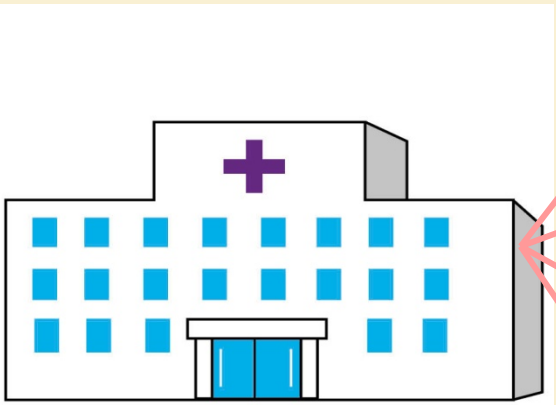
Effective Genetic Operators of Cooperative Genetic Algorithm for Nurse Scheduling



general hospital

- surgery
- internal medicine
- pediatrics
- obstetrics
- ...

Fifteen or Thirty nurses are working in each section.

A clinical director of the section make their shift schedule every month.

He/she needs one or two weeks for scheduling.

Automation of the nurse scheduling is required.

2. Nurse Scheduling by Cooperative GA (CGA)

One month schedule of a nurse n_i is coded by consisting of task symbols.

nurse n_i	D	H	M	S	H	H	D	M	· · · · ·	D	T	D	R	H	D	S	R

population

individual n_1
individual n_2
individual n_3
▪ ▪ ▪
individual n_i
▪ ▪ ▪
individual n_N

In the CGA, the individual is coded as an one-month schedule of one nurse.

The population consists of one-month schedules of each nurse.

The population denotes the whole nurse schedule of the current month.

The population, or the nurse schedule, is locally optimized by applying a crossover operator to pairs of the individual.

3. Performing the Nurse Schedule

Twelve penalty functions are defined for performing the nurse schedule.

* Duty load of each nurse : $F_{1i} = \sum_{j=2}^{D-1} p_{ij}$

* Fairness of holidays and night time duties of each nurse :

$$F_{2i} = \left| N_i^{\text{hom}} - N_{\text{hom}} \right| \qquad F_{3i} = \max\left(N_i^{sem} - N_{sem}, 0\right) + \max\left(N_i^{mid} - N_{smid}, 0\right)$$

* Intensiveness of night time duty assignment of each nurse :

$$F_{4i} := F_{4i} + \max\left(N_{night/6} - 3, 0\right)$$

* Violation of prohibition of the training at the next day of night duty : F_{5i}

* Consecutive duty days without holidays :

$$F_{6i} := F_{6i} + \max\left(N_{cons} - 5, 0\right)$$

∗ Total nursing levels of the day time, the semi night and the mid night duties at a duty day:

$$F_{7j} = \max\left\{ L_j^{day} - \sum_i L(n_i), 0 \right\},\ n_i \in M_j^{day} \qquad F_{8j} = \max\left\{ L_j^{sem} - \sum_i L(n_i), 0 \right\},\ n_i \in M_j^{sem}$$

$$F_{9j} = \max\left\{ L_j^{mid} - \sum_i L(n_i), 0 \right\},\ n_i \in M_j^{mid}$$

