NURSE SCHEDULING BY COOPERATIVE GA WITH VARIABLE MUTATION OPERATOR

Nurse Scheduling → very complex task!

many requirements

- requirements on the hope holiday.
- duty load in equality.
- the number of the night duties in equality.
- the affinity between the nurses in the night shift.

etc

Veteran director requires one or two weeks.

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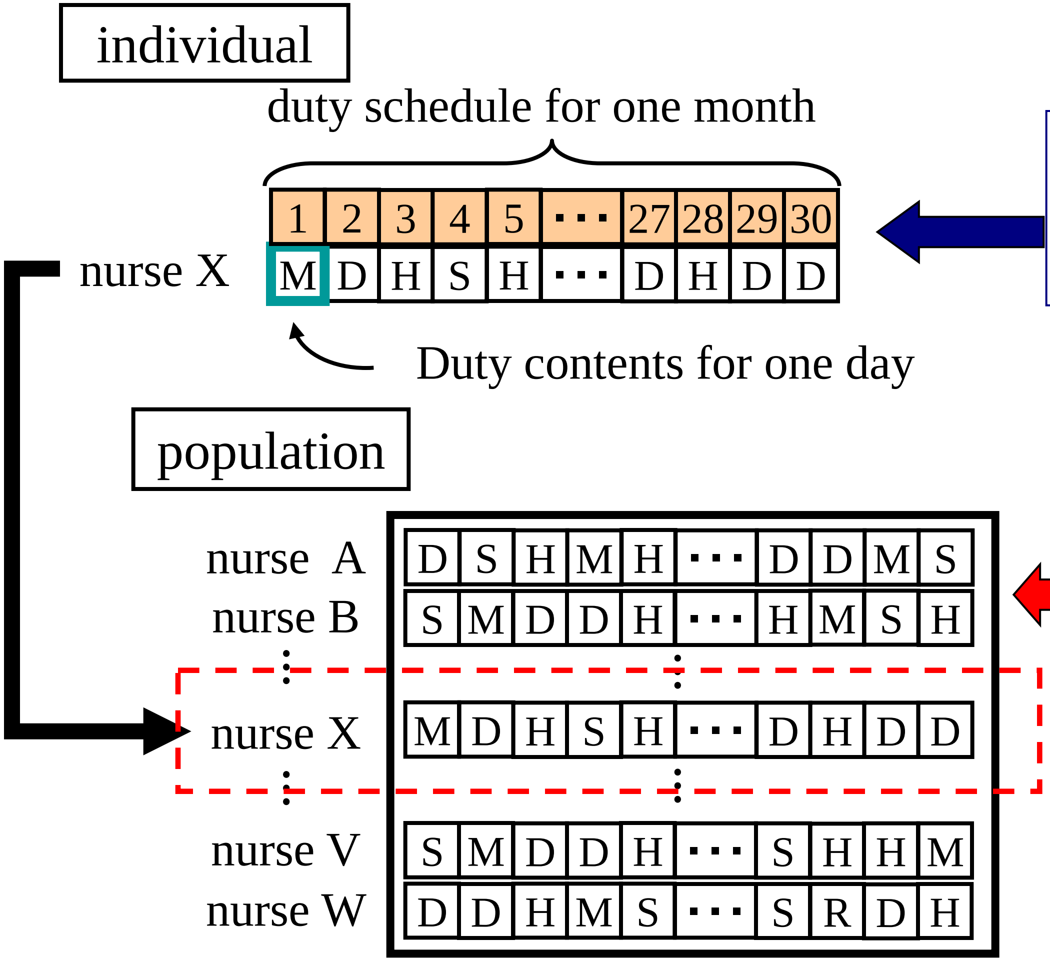
Automatic Nurse Scheduling

In the past research.....

an effective technique to optimize
the Nurse Schedule
by Cooperative Genetic Algorithm (CGA)

2.1 Coding of Nurse Schedule



individual

duty schedule for one month

	1	2	3	4	5	・・・	27	28	29	30
nurse X	M	D	H	S	H	・・・	D	H	D	D

Duty contents for one day

defined in a chromosome which shows one-month schedule of a nurse.

