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FBDScenaGen+: GA-based High-Quality Scenario Generator for FBD Simulation

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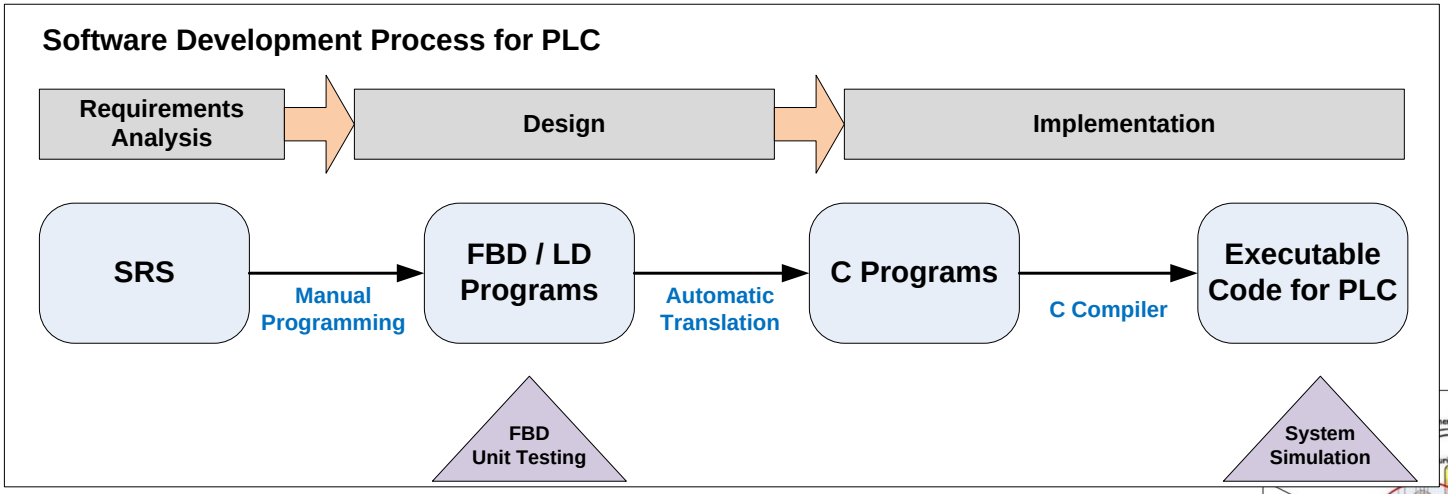
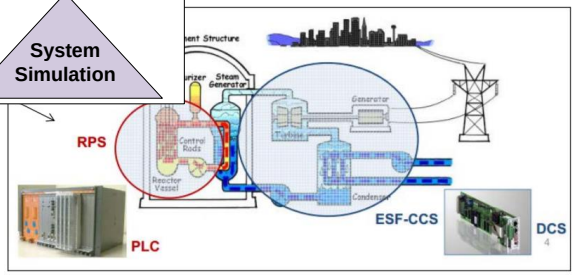
Contents

Introduction

- **FBDScenaGen+**: GA-based High-Quality Scenario Generator for FBD Simulation
  - **Objective**
    - High-Quality Scenario generation for **FBD** program simulation
  - **Target system:**
    - PLC-based software system in nuclear plants
    - Typical development process : SRS – **FBD** – C – executable SW

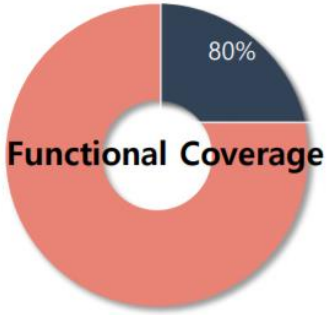


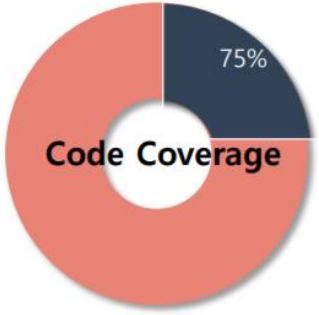


Introduction

- **Q. How Adequately the Testing has been Performed?**
  - Test Done = Test Plan Executed and All Codes Executed

- **Q. How much efforts is needed to accomplish some coverages?**
  - Our Issue: **FBD Coverage + GA Techniques** ➔ High-quality scenarios





Functional Coverage

- = Requirements Coverage
- This coverage will be defined by the user
- User will define the coverage points for the functions to be covered
- 100% of functional coverage is always required

Code Coverage

- = Structural Coverage
- How many lines are executed, how many times expressions, branches executed, etc.
- Code coverage is collected by the simulation/testing tools.
- Users use code coverage to reach those corner cases which are not hit by the test cases.
  - Unfortunately, errors and bugs are often found in the corner cases.
- To assure a high quality of functional verification, code coverage is important as well as functional coverage

1. FBD Structural Coverage
2. Genetic Algorithm

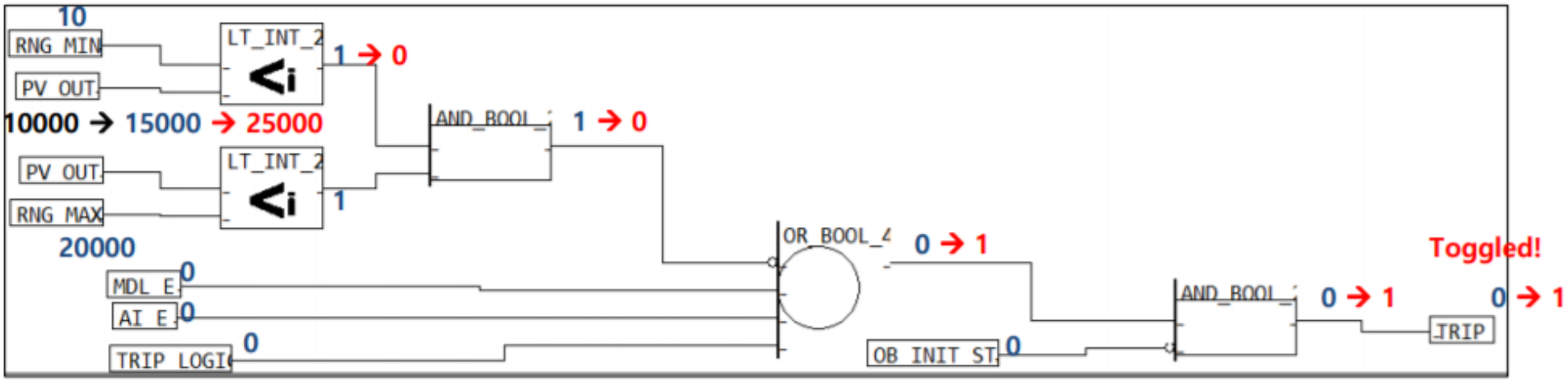
BACKGROUNDS

FBD Structural Coverage

- A metric for measuring simulation effectiveness
  - To help determine when a system is adequately tested

