:

$$L_m : \mathbf{N} \cup \{0\} \to [0,1]$$
$$n \mapsto L_m(n). \quad (19)$$

Daily-required members function N is:

$$N : \mathbf{T}' \to \mathbf{N} \cup \{0\}$$
$$t' \mapsto N(t'). \quad (20)$$

Daily work time function W_m is:

$$W_m : \mathbf{T}' \to \{0,1\}$$
$$t' \mapsto W_m(t'). \quad (21)$$

If $W_m(t')$ is zero, member *m* does not work in t'. If $W_m(t')$ equals one, member *m* works in t'.

Total work time (in one-day) for member *m* is $TT_m \in \mathbf{N} \cup \{0\}$.

C. Quiasi-optimized daily WS problem useing GA

The proposed method uses chromosome with $|\mathbf{M}|$ genes as shown in Fig. 3.

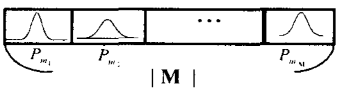

Figure 3: Chromosome for daily WS problem

The graphs in each genes refer to the partial work time membership function L_m, that has a Gaussian distribution:

$$P_m(t') = \frac{1}{\sqrt{2\pi\sigma_i^2}} \exp(-\frac{(t'-\mu_i)^2}{2\sigma_i^2}). \quad (22)$$

Figure 4 shows the section of evaluation of daily WS problem.

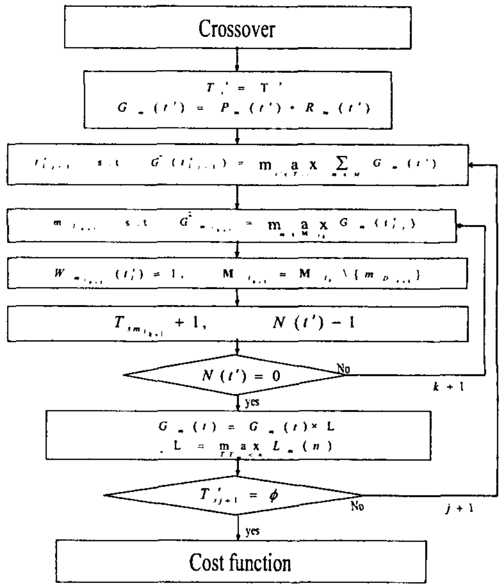

Figure 4: Section of evaluation

D. Cost function of daily WS problem

The generated schedule is evaluated using the following cost function:

$$Val = -0.8 \times \sum_{m \in \mathbf{M}} \left(TT_m - \sum_{t' \in \mathbf{T}'/\{5\}} \left(W_m(t') \times W_m(t'+1) \right) - 1 \right)$$
$$-0.2 \times \sum_{m \in \mathbf{M}} \left(1 - L_m(TT_m) \right). \quad (23)$$

The weights of the terms are empirically determined. Note that, if $t' = 23$ then $t'+1$ is set to 0.

E. Quiasi-optimized algorithm for weakly WS problem

The GA of weakly WS problem generates quasi-optimization solutions of restaurant WS problem based on constraints of the weakly WS problems from daily search space that is from the combined solutions of the 7 daily WS problems. These solutions are then evaluated by a weakly cost function.

IV. Evaluation Experiment Using Real Chain Restraints Data

The evaluation experiment is done using the real data of a

Japanese chain restaurant (15 members and 24-hours operation).

Table 1 shows the parameters in the applied GA to solve the daily and weakly WS problems in the experiment.

	population size	generation
Daily WS problem	1000	25000
Weakly WS problem	100	1000

Table 1: Parameters of used GA's

Figure 5 shows the schedule obtained by the proposed algorithm, where the black bars represent the work time, and blanks between the work times show the rest times.

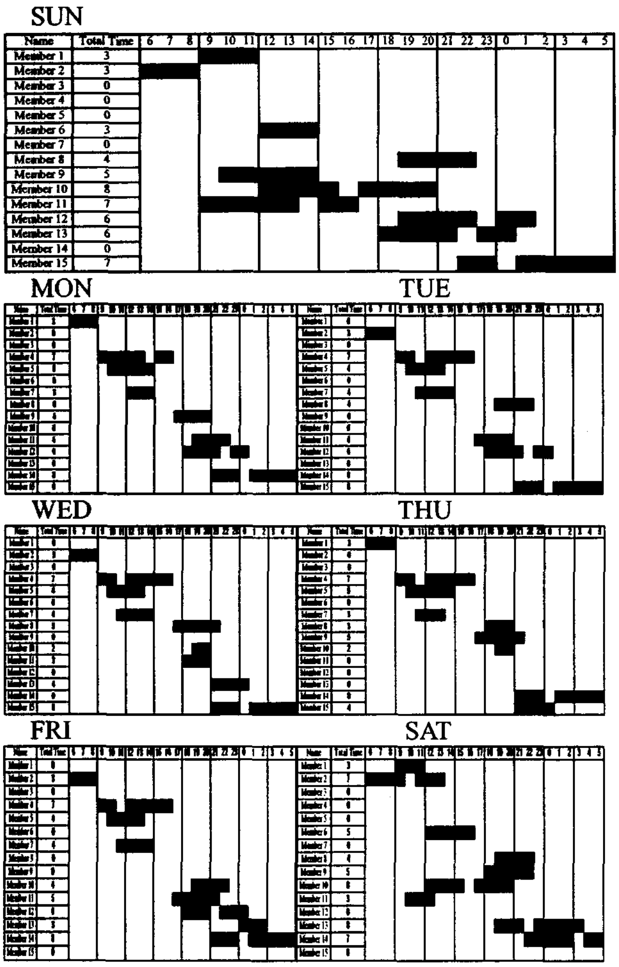

Figure 5: Example of obtained work schedules

A weekly schedule for 15 workers and 24 hours in the chain restaurant is obtained within 6 minutes using C++ language program on a PC (Athlon XP 1900+). The quality of WS is evaluated and authorized by professional experts. The proposed system is now tested in real Japanese chain restaurants for the practical use.

V. CONCLUSIONS

A quasi-optimization algorithm for generating a chain restaurant WS is proposed, where the WS problem of a week is fuzzily decomposed into 7 daily WS problems. Then the solutions of the daily problems are fuzzily combined to obtain the solution of the weekly WS problem. Then a system based on Genetic Algorithm with fuzzy logic is developed for the real world chain restaurant WS problems in Japan.

In the daily WS problem, each gene contained in the chromosome represents the partial work time of the corresponding member. From these chromosomes, the proposed algorithm uses membership functions based on fuzzy logic to generate the solutions for the daily WS problem. The method using fuzzy membership functions makes it possible to evaluate factors not easily includable in a cost function, e.g., satisfaction degree of the members and other conditions of non-crisp order.

In the weakly WS problem, a weakly search space is generated from the combined solutions of 7 daily WS problems. Then GA is used to generate quasi-optimization solutions based on constraints of the weakly WS problems, that are evaluated by a weakly cost function.

A weekly schedule is obtained within 6 minutes using the proposed algorithm implemented on a PC (Athlon XP 1900+) with C++ language. The proposed system is tested for the practical use in real Japanese chain restaurants.

The proposed algorithm will be modified and applied to other types of problems in chain restaurants and also extended to other types of shops.

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