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*Automatic Design for Pipe Arrangement
using Multi-objective Genetic Algorithms*

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2. Formulating Pipe Arrangement Design Problem
3. Designing Multi-objective Genetic Algorithms
4. Experiments and Results
5. Conclusions and Remarks

Background

Reduce labor requirements

Advances in CAD

- efficiency improvement
- labor saving

Automation of pipe arrangement design has not yet achieved.

Objective

Design pipe arrangement automatically

1. Formulating pipe arrangement design problem

Large-scale multi-objective optimization problem

2. Designing multi-objective genetic algorithms

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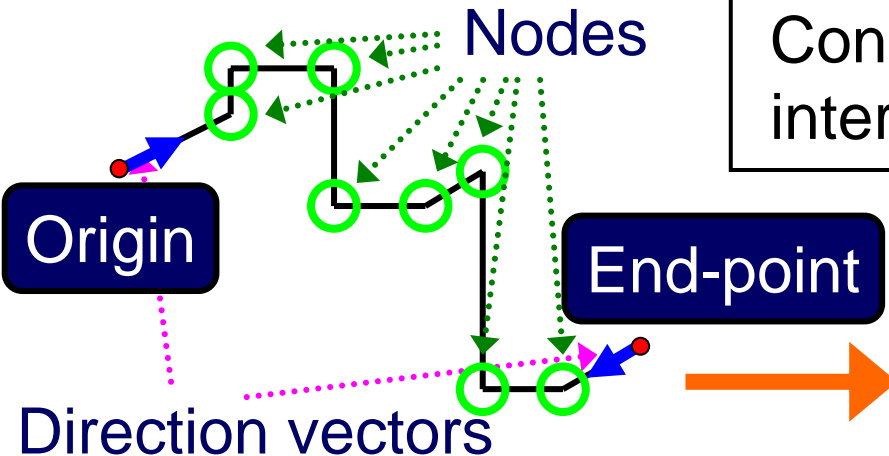
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Designing Pipe Arrangement

When both origin and endpoint coordinates and direction vectors are provided,

Piping route is automatically designed.

Considering interference with pipes and obstacles

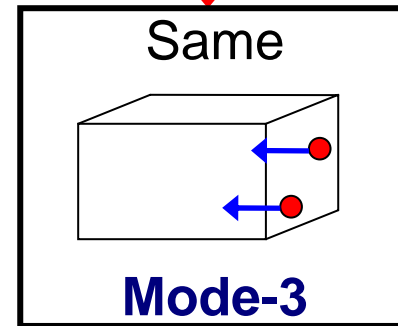
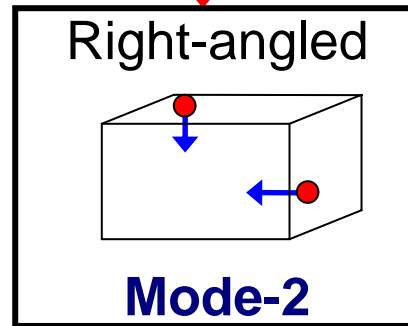
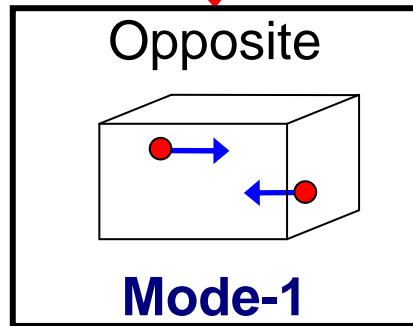


An infinite number of piping route

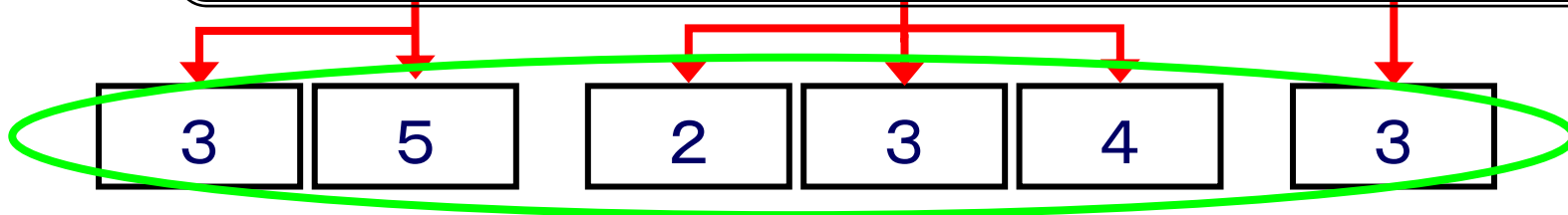
A limit is imposed on the degrees-of-freedom for the route.