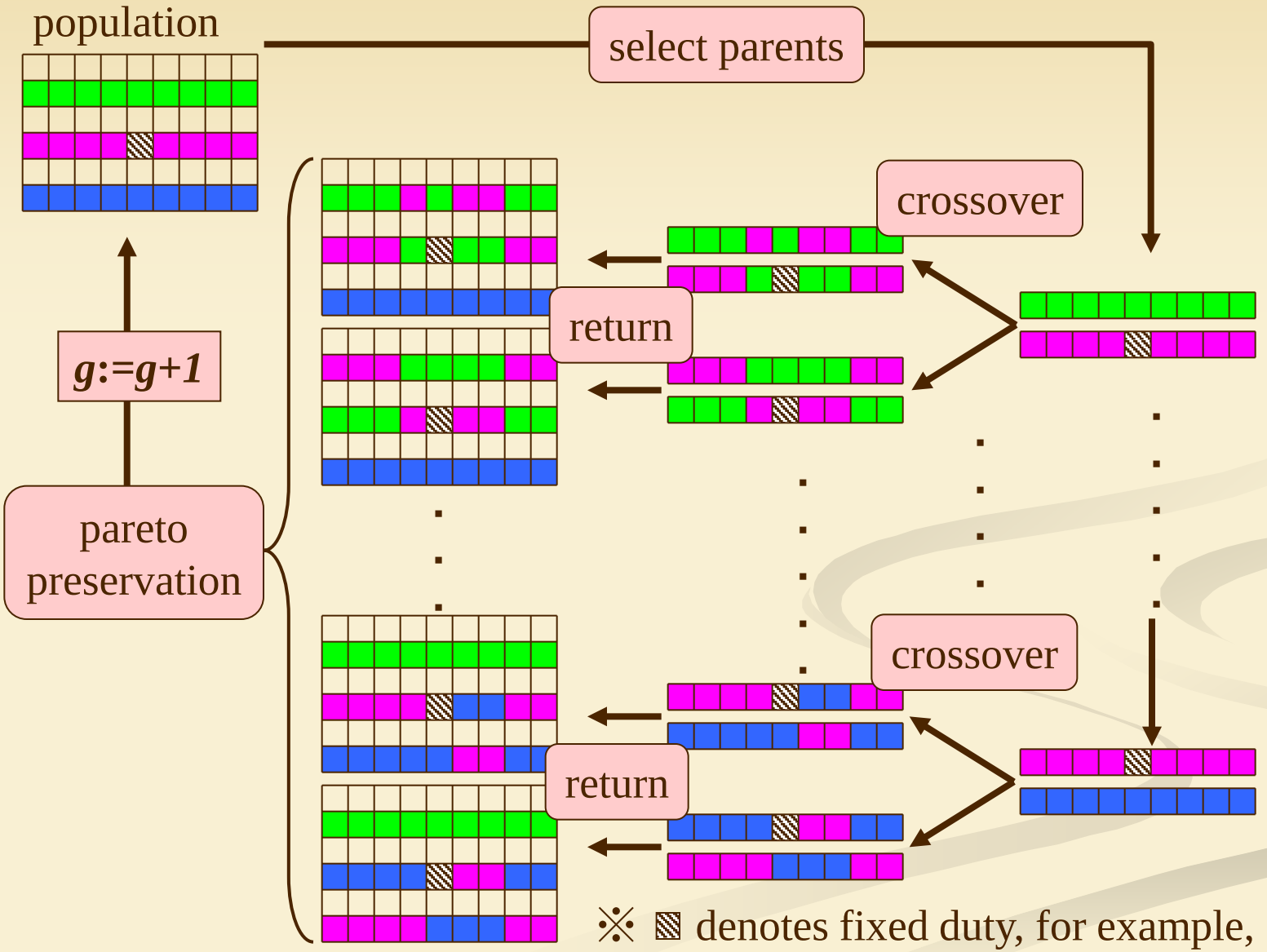
∗ Bad affinity combination of nurses assigned to the mid night duty at a duty day : F_{10j}

∗ Assignment of two or more new faces to the night duty at a duty day :

$$F_{11j} := F_{11j} + \begin{cases} 0 & , N_{j,new}^{mid} < 2, \\ \sum_{i=0}^{N_{j,new}^{mid}-2} \left(N_{j,new}^{mid} - i \right) & , N_{j,new}^{mid} \geq 2, \end{cases}$$