- Two coverage
  - **Toggle coverage**
  - MC/DC coverage

Ex) 1-to-0 and 0-to-1 → 100% toggle coverage



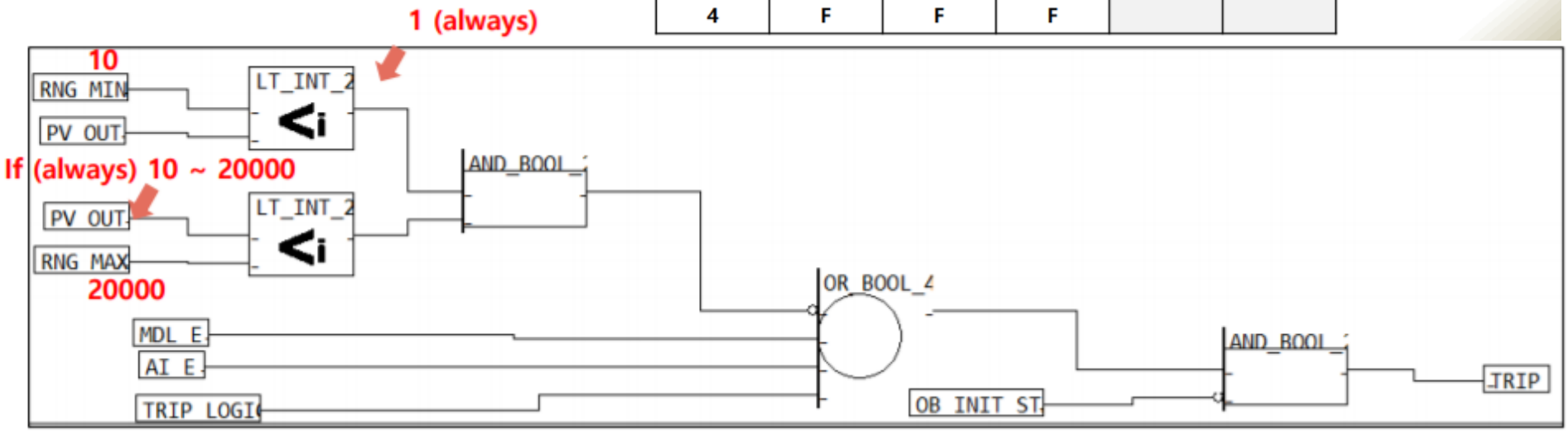
FBD Structural Coverage

- A metric for measuring simulation effectiveness
  - To help determine when a system is adequately tested

- Two coverage
  - Toggle coverage
  - **MC/DC coverage**

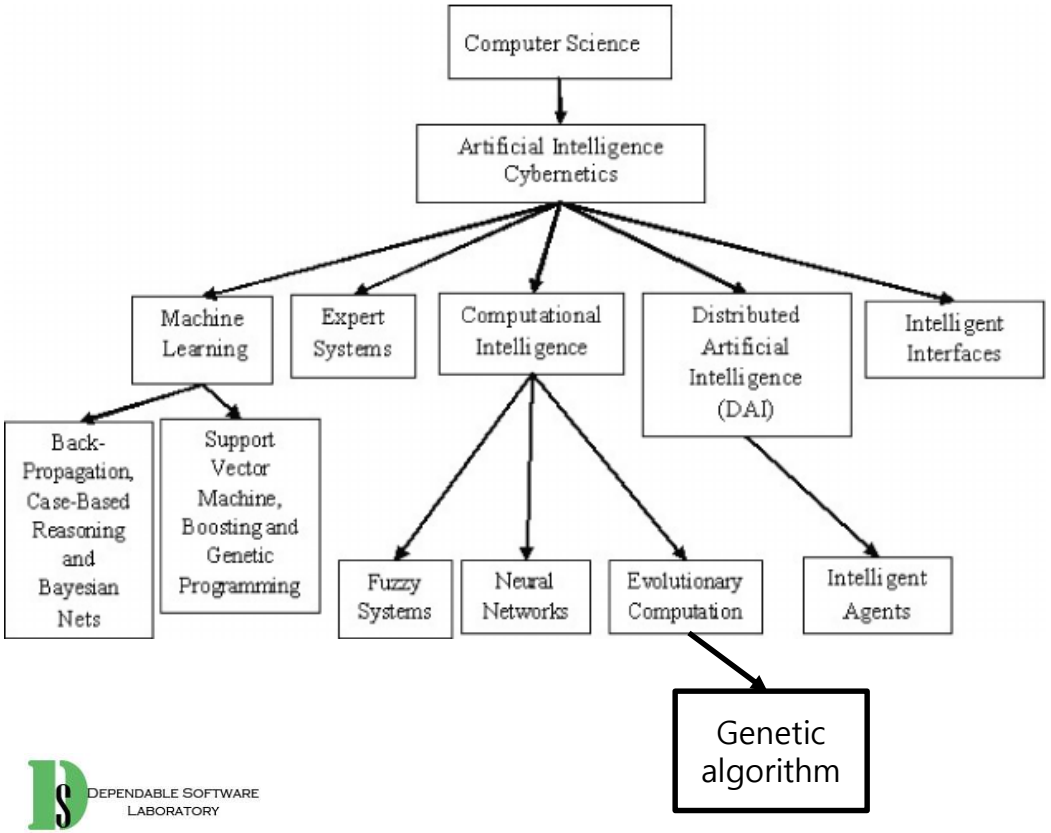
Case #	A	B	OUT	A	B
1	T	T	T	O	O
2	T	F	F		O
3	F	T	F	O	
4	F	F	F		

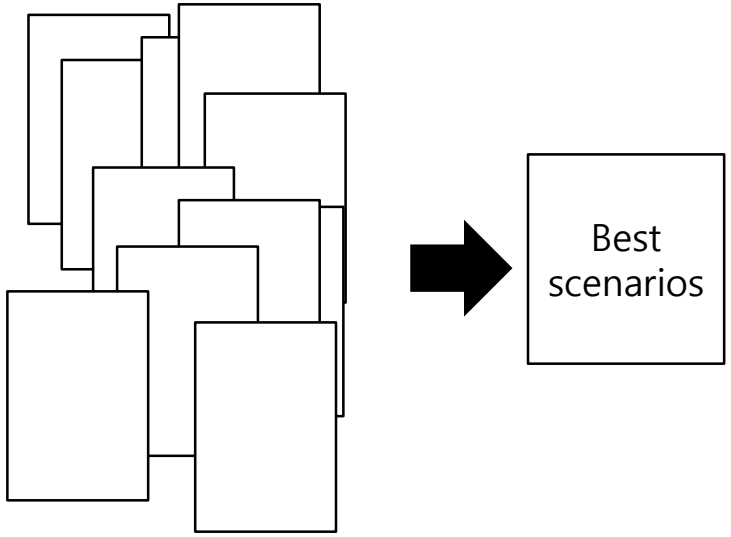
100% MC/DC
➔ (T,T), (F,T), (T,F)



Genetic Algorithm

- Genetic algorithm (GA)
  - A metaheuristic **inspired by the process of natural selection.**
  - Belongs to the larger class of evolutionary algorithms (EA).
  - **High-quality solutions** to optimization and search problems