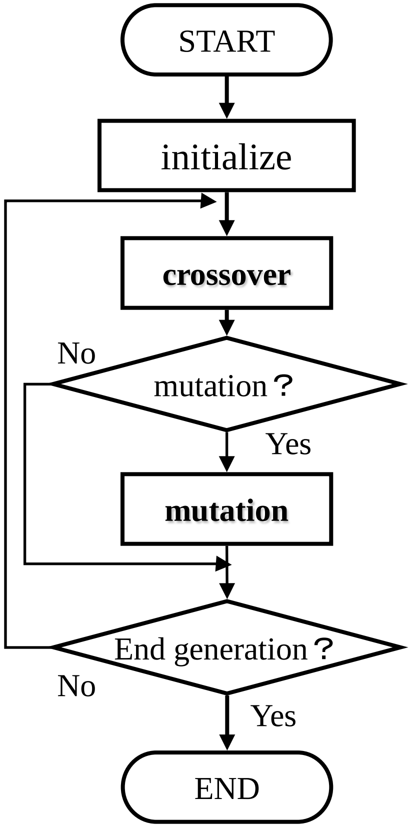
population

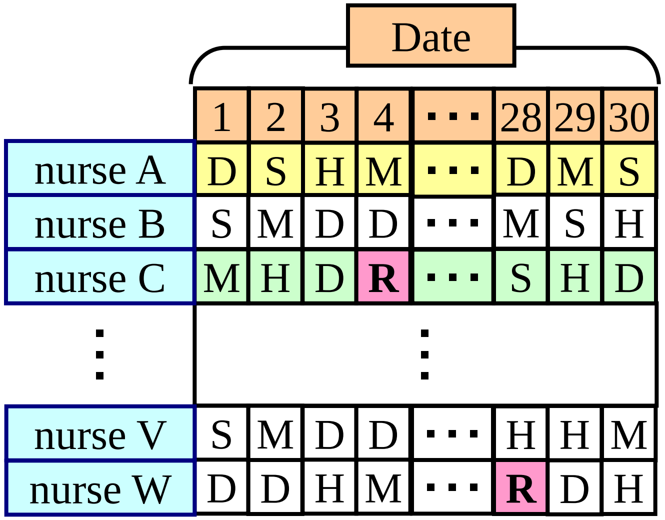
nurse A	D	S	H	M	H	・・・	D	D	M	S
nurse B	S	M	D	D	H	・・・	H	M	S	H
⋮						⋮				
nurse X	M	D	H	S	H	・・・	D	H	D	D
⋮						⋮				
nurse V	S	M	D	D	H	・・・	S	H	H	M
nurse W	D	D	H	M	S	・・・	S	R	D	H

represents the whole nurse schedule of one month.

D: day time duty, S: semi-night duty, M: mid-night duty, H: holiday, R: requested holiday