Generation pattern

1. According to direction vectors



2. According to the number of nodes

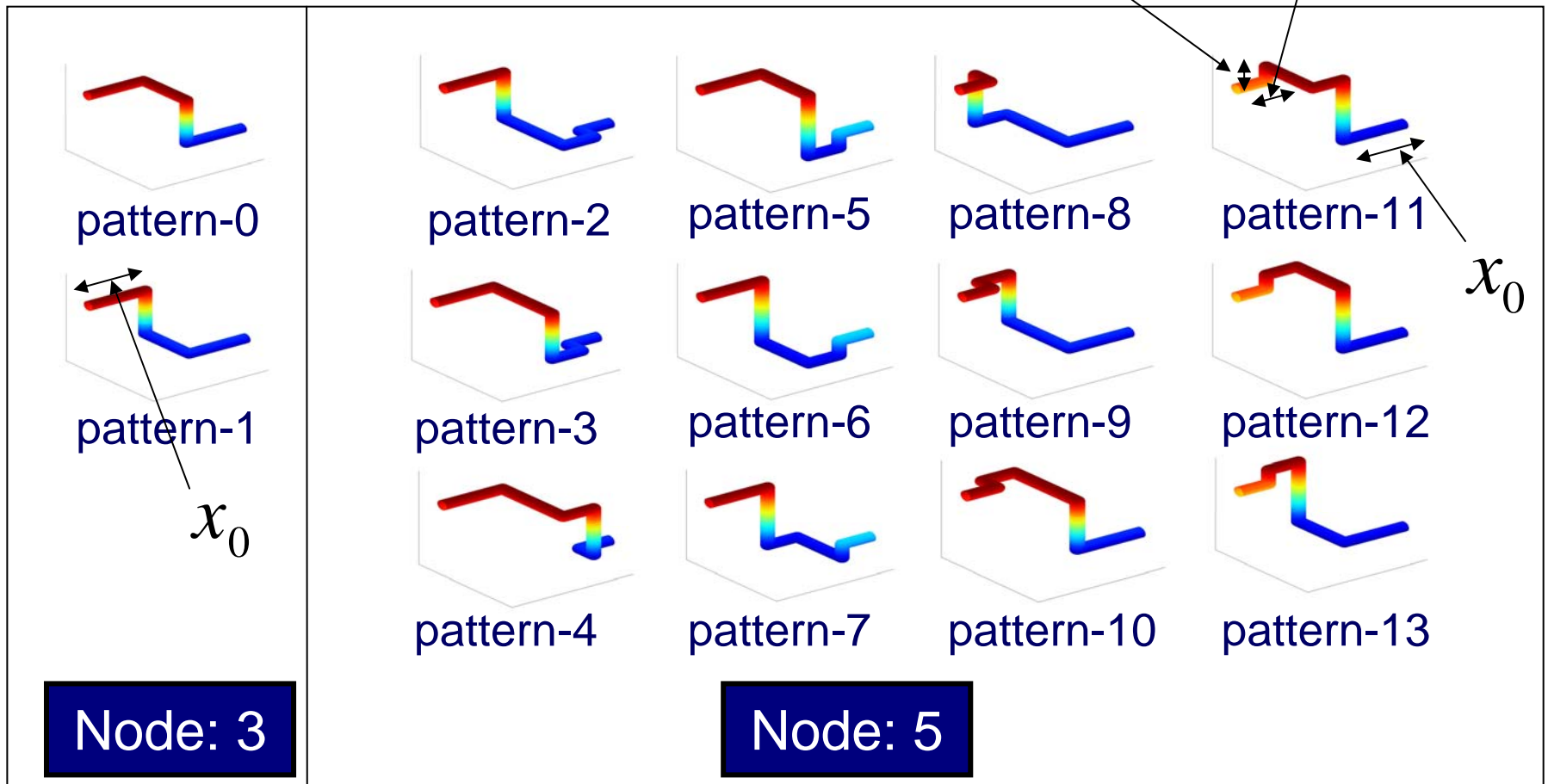


The number of nodes increases

Degrees-of freedom expands

The number of nodes should be minimized while avoiding interference with other pipes and obstacles.