∗ Violation of a rule that one or more expert nurses at a duty day : F_{12j}

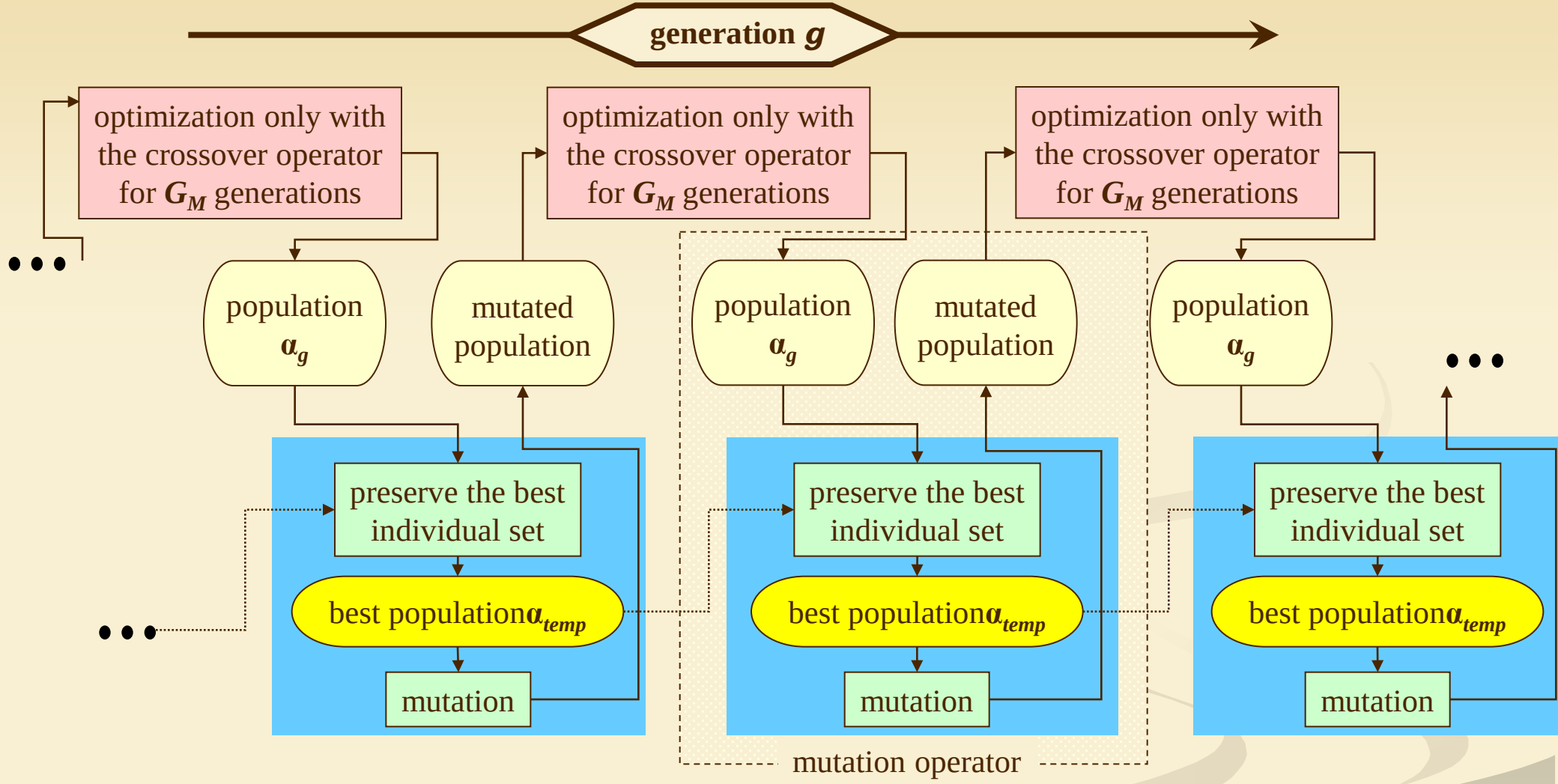
4. Basic Optimization Cycle by Crossover Operator



※ ▧ denotes fixed duty, for example, meeting, duty and requested holiday.