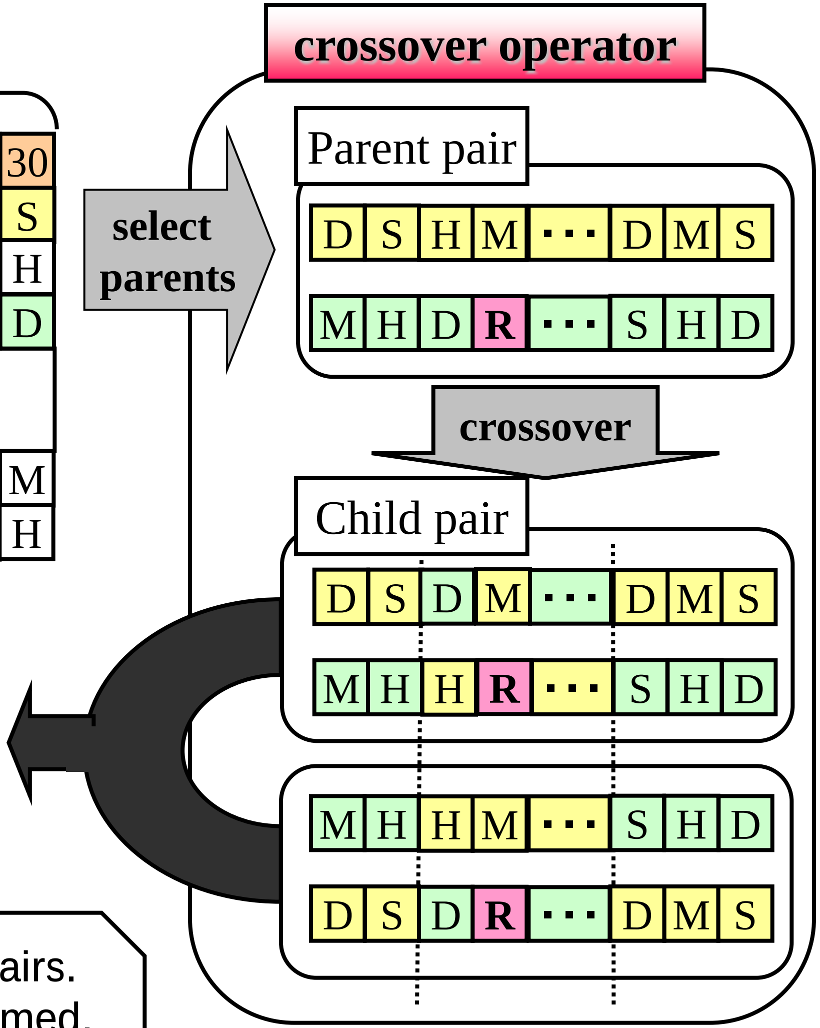
2.2 The Flow of Optimization





	1	2	3	4	···	28	29	30
nurse A	D	S	H	M	···	D	M	S
nurse B	S	M	D	D	···	M	S	H
nurse C	M	H	D	**R**	···	S	H	D
⋮					⋮			
nurse V	S	M	D	D	···	H	H	M
nurse W	D	D	H	M	···	**R**	D	H

crossover operator



-Return the child pairs to the original position of the population.