Mode-1

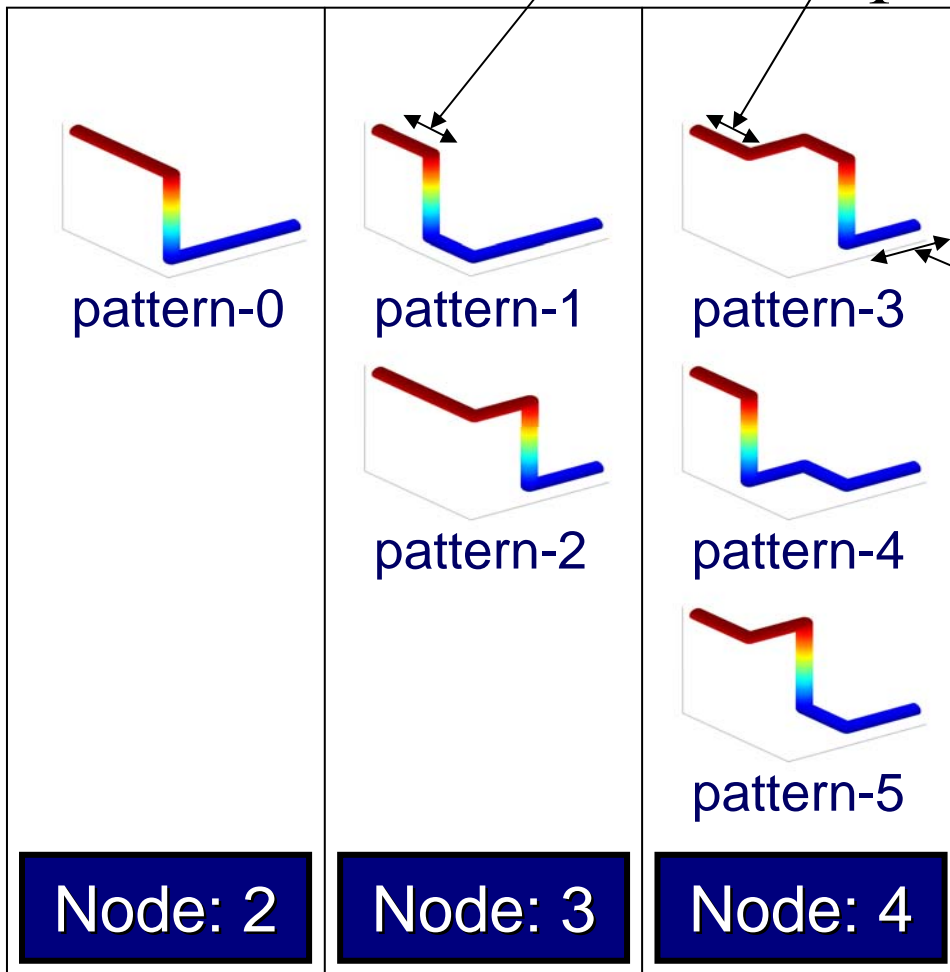


The number of combination: 14
The number of variables: 3



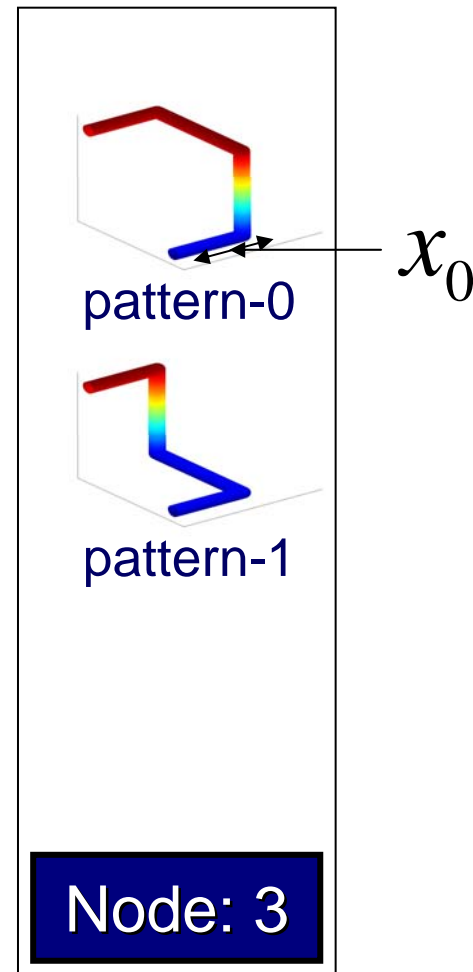
A pipe is characterized uniquely.

Mode-2



The number of combination: 6
The number of variables: 2

Mode-3



The number of combination: 2
The number of variables: 1

Evaluation function for obstacle (1)

A space set aside to allow for maintenance people to pass



This space is considered as an obstacle.

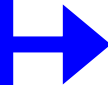
Need not completely avoid the obstacle



Avoid the obstacle **as much as possible**



Evaluation function



Minimize the evaluation value



Optimization problem

Evaluation value for obstacle (2)

$$f_{_obstacle} = \sum_{l=1}^{n_o} \sum_{k=1}^{n_p} (b_{kl} - \bar{a}_{kl} + A_l)$$

\underline{b}_{kl} : The length of intersection when the pipe k intersects the obstacle l

\underline{a}_{kl} : The averaged length between the center of the gravity of the obstacle k and the part divided by each node of the pipe l

A_l : The length between the center of the gravity and the top of the obstacle l

n_o : The number of obstacles

n_p : The number of pipes

Minimum value = 0
(All pipes not interfering with obstacles)

Evaluation values are worse

when a pipe passes through the center of an obstacle and the length of the intersection is long.

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Characteristic of this problem

This problem includes numerical optimization and combination optimization problems.

Using GA, which is direct search method

It is difficult to optimize this problem using usual optimization techniques.

- Annealing method
- Downhill simplex method, etc.