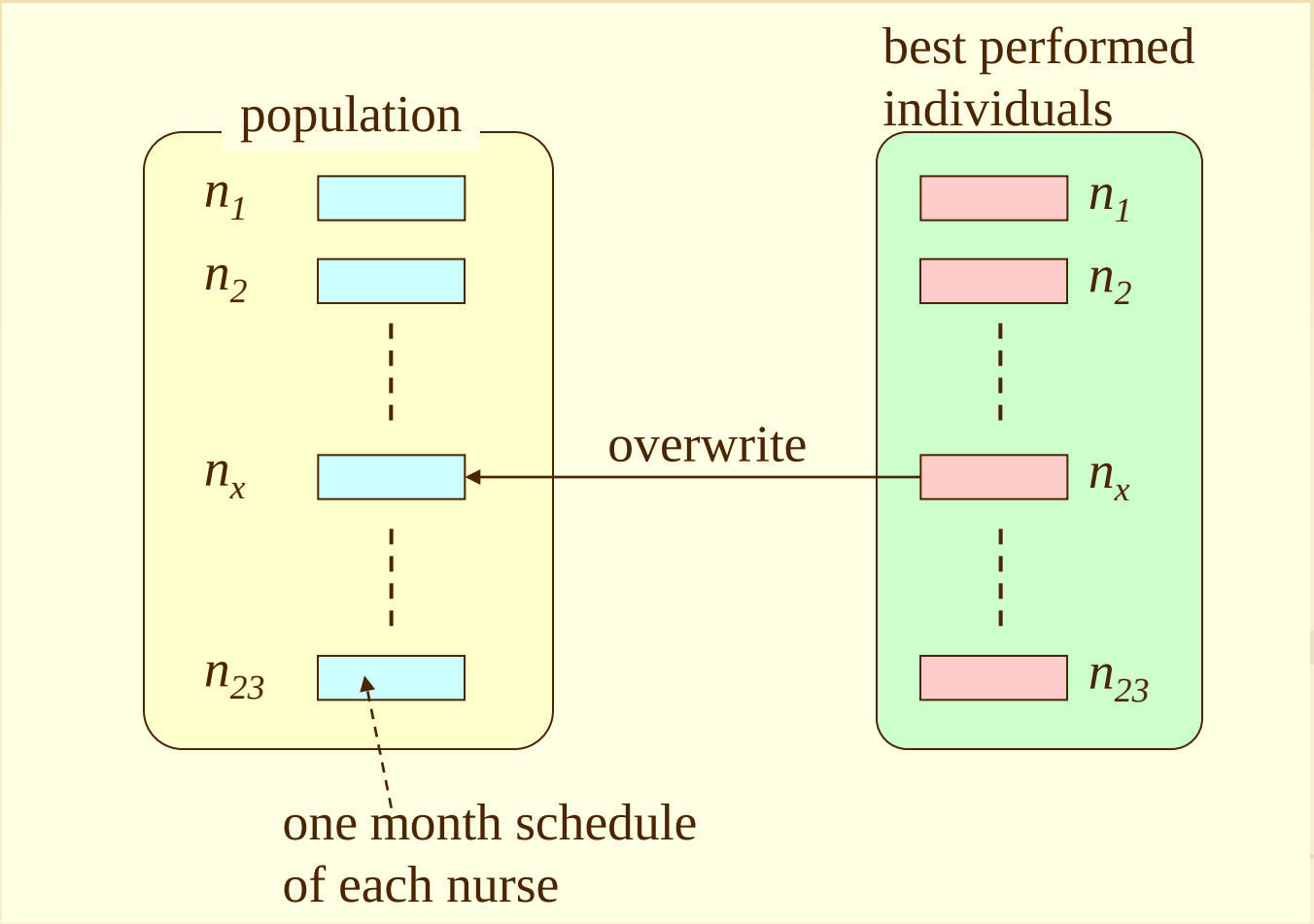
5. New Effective Operators

(1) Mutation Operator



- The mutation operator changes some parts of the population in the G_M generations interval without losing its consistency.
- The optimization before the mutation is carried out only by using the crossover operator for G_M generations.