-Evaluate new populations.

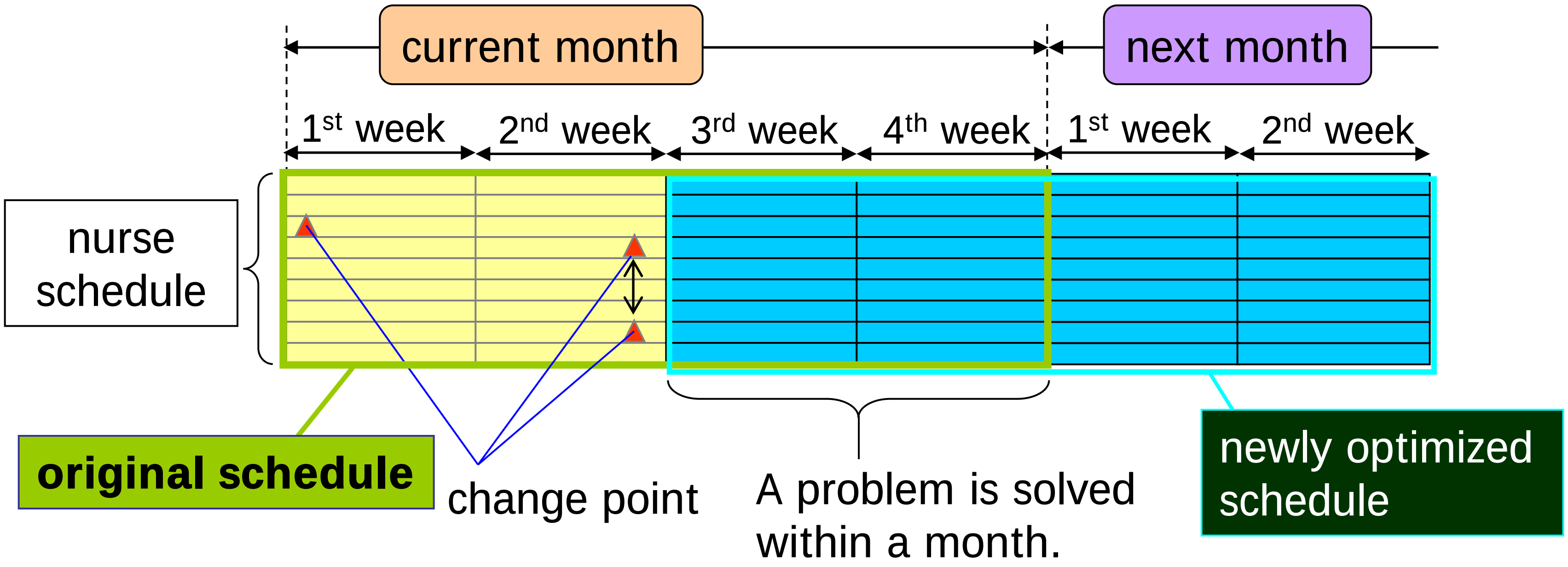
-This operation is executed to 100 parent pairs.
-Therefore, new 200 populations are performed.
-The best population is selected to the next generation.

mutation operator

changes some parts of the population.