The length of pipe

Trade-off

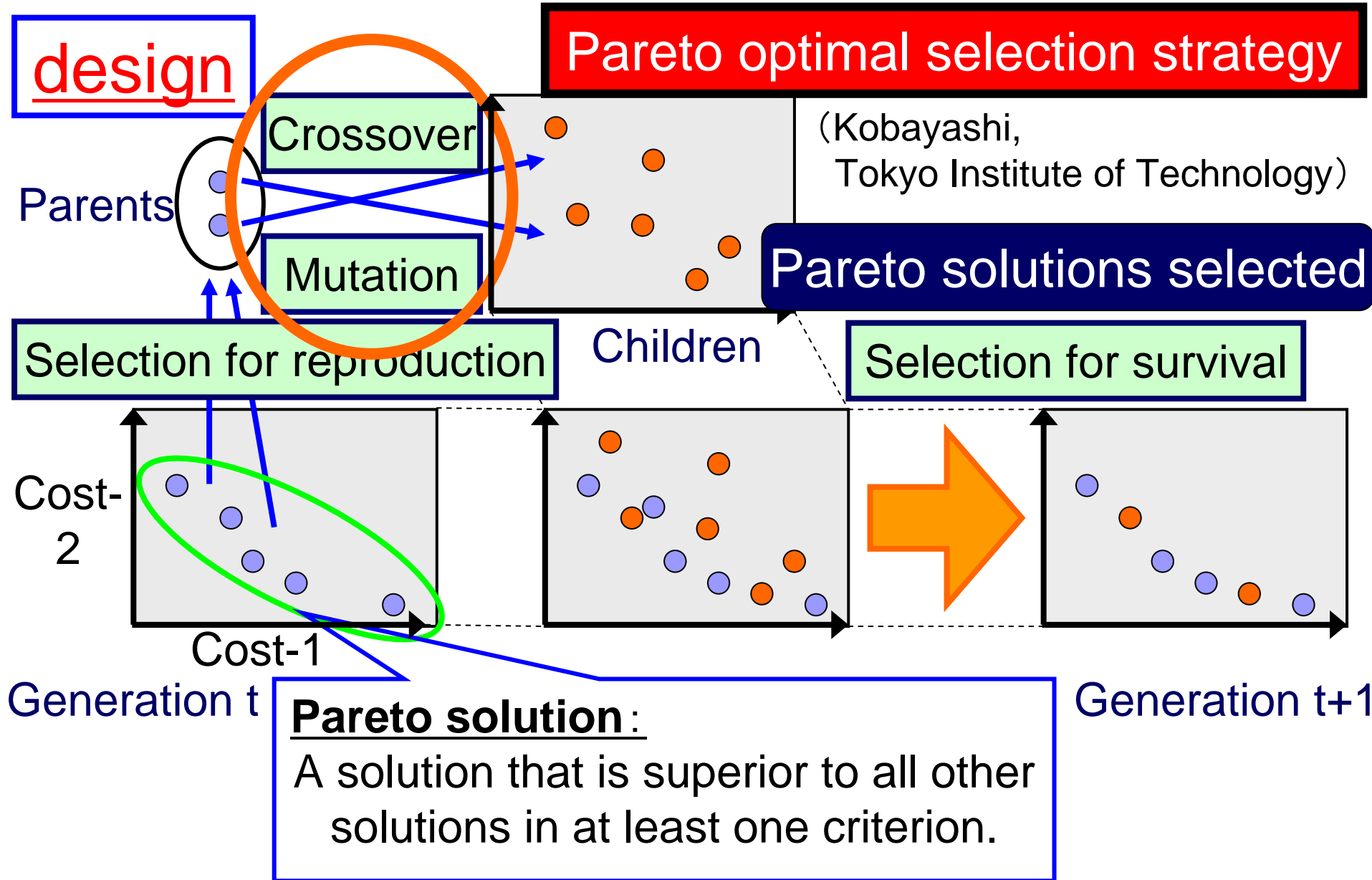
Multi-objective optimization problem

The Evaluation value for obstacle

Multi-objective GA



Multi-objective genetic algorithms



Representation

Pattern of generation

Numerical parameters



A pipe is characterized by them