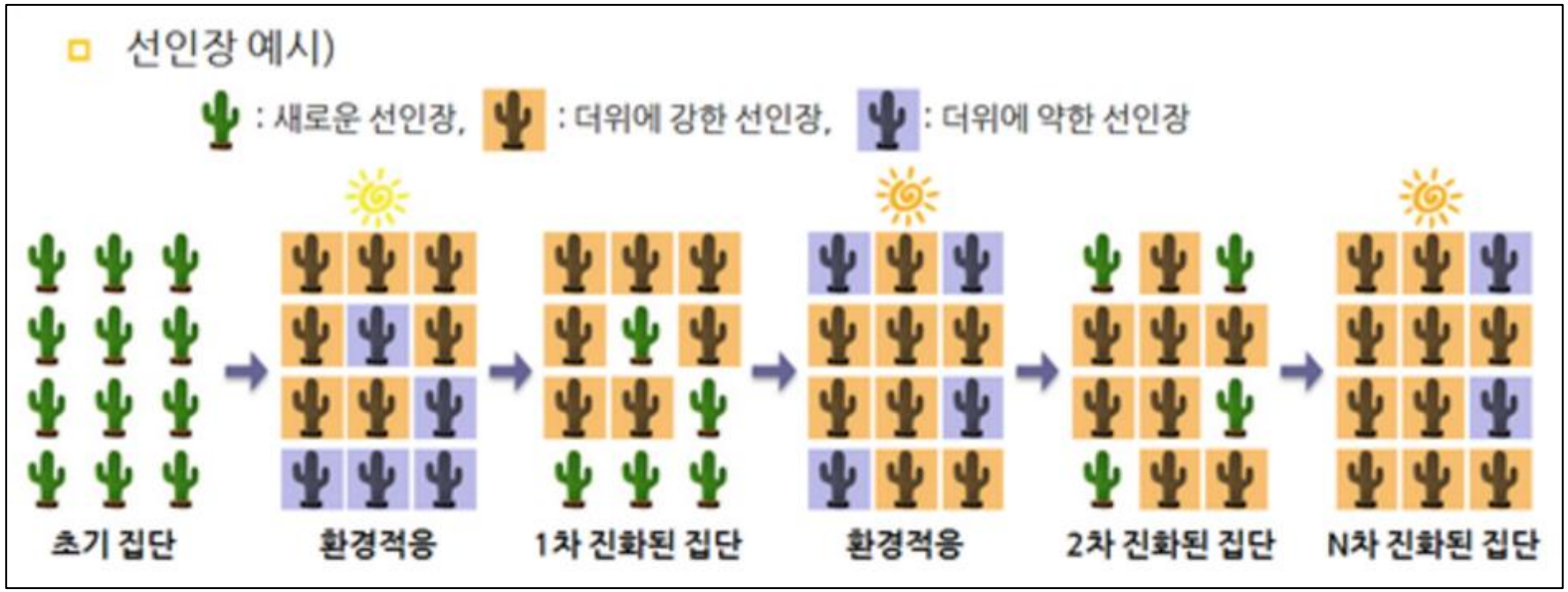




Genetic Algorithm

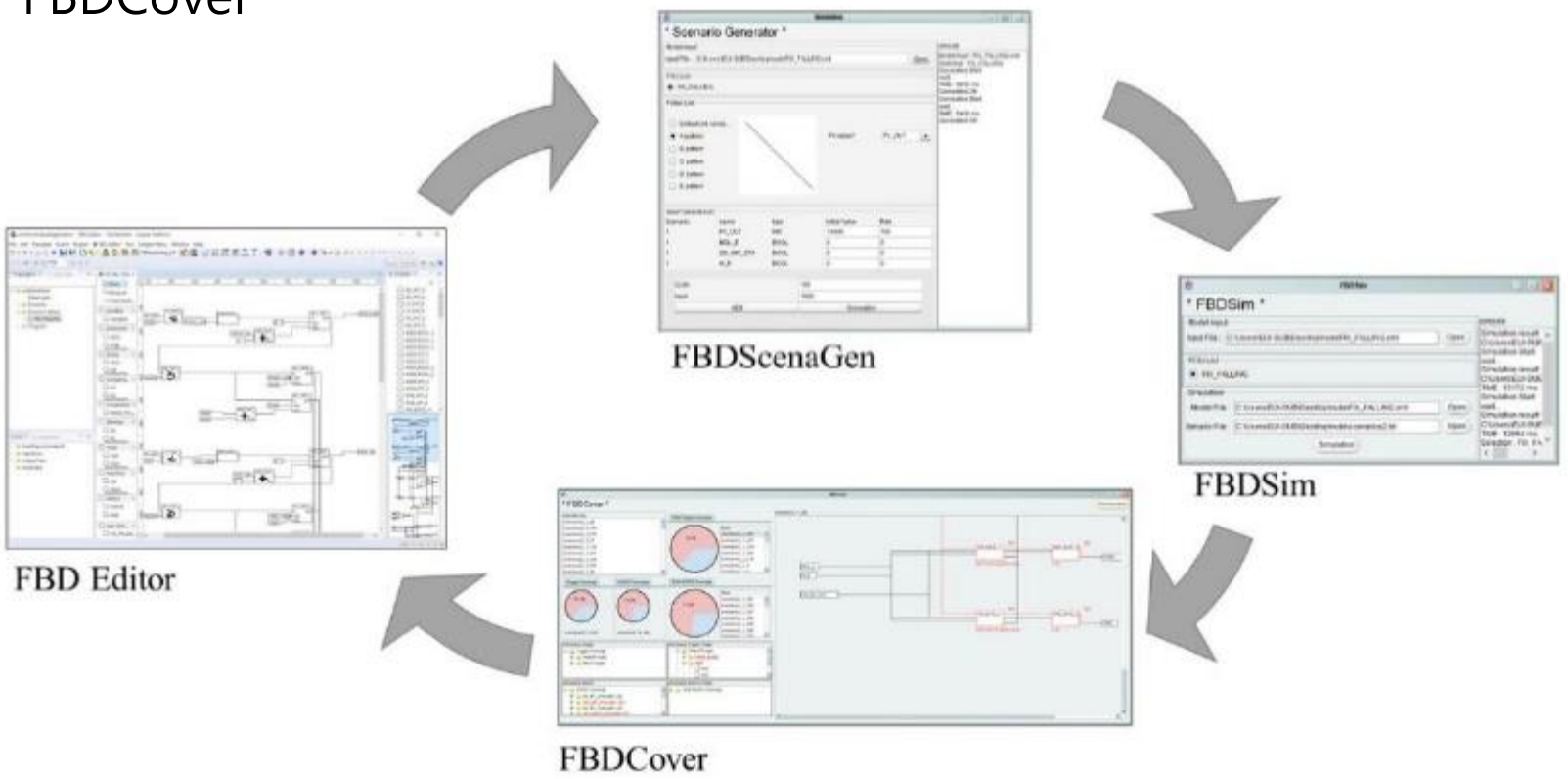
- Genetic algorithm (GA)
  - A metaheuristic **inspired by the process of natural selection.**
  - Basic process: **1) selection, 2) crossover, 3) mutation**

Many scenario set → Many scenario set → Best scenarios



FBD Simulation Framework

- FBD Editor
- FBDScenaGen
- FBDSim
- FBDCover

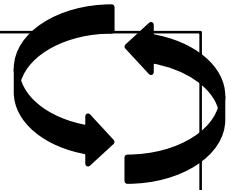


FBDScenaGen+
(GA-based High-Quality Simulation Scenario Generator)