3. Extension of Nurse Scheduling to permit changes of the schedule

We consider that one or two duties have been changed.



We consider the following cases as the changes……

1. A certain nurse took a holiday on a duty date.
2. A certain nurse worked in a holiday fixed day.
3. Two nurse’s shift were changed.
4. A certain nurse resigned from his/her job.
5. A certain nurse increased newly.

●Performing the Nurse Schedule by Penalty Functions

The penalty of each nurse

F_{1i}: Fairness of duty load
F_{2i}: The days of a vacation
F_{3i}: The days of night duty
F_{4i}: Degree of concentration of night duty
F_{5i}: Violation of prohibition of the training at the next day of night duty
F_{6i}: Consecutive duty days without holidays

The penalty in each duty day

F_{7j}: The nursing level in day time duty
F_{8j}: The nursing level in semi-night duty
F_{9j}: The nursing level in mid-night duty
F_{10j}: Affinity between the nurses in a night shift
F_{11j}: The prohibition of the mid-night duty between Newcomer
F_{12j}: Violation of a rule that one or more expert nurses

The penalty to the contents change of duty

F_{13}: Difference with the 3-4th week of the original nurse schedule.

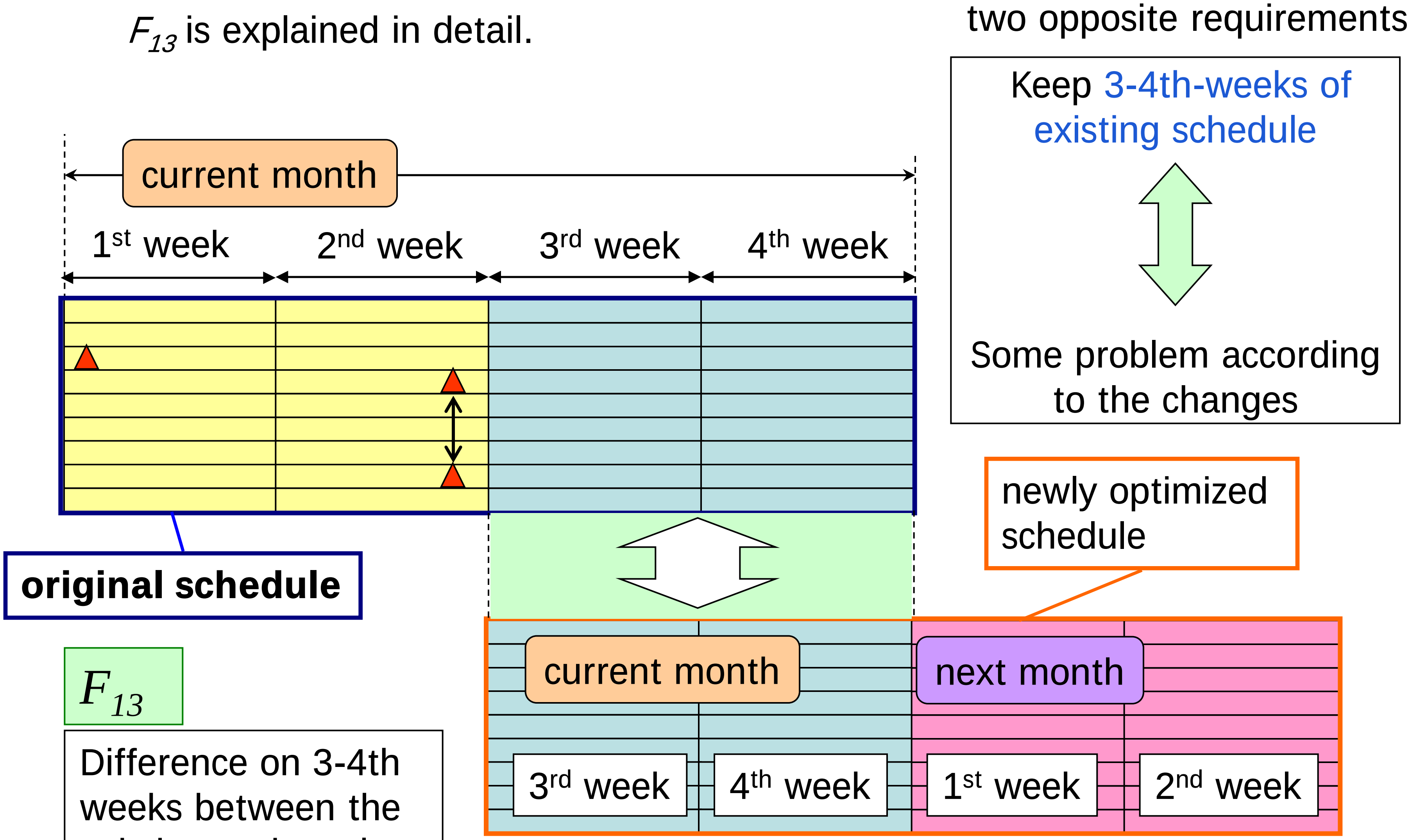
Total penalty

$$E = \left\{\sum_i \left(h_1 F_{1i} + h_2 F_{2i} + h_3 F_{3i}\right)\right\}^2 + \left\{\sum_i \left(h_4 F_{4i} + h_5 F_{5i} + h_6 F_{6i}\right)\right\}^2 + \left\{\sum_j \left(h_7 F_{7j} + h_8 F_{8j} + h_9 F_{9j}\right)\right\}^2 + \left\{\sum_j \left(h_{10} F_{10j} + h_{11} F_{11j} + h_{12} F_{12j}\right)\right\}^2 + h_{13} F_{13} \tag{1}$$

A Nurse schedule giving the smaller value of the total penalty denotes the better one.

●The Penalty F_{13} on Duty Change

F_{13} is explained in detail.



two opposite requirements

Keep 3-4th-weeks of existing schedule

Some problem according to the changes

current month

1st week

2nd week

3rd week

4th week

original schedule

newly optimized schedule

current month

next month

3rd week

4th week

1st week

2nd week

F_{13}

Difference on 3-4th weeks between the existing and newly modified schedules.