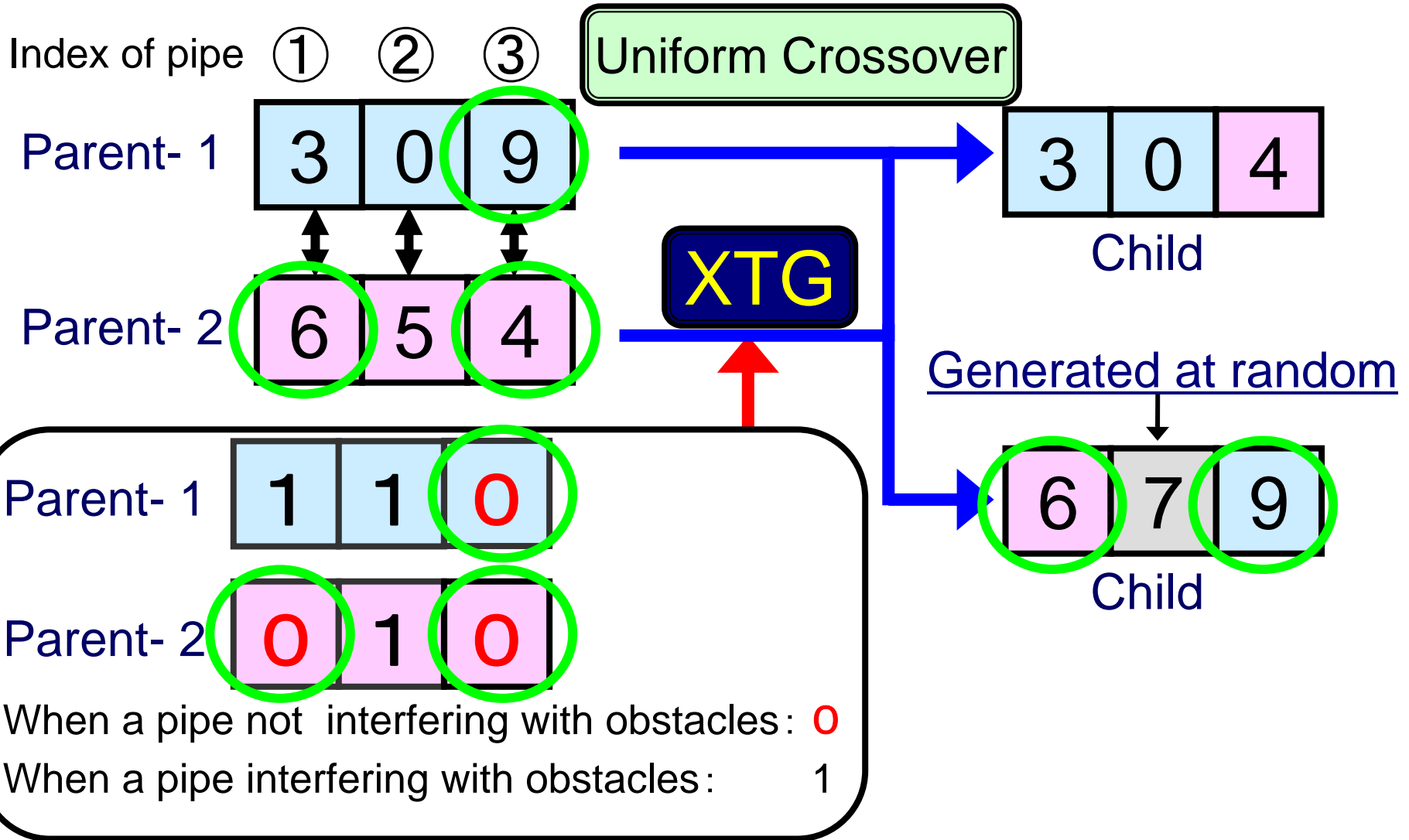


A combination of them are used
as the solution representation

Solution structure

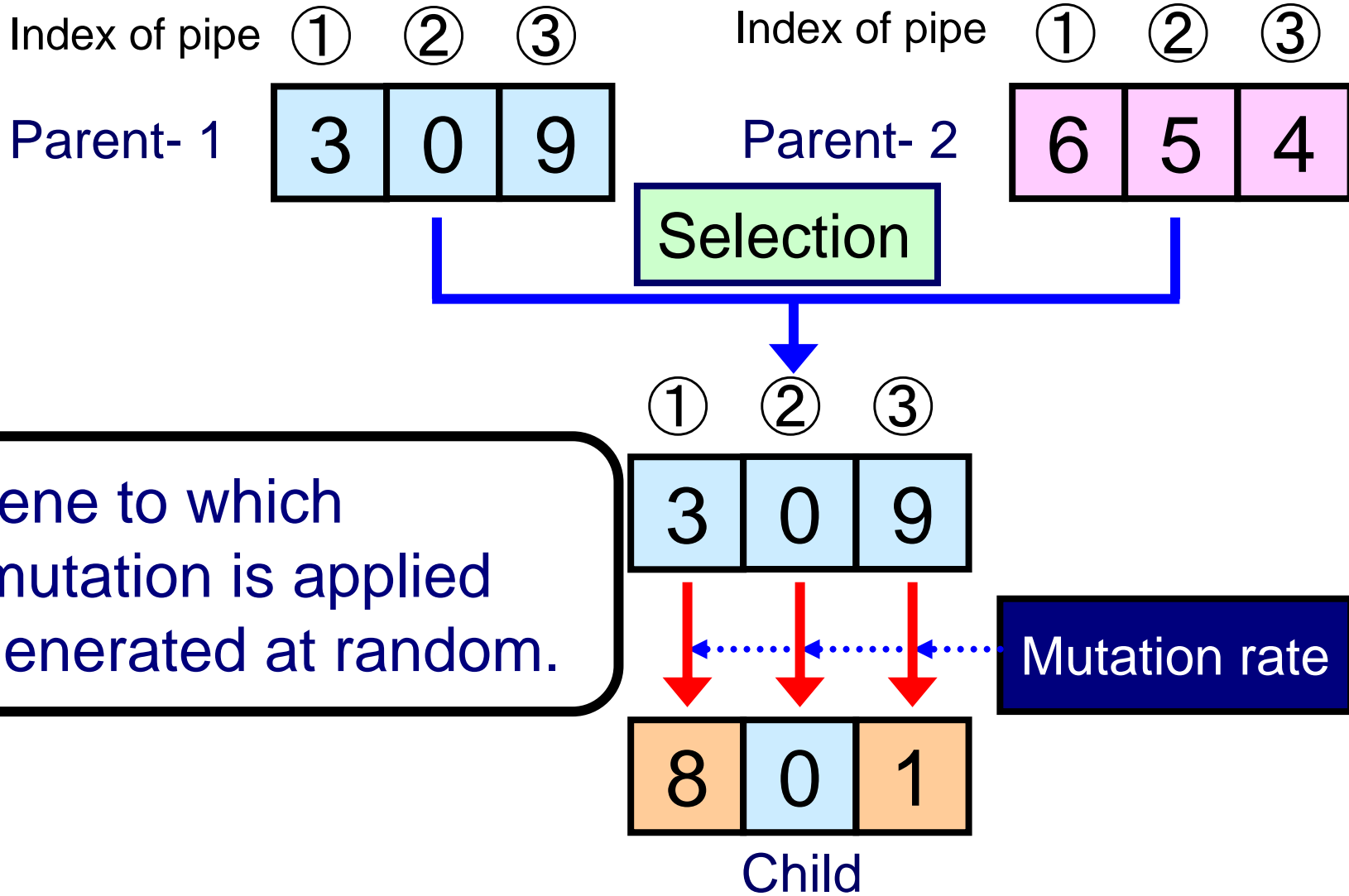
Pattern of generation	$pattern_1$	$pattern_2$	$pattern_n$
	x_{10}	x_{20}	x_{n0}
Numerical parameters	x_{11}	x_{21}	x_{n1}
	x_{12}	x_{22}	x_{n2}
	pipe 1	pipe 2		pipe n