(2) Virus Operator



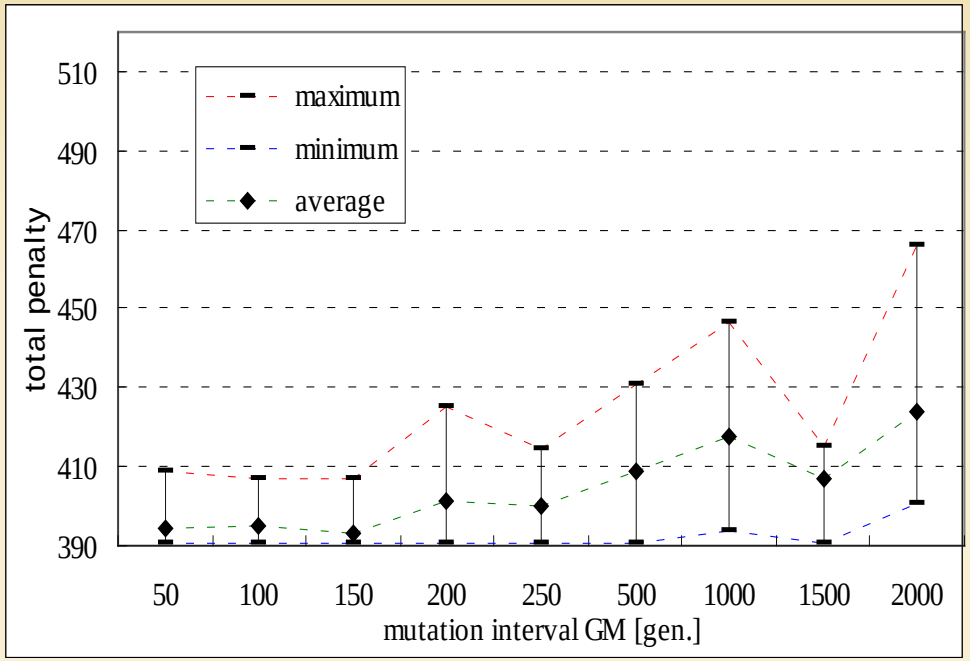
•After the pareto preservation, the best performed schedule of each nurse is preserved.

•When the mutation operator is execeuted G_v times, the virus operator is exectuted instead of the mutation operator.

•The virus operator overwrites the best performed individual onto an individual of the population.

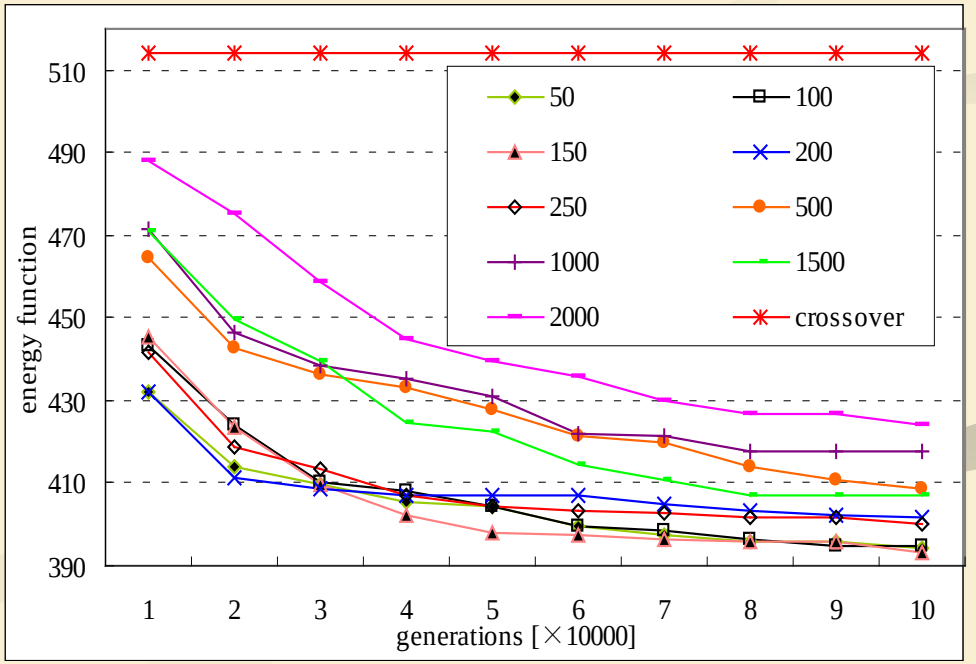
6. Results and Conclusion

We have considered on the mutation rate, G_M.