4. Mutation by Optimization Speed

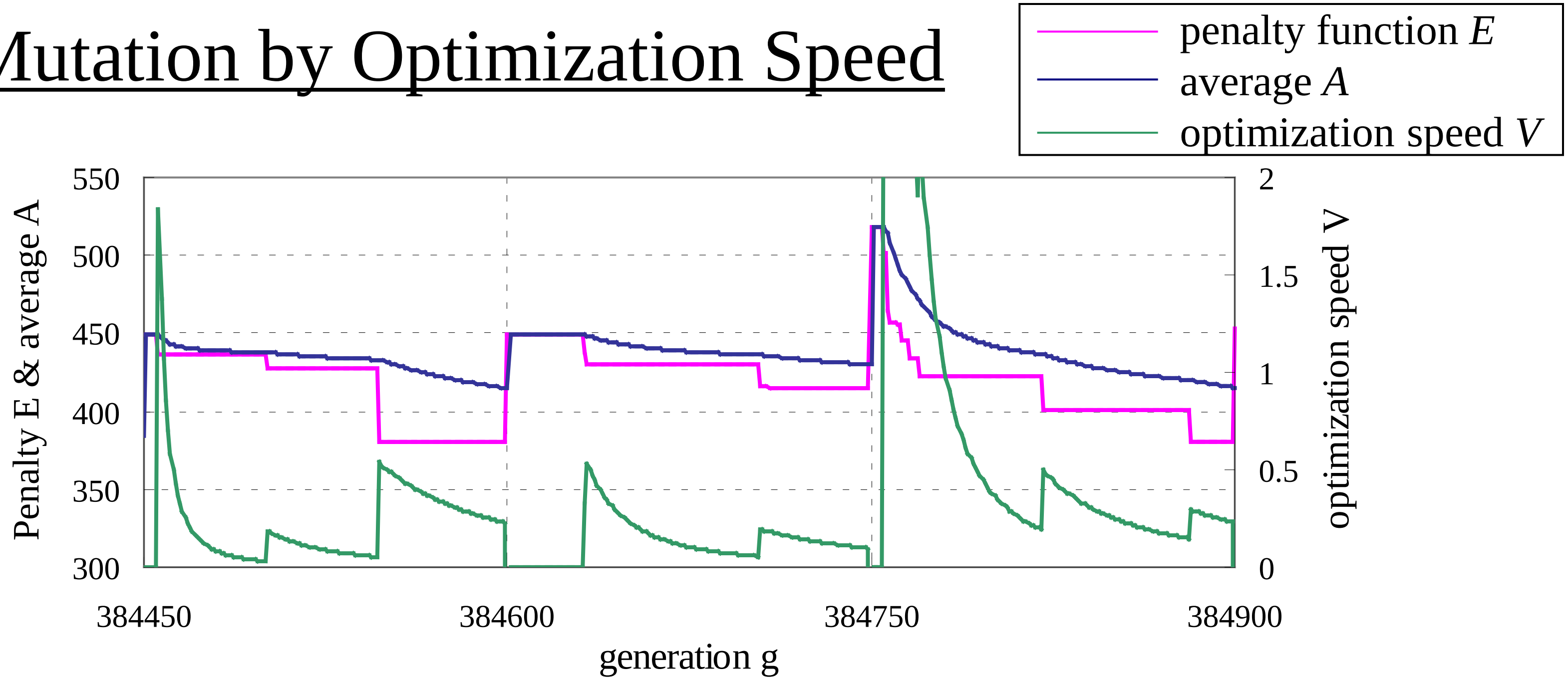


Fig.1. The total penalty function, *E(g)*, the average of the total penalty function, *A(g)*, and the optimization speed, *V(g)*, to the generation, *g*, when using the conventional mutation .

1. Average value A of the penalty value for N_g generations after mutation,

$$A(g) = \frac{1}{N_g} \sum_{i=0}^{N_g - 1} E(g-i). \qquad (2)$$

2. optimization speed V (Time difference of the average, A)

$$V(g) = A(g-1) - A(g) \qquad (3)$$

- Mutation is executed when optimization speed becomes less than a threshold **ε**.

- Optimization may not advance for several generations after the mutation.

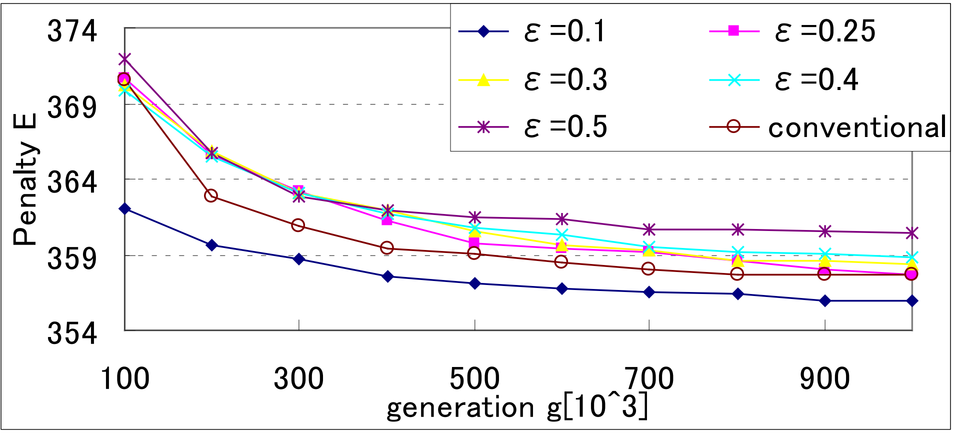
- Then, the mutation is prohibited for an <u>interval G_G right after the mutation</u>.