Crossover with Two Gene: XTG

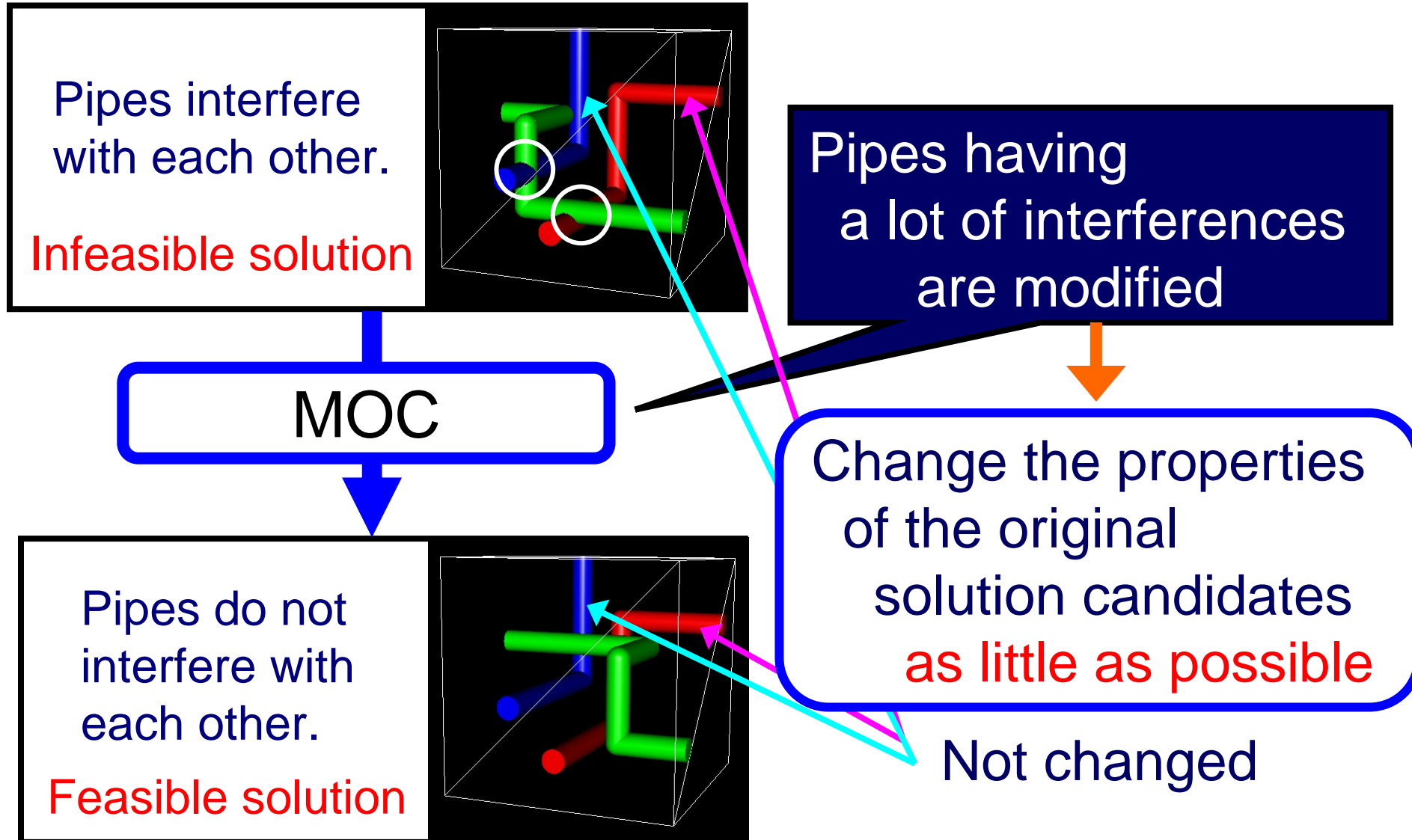


The evaluation value for obstacle can be expected to be improved.

Mutation



Modification operator on Contact: MOC

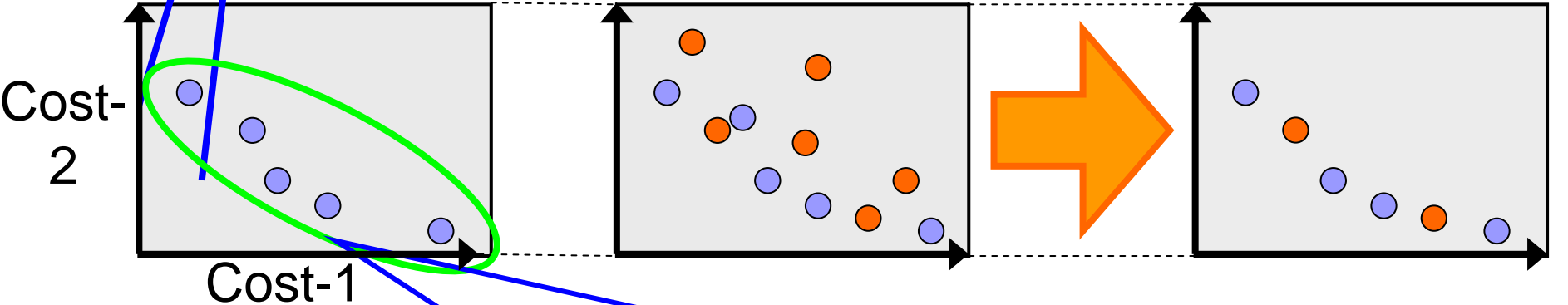
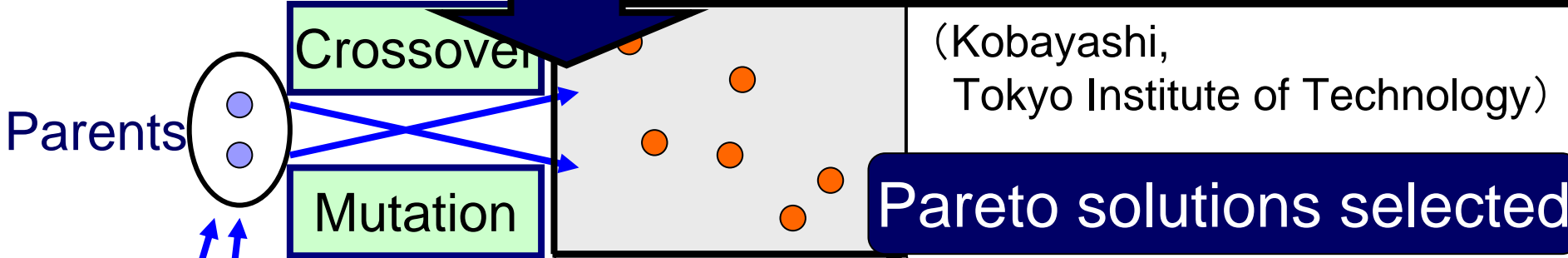


Multi-objective algorithms

MOC

Pareto optimal selection strategy

(Kobayashi, Tokyo Institute of Technology)



Pareto solution:
A solution that is superior to all other solutions in at least one criterion.

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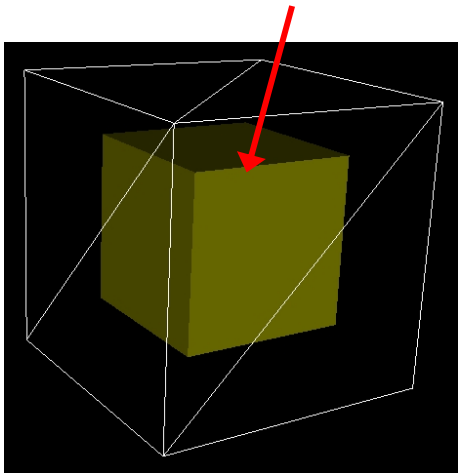
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Experiments

	Mode-1	Mode-2	Mode-3
The number of pipes	5	7	3
The number of variables	3	2	1
The number of combinations	14	6	2
The total number of variables	15	14	3
The total number of combinations	537,824	279,936	8
The number of all variables	32		
The number of all combinations	Approximately 1.2 trillion		

The space where a obstacle exists

Large-scale optimization problems



We set the problem where many pipes exist closely and a big obstacle exists.