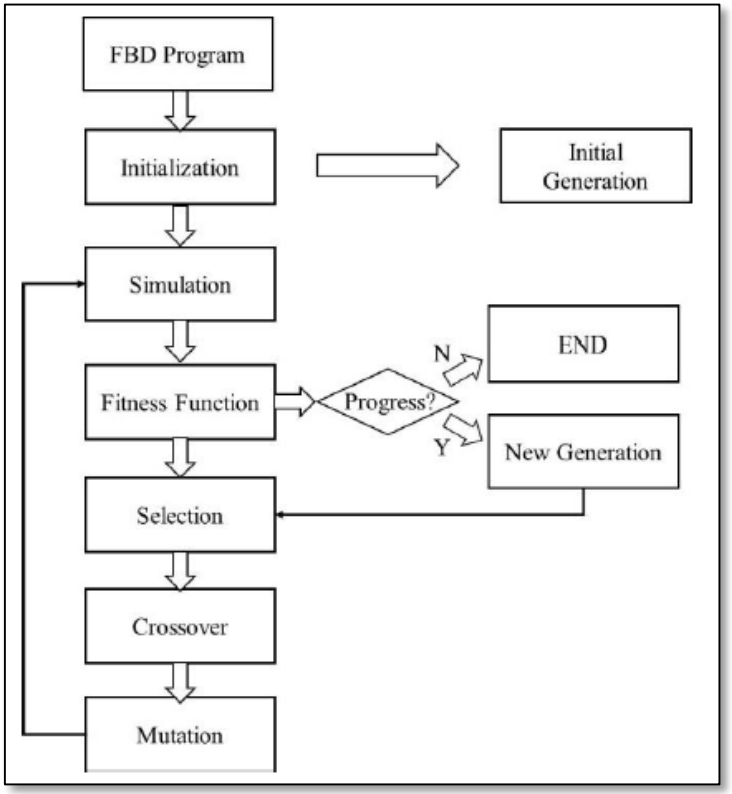
1. Initialization

loop

2. Selection
3. Crossover
4. Mutation
5. Simulation
6. Evaluation (Fitness function)
7. Progress?



Evolution!



A genetic representation of scenario

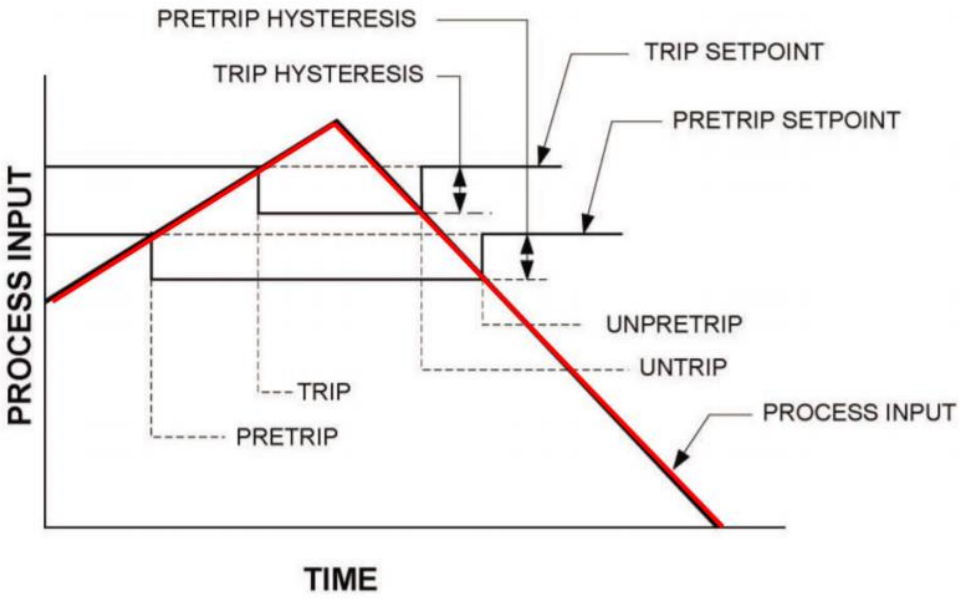
- A chromosome = Sequence of Input value change

Fitness Score	Generation (T)						
1	-	↑5	↓7	…	-	-	↑1
4	-	↑1	↓8	…	↓1	↓2	↓1
5	-	↓2	↑1	…	-	-	-
6	-	-	↑3	…	↑9	-	↓4
2	-	-	↓8	…	↑1	↓9	↓2
3	-	-	-	…	-	-	-
5				. . .			
8							
2							
0	-	↓9	-	…	↑5	-	-
1	-	-	-	…	↑6	↑5	↑5
7	-	↓2	↓7	…	↓2	↓3	-
2	-	↑2	↑	…	↑9	↑3	↑6
9	-	↓8	↓3	…	↓1	-	-
2	-	↑9	-	…	-	↑2	↑9
1	-	↑1	↓2	…	↑2	↓1	↓5

Gene

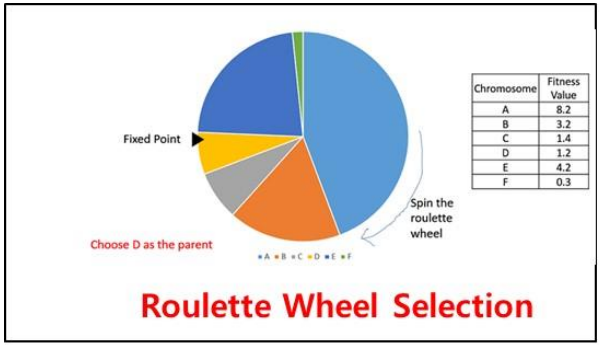
Chromosome

Population

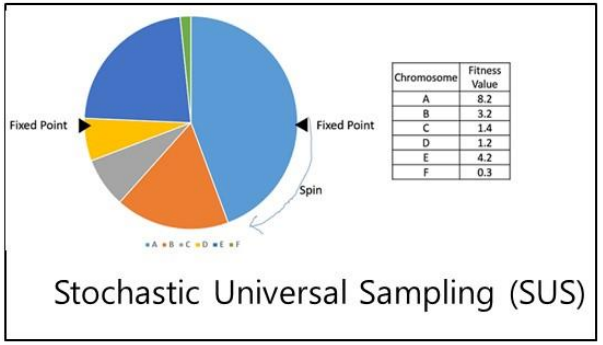


Selection operator

- Select good chromosome for new generation (t+1)
- Roulette wheel selection for gene diversity