Guard Interval

5. Result

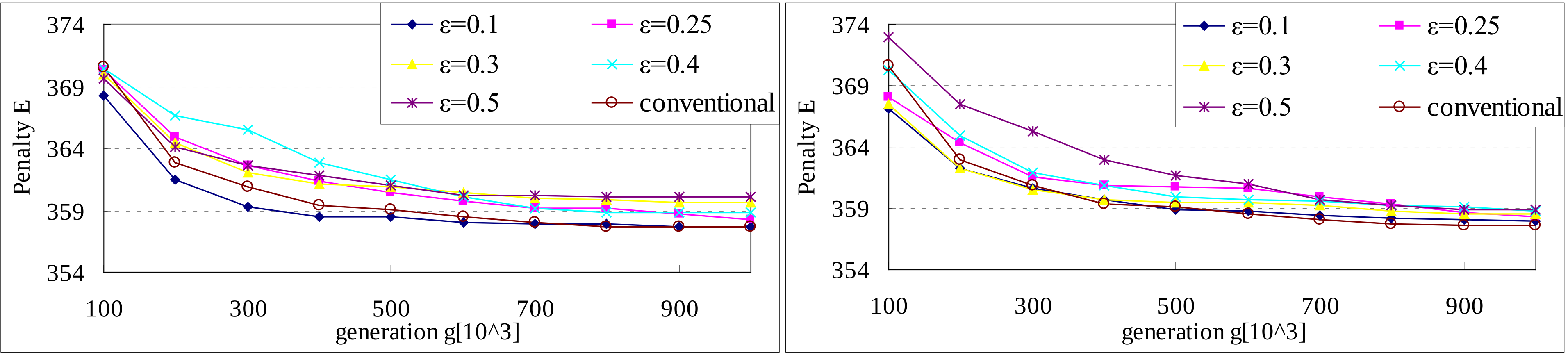
We’ve performed the NSP with……

- The number of nurse: 23
- The number of duty days: 28
- In this problem, We assume that one change of duty has been occurred in the past two weeks.



(a) G_G=10

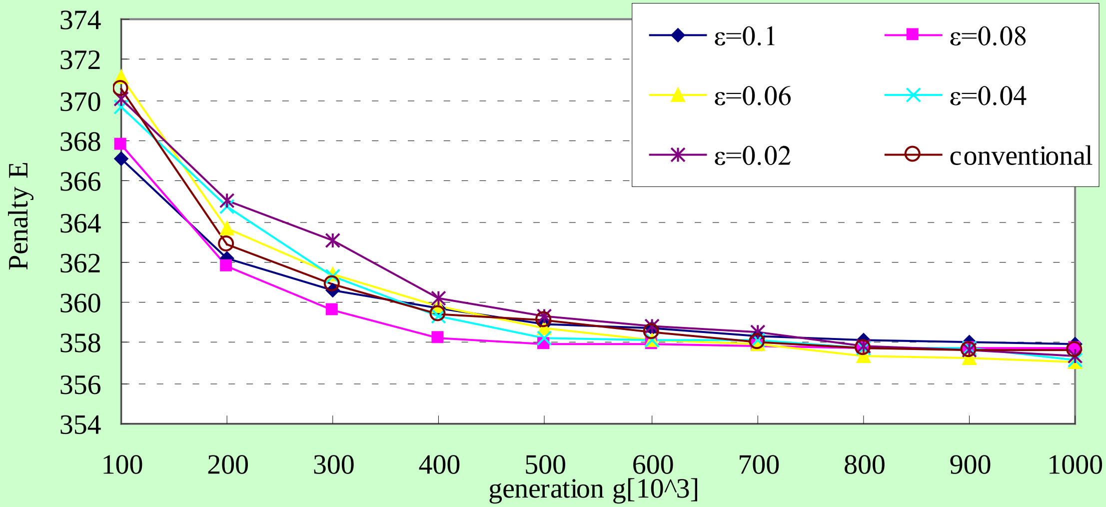
- When the speed threshold **ε** is set to 0.1 under any G_G, the optimization results have been performed better than the conventional mutation operator.