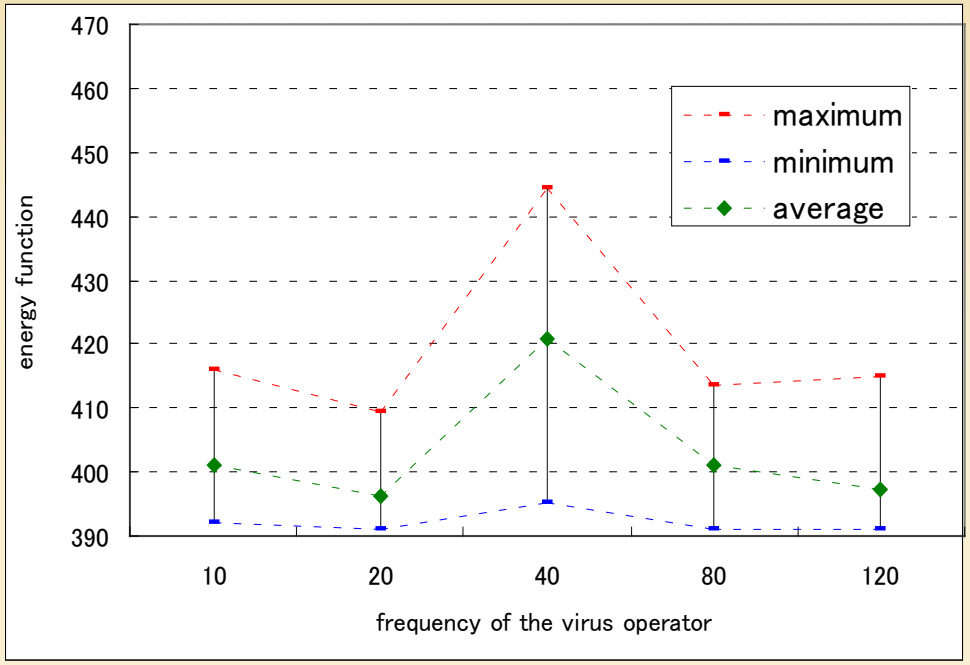


(a) Comparison of the mutation rate, G_M. This result shows that the mutation rate should be decided less than **150**.

(b) Average of the penalty for **10** trials with several mutation intervals. This result shows that the mutation with the mutation rate, G_M, less than **200** effectively works.