Chromosome	Fitness Value
A	8.2
B	3.2
C	1.4
D	1.2
E	4.2
F	0.3



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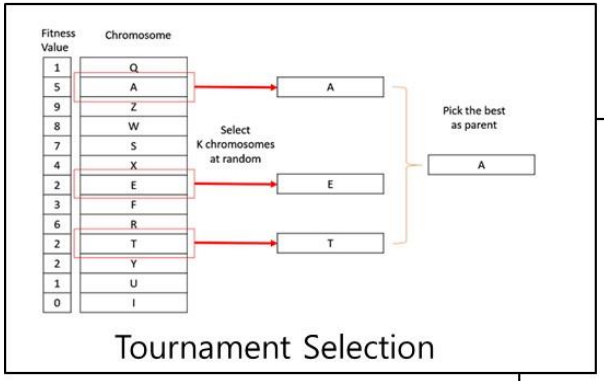
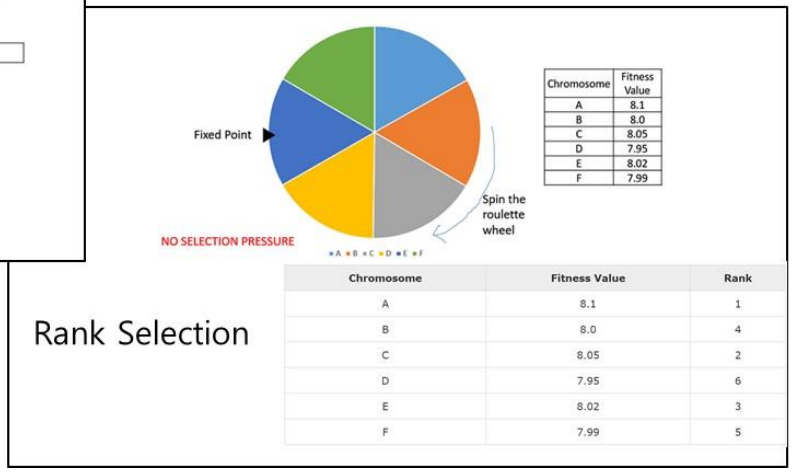
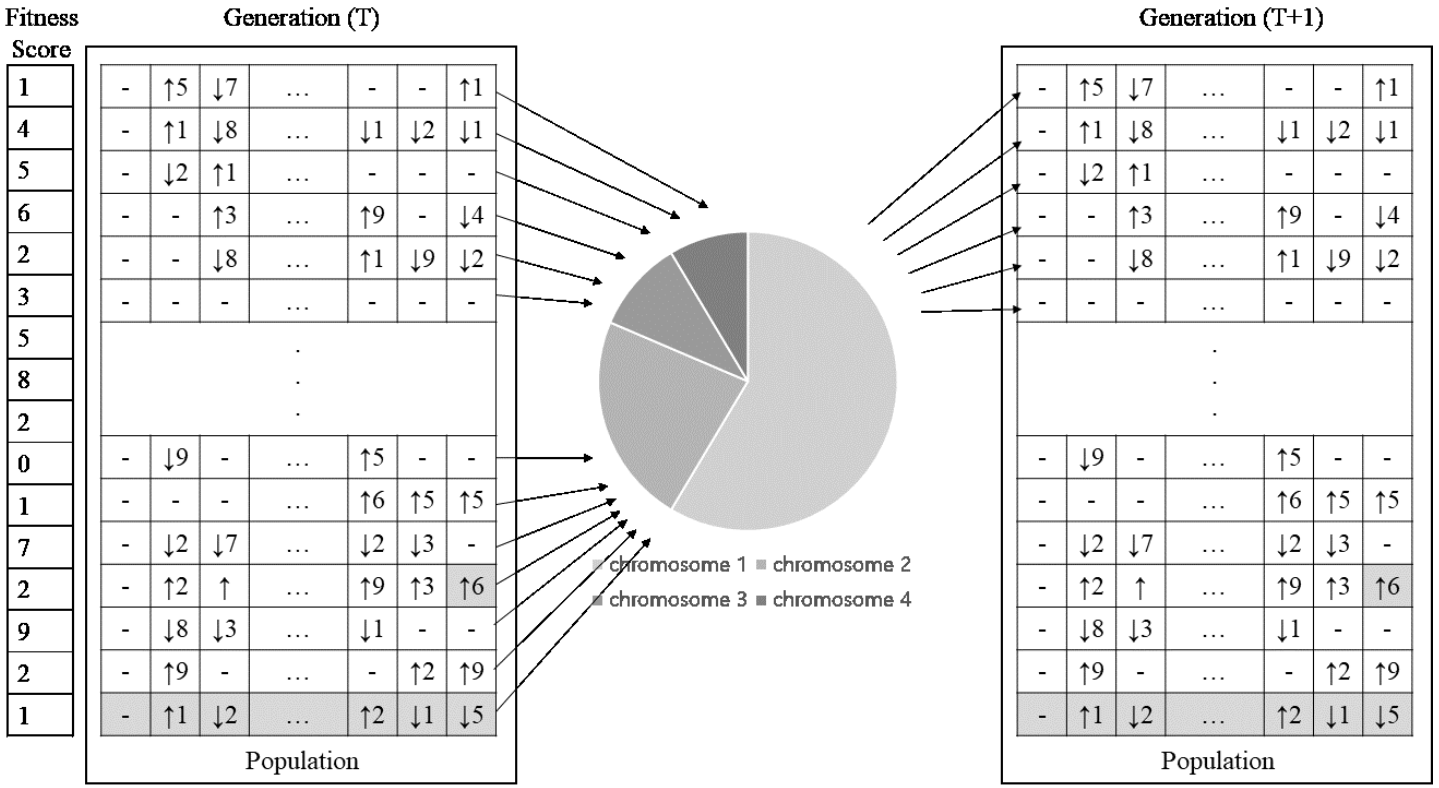




Chromosome	Fitness Value
A	8.1
B	8.0
C	8.05
D	7.95
E	8.02
F	7.99

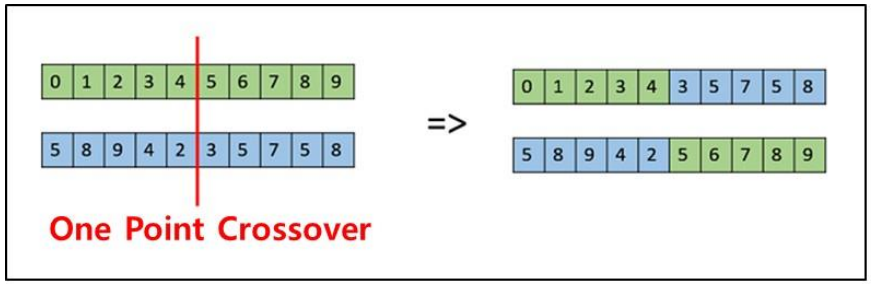
Chromosome	Fitness Value	Rank
A	8.1	1
B	8.0	4
C	8.05	2
D	7.95	6
E	8.02	3
F	7.99	5