(b) G_G=30

(c) G_G=50

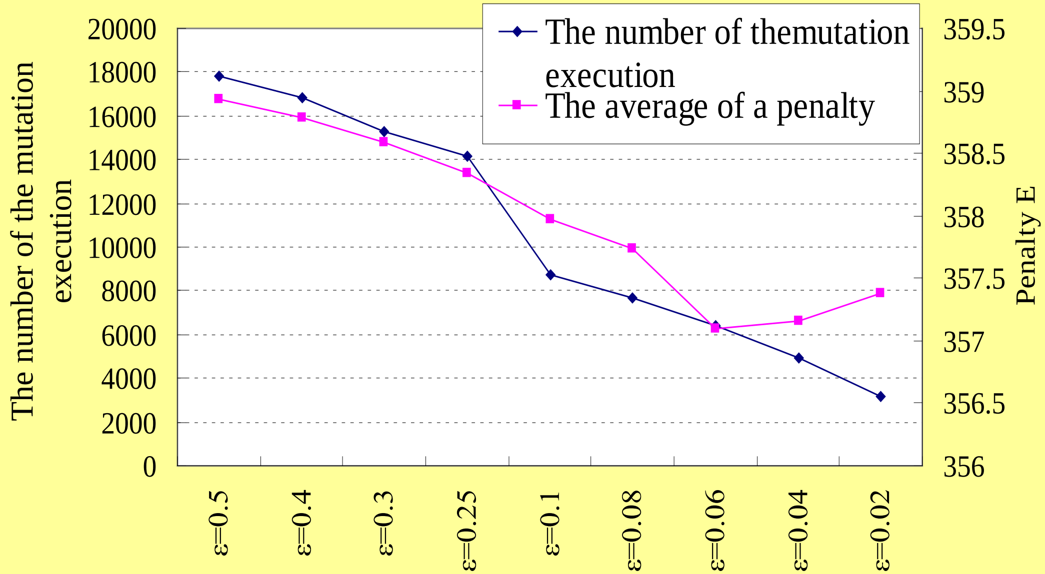
Fig.2. Comparison among optimization results with several of the guard interval. We have tried the optimization under each condition forty times. We took average of each forty trials to the generation, *g*.



- The **best** result is obtained when **ε** is set to 0.08.

- When **ε**≦0.06, the optimization results have been performed **worse**.

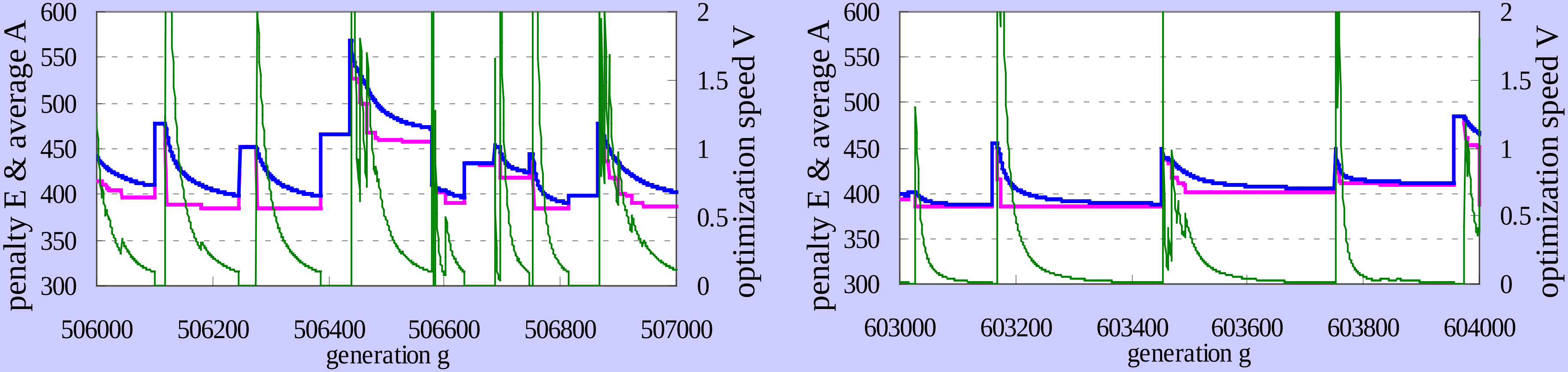
Fig.3. Average of the optimization results given by forty trials when G_G=50 and speed threshold **ε** is set to less than 0.1.



- When ε is set to small value, the number of the mutation execution increases.

- When **ε** is set to 0.06, the average of the penalty value yields the minimum.

Fig.4. The average of the number of the mutation execution and the penalty values at a million generations given by forty trials under several threshold **ε** when G_G=50.



(a) **ε**=0.07 (b) **ε**=0.01

Fig.5. The total penalty function, *E(g)*, the average, *A(g)*, and the optimization speed, *V(g)*, to the generation *g*, when using the variable mutation operator respectively

- The good results have been obtained when the speed threshold ε ≦ 0.1.
- If ε is set to too small value(like (b)), the mutation does not operate even when the optimization stagnates.

6. Conclusion

- We have extended the nurse schedule problem to permit the change of the schedule.
- The optimization speed is defined to start the mutation operator.
- This technique effectively works to optimize the nurse schedule.

- We will apply a parallel processing technique to the nurse scheduling.
- We will investigate a more effective genetic operator for the nurse scheduling.