Initial Pareto solutions

Calculation environment

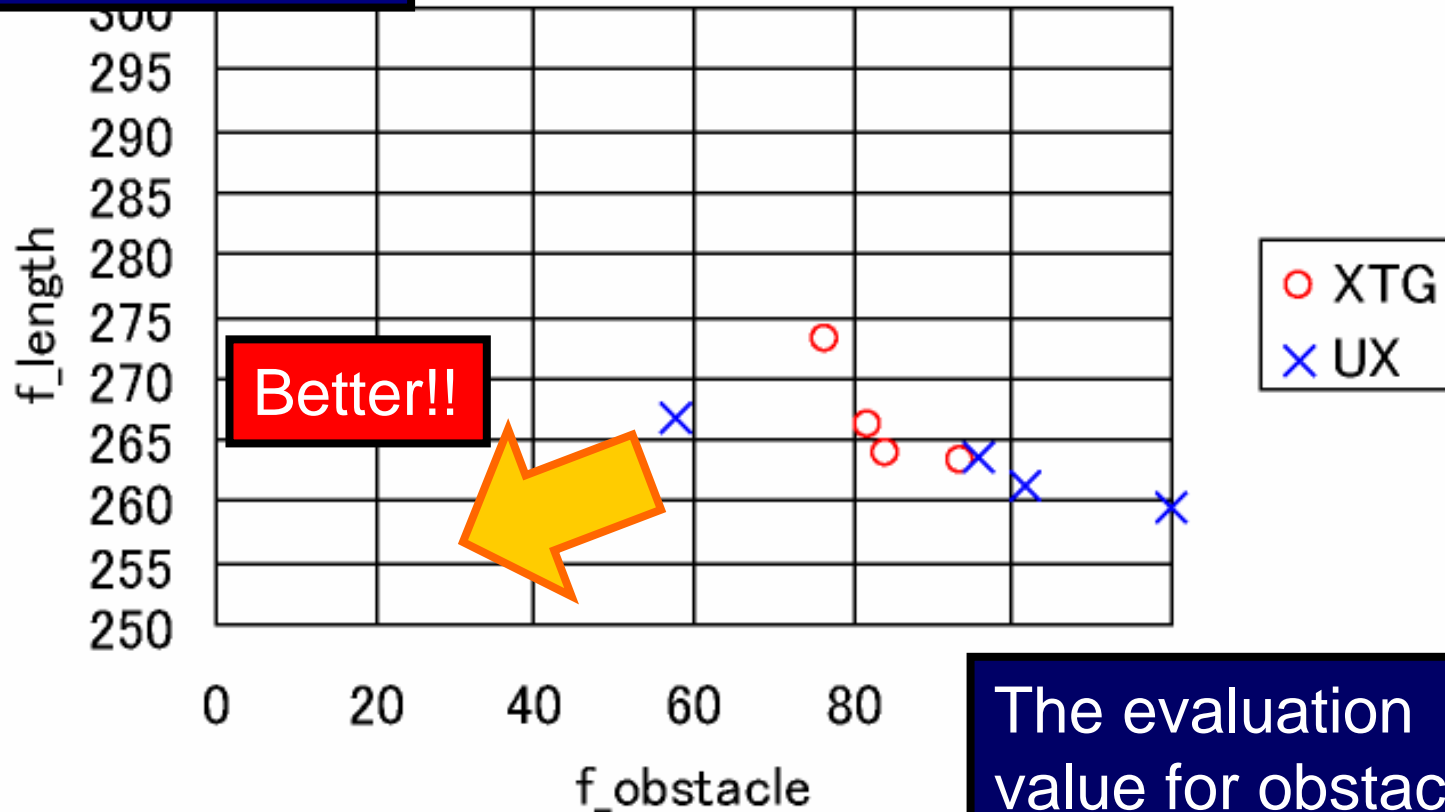
Pentium 4 2.40GHz

512MB

Windows XP

Java

The sum total of
the length of pipe

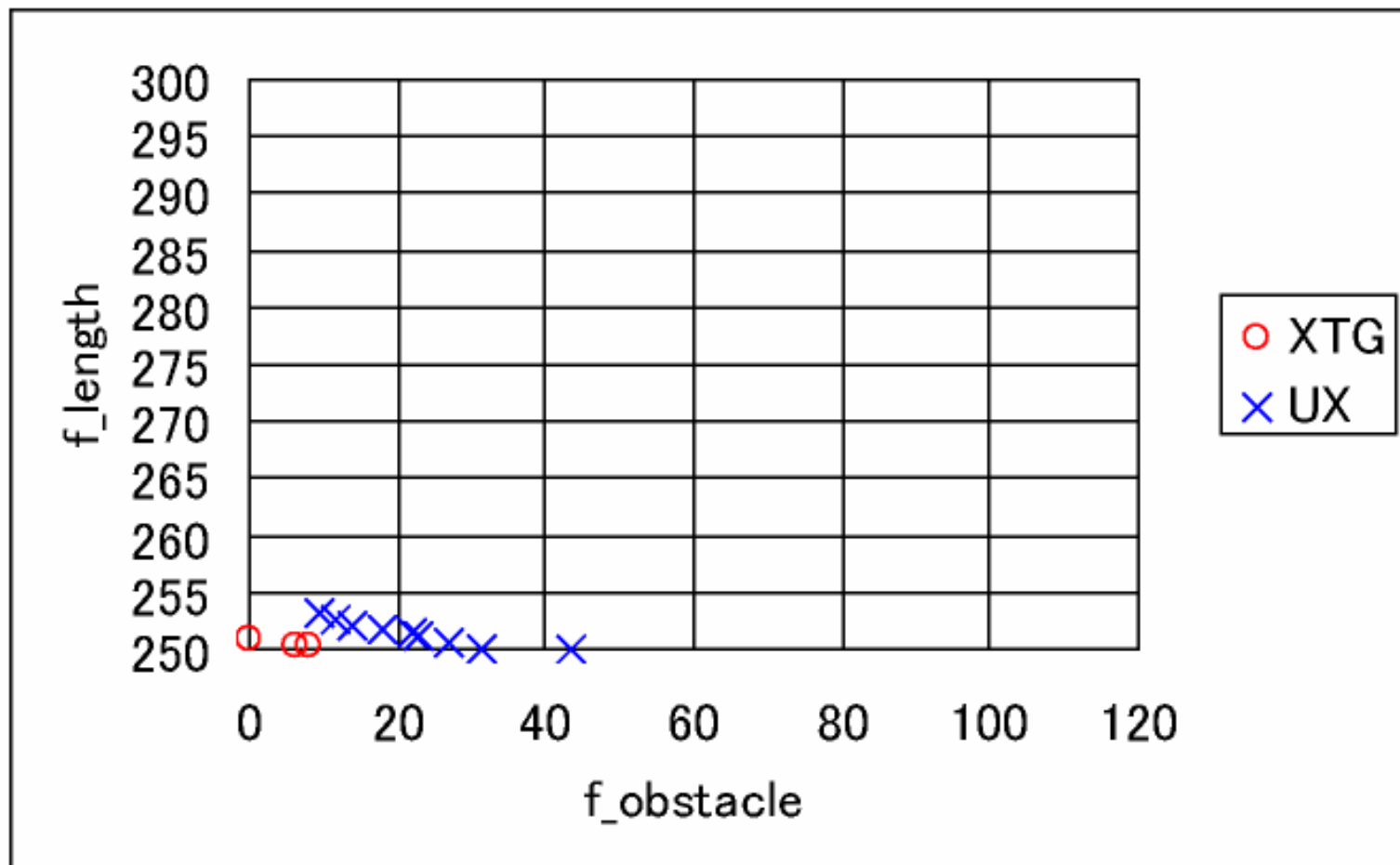


Better!!

The evaluation
value for obstacle

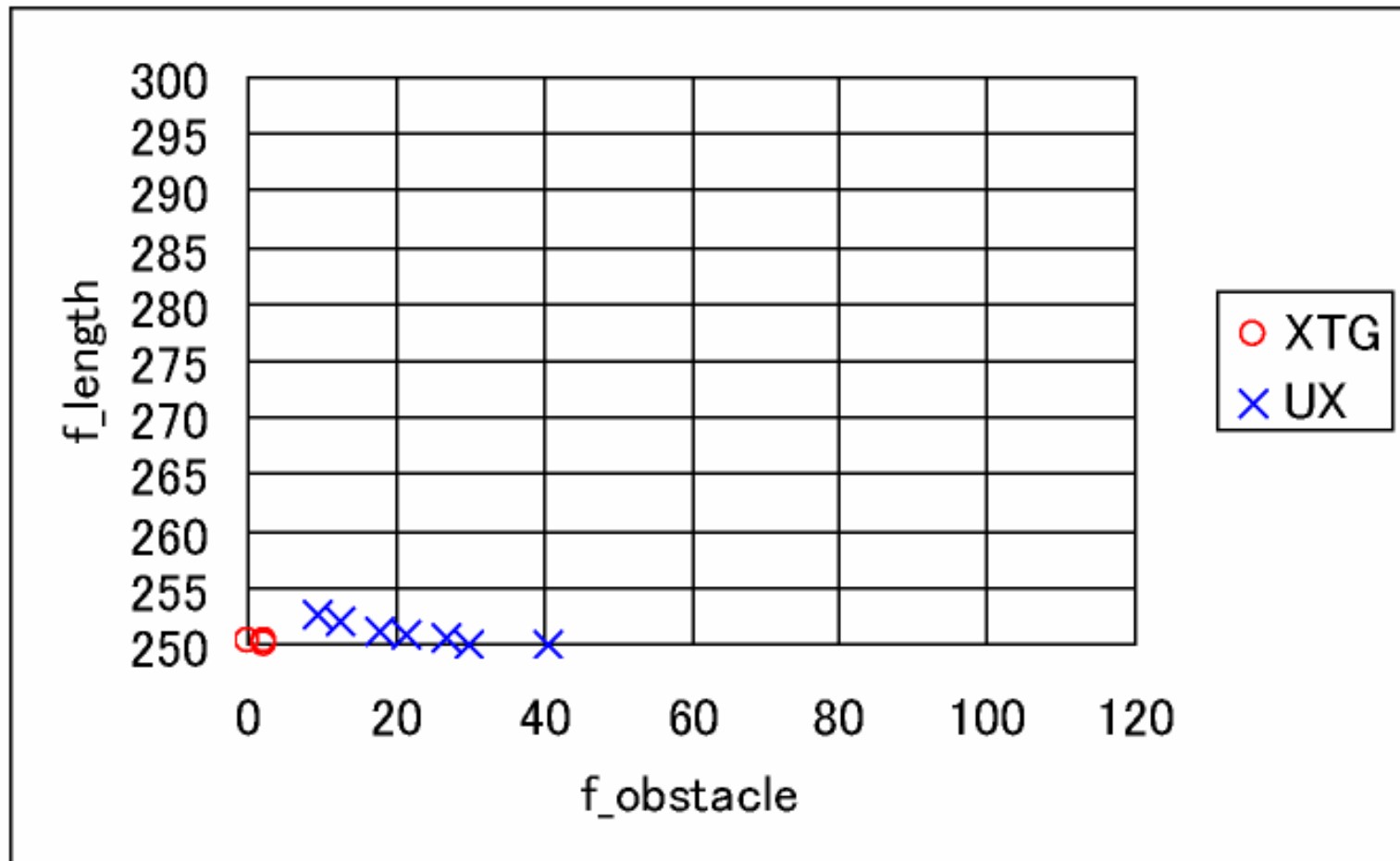
Pareto solutions in 100th generation (1.0×10^4 solution candidates evaluated.)

About **10 minutes** for searching



Pareto solutions in 1000th generation
(1.0×10^5 solution candidates evaluated.)

About 60 minutes for searching



Results

Programming language: Java3D

start

The number of pipes: 15
The number of obstacles: 2

15_2

The number of pipes: 20
The number of obstacles: 1

20_1

The number of pipes: 20
The number of obstacles: 3

20_3

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Conclusions

- A design problem for pipe arrangement was formulated.
- A multi-objective Genetic Algorithms suitable for this problem was developed.
- The effectiveness of the proposed method was verified through several experiments.

Future works

- Applying this methodology to a practical design
- Improvements to the proposed algorithms