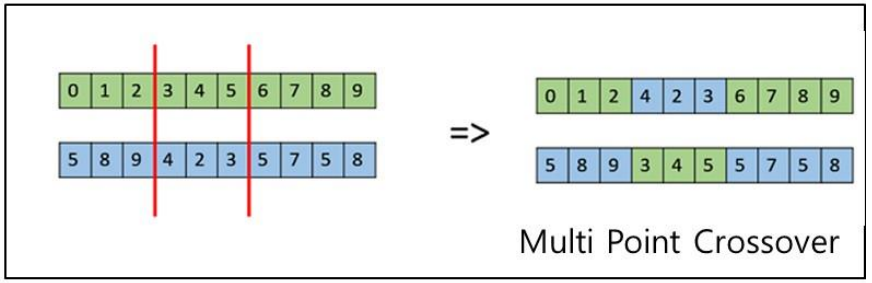
Roulette wheel selection

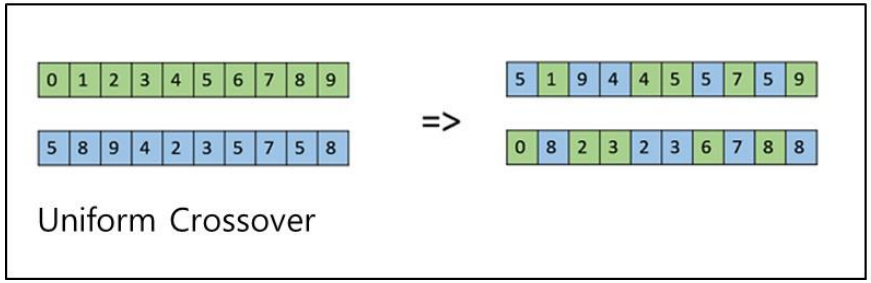


Crossover operator

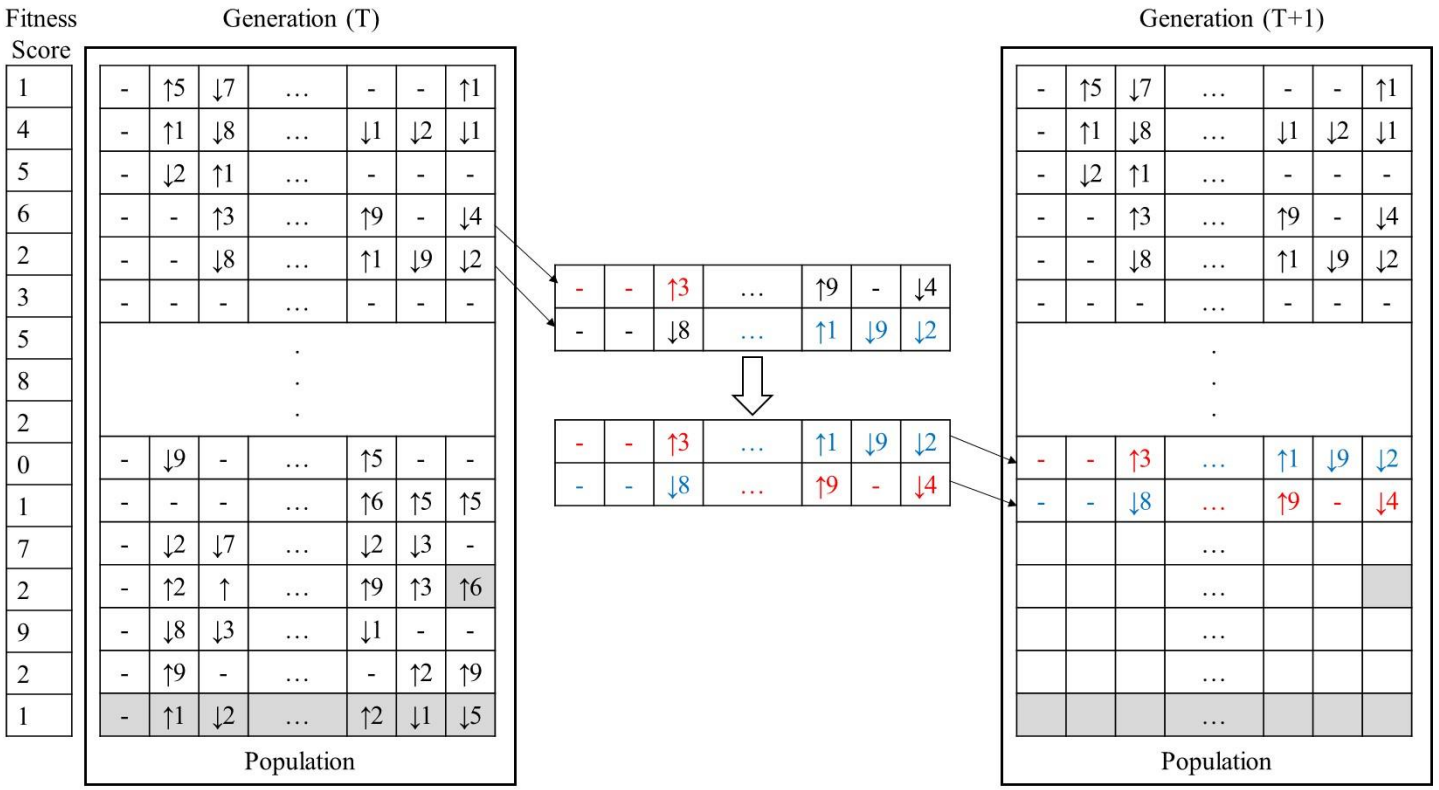
- Crossover with good chromosomes for new generation (t+1)
- Single point crossover