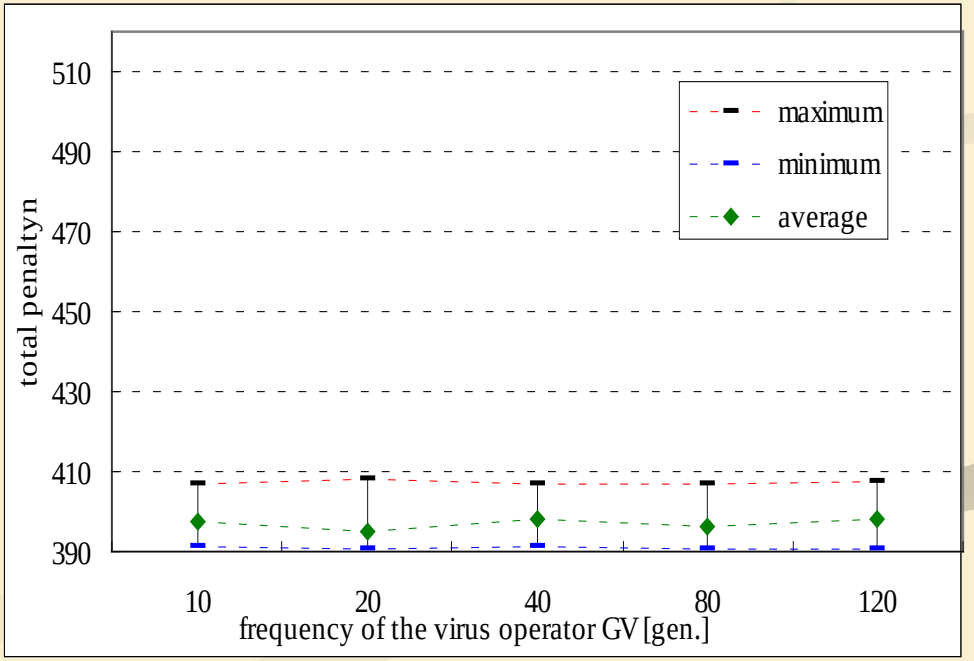


We have considered on the penalty configuration of the virus operator.

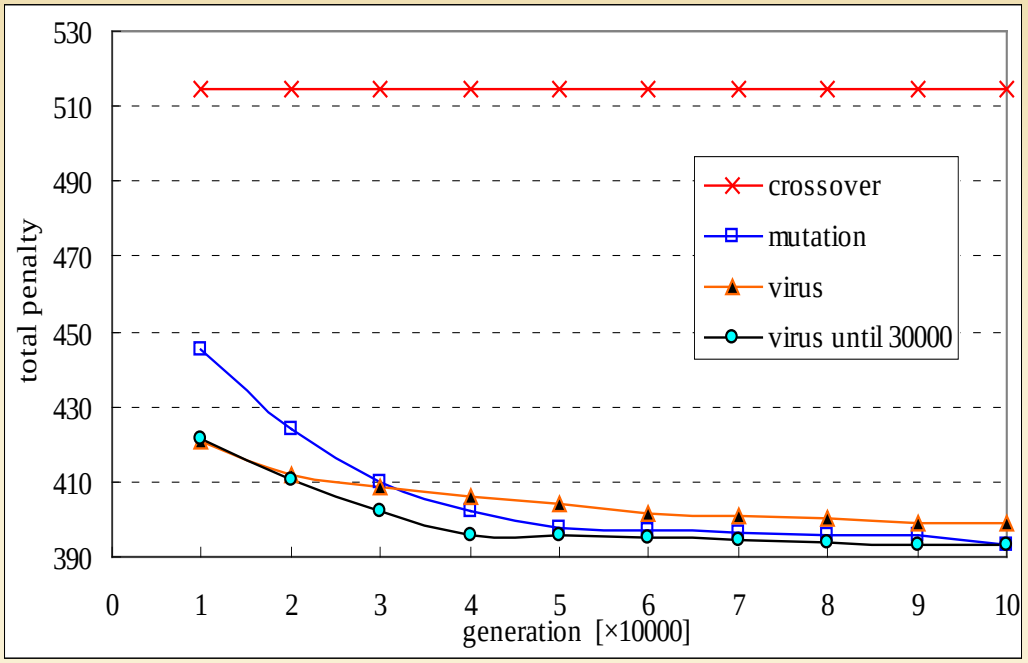


(c) In this case, penalty functions F_{1i}-F_{6i} are applied for the best individual selection. This approach does not stably good solution.

(d) We have tried to exclude the penalty function, F_{1i}, for the best individual selection. The penalty functions F_{2i}-F_{6i} are applied for the best individual selection. This modified approach stably good solution.



Finally, we have combined the new operators.



(e) Average of the penalty for **10** trials by using several techniques.

- The mutation operator slowly searches in the solution space and finally fined the best solution.
- The modified virus operator does not effectively searches after 30000 generations.
- The combined algorithm, shown by “virus until 30000”, gives the best performance.
- This result shows that the combined technique only requires 40000-50000 generations for the nurse scheduling.

Conclusion

- The nurse scheduling technique using CGA is proposed.
- The conventional CGA optimizes the schedule using only the crossover operator.
- Two new genetic operators, the mutation and the virus operators, are proposed to improve the optimization speed.
- We have considered on the mutation rate and the configuration of the penalty functions for the best individual selection.
- Finally, we have proposed the combined technique which quickly gives the best solution.