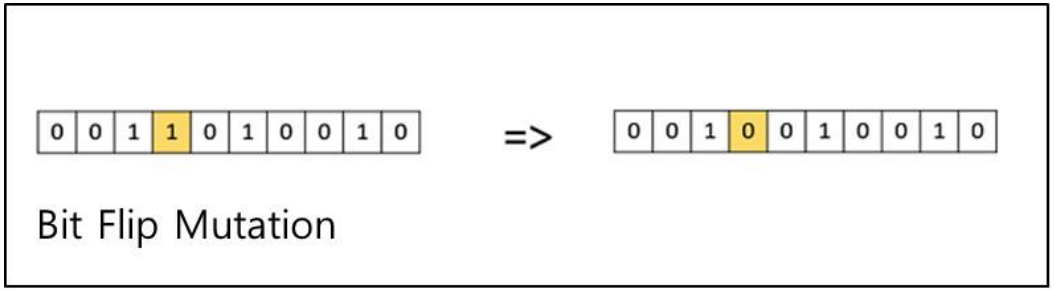


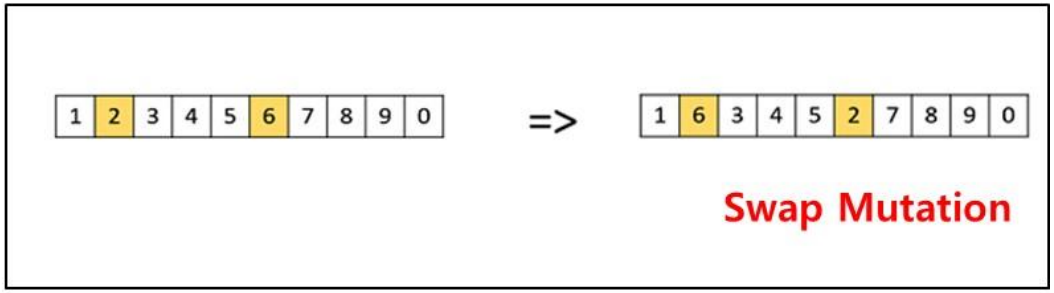
Single point crossover

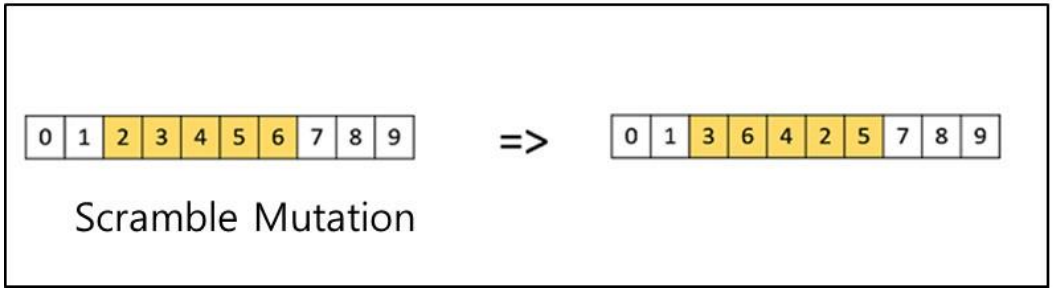


Mutation operator

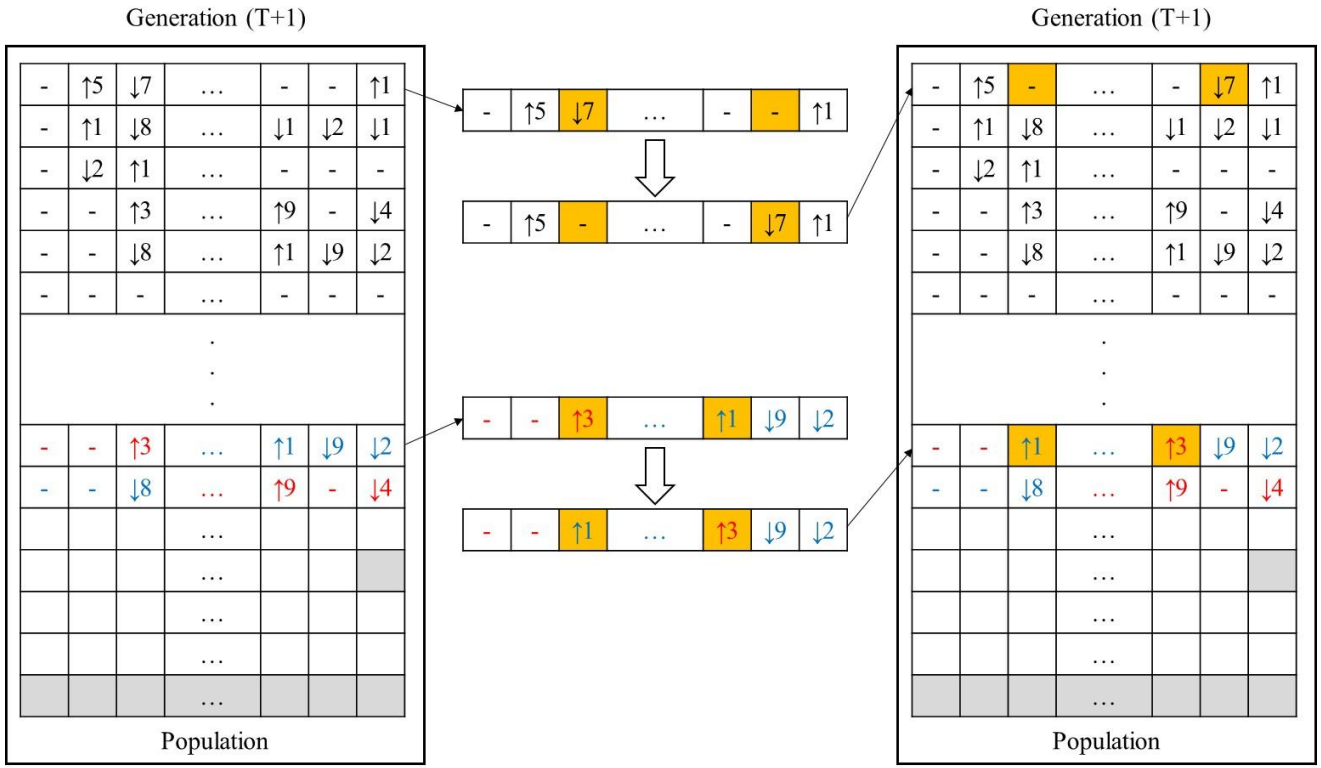
- Mutate a chromosome for gene diversity







Swap mutation



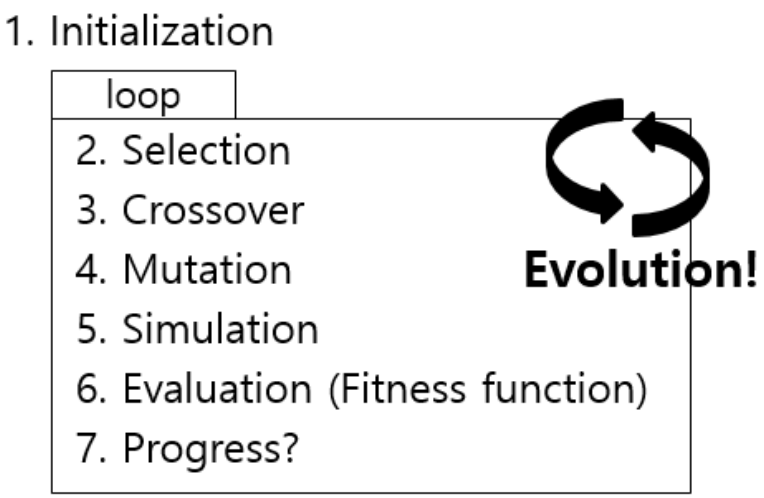
Fitness function

- fitness for toggle coverage:
  - $f_T = \frac{\begin{pmatrix} nuber\ of\ toggled\ blocks \\ and\ output\ variables \end{pmatrix}}{\begin{pmatrix} number\ of\ boolean\ blocks \\ and\ output\ variable \end{pmatrix} \times 2}$
- fitness for MC/DC coverage:
  - $f_M = \frac{\begin{pmatrix} number\ of\ simulated \\ imporant\ combinations\ of\ conditions \end{pmatrix}}{\begin{pmatrix} all\ important\ combinations\ of\ conditions \\ for\ all\ boolean\ function\ blocks \end{pmatrix}}$
- fitness function:
  - $f = f_T \times f_M$

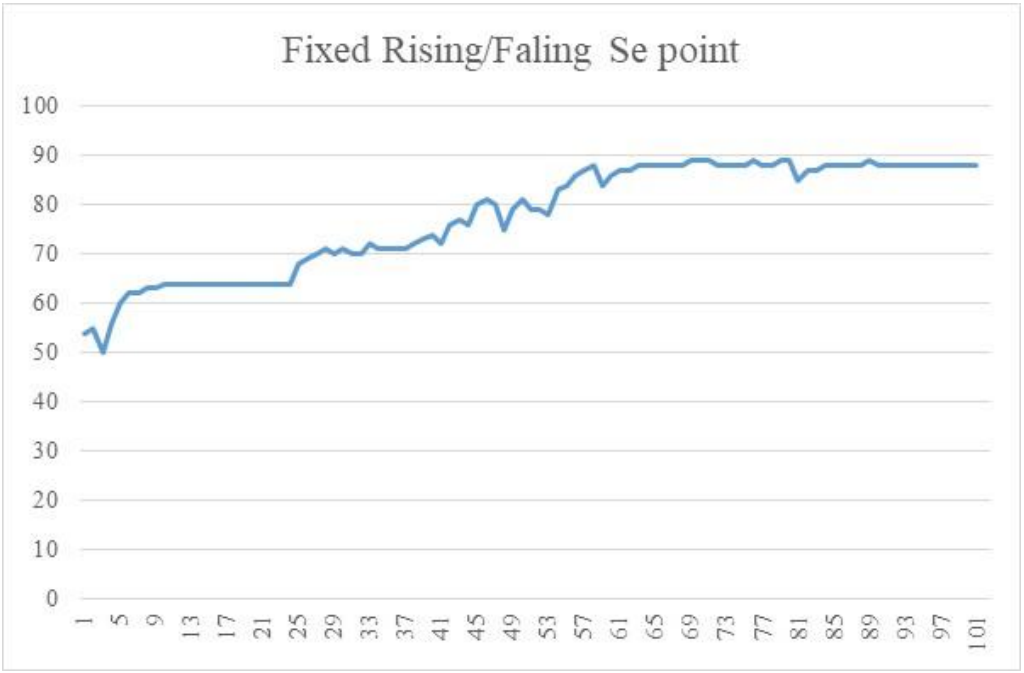
Case Study

- Target: an example replicating a KNICS APR-1400 RPS BP

- We used our tool-set of
  - FBD Editor
  - **FBDScenaGen+**
  - FBDSim
  - FBDCover



Evolution


Fixed Rising/Faling Se point
100
90
80
70
60
50
40
30
20
10
0
1
5
9
13
17
21
25
29
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73
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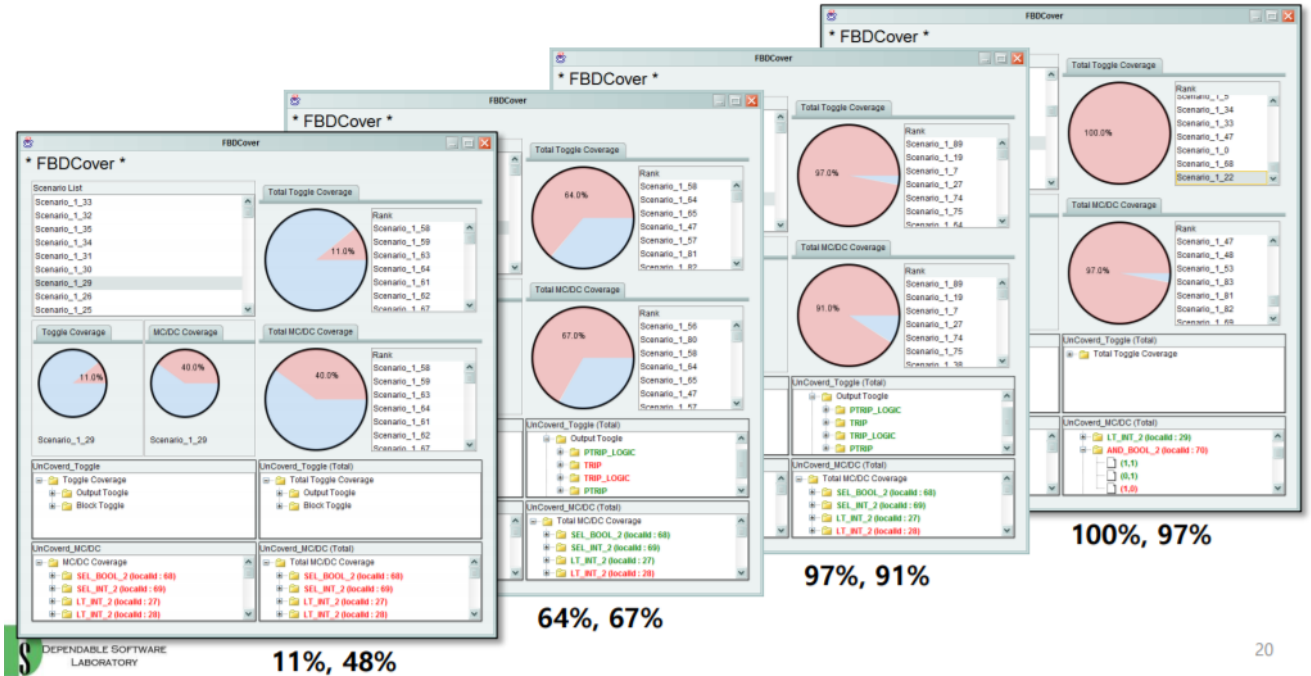
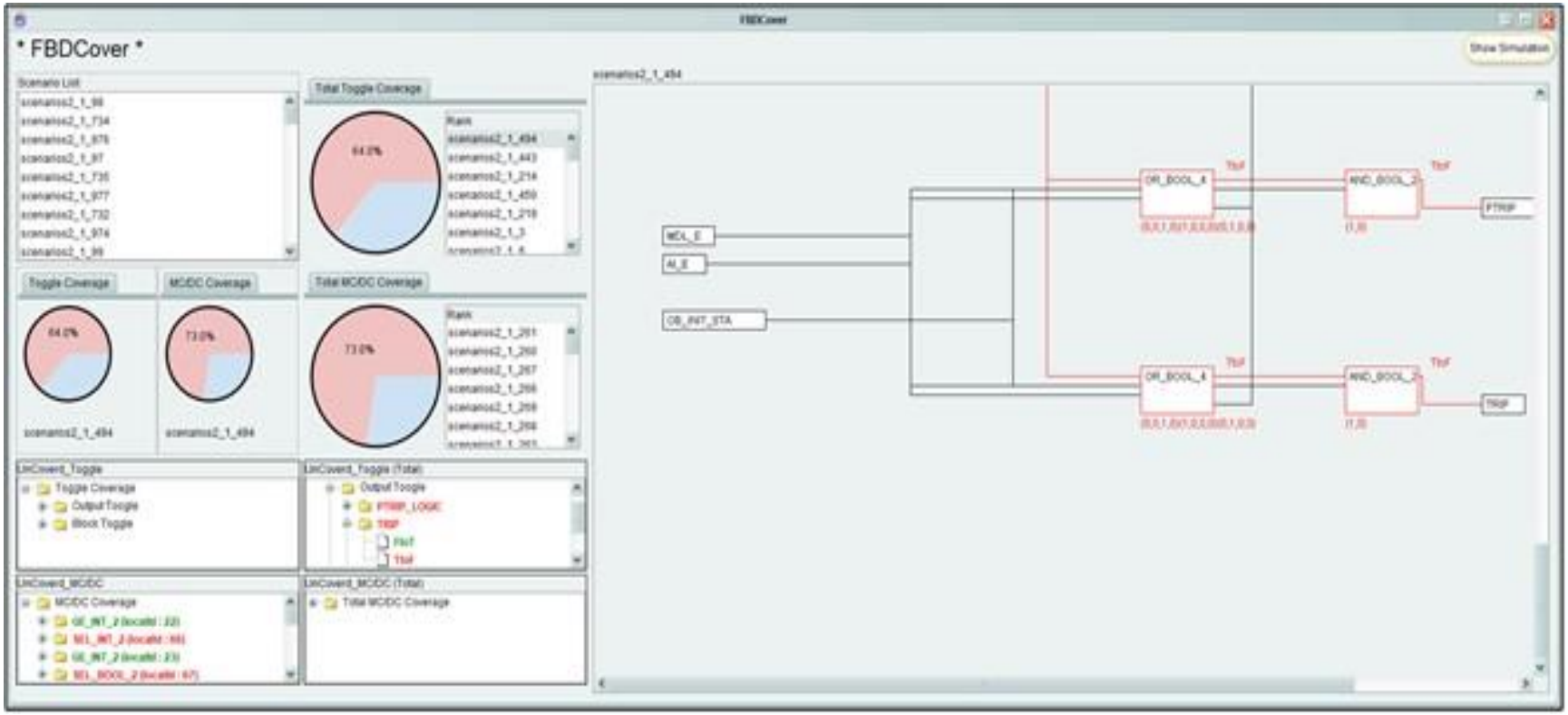
81
85
89
93
97
101


* FBDCover *
11%, 48%
64%, 67%
97%, 91%
100%, 97%

Uncovered points



Conclusions

- We applied basic **GA techniques** to the scenario generation
  - for a **high-quality scenarios for FBD simulation**
- The prime objective
  - check a **feasibility** and efficiency of applying **GA techniques**
- We developed **FBDScenaGen+**
  - it can automatically generates high-quality scenarios
  - **The result (quality of scenarios) is increased during repetition.**
- Future work
  - Using High-level AI techniques
  - Adapting various fields in NPP

- Thank you –

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