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*Safety system optimization
by improved strength Pareto
evolutionary approach
(SPEA2).*

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Safety System Optimization By Improved Strength Pareto Evolutionary Approach (SPEA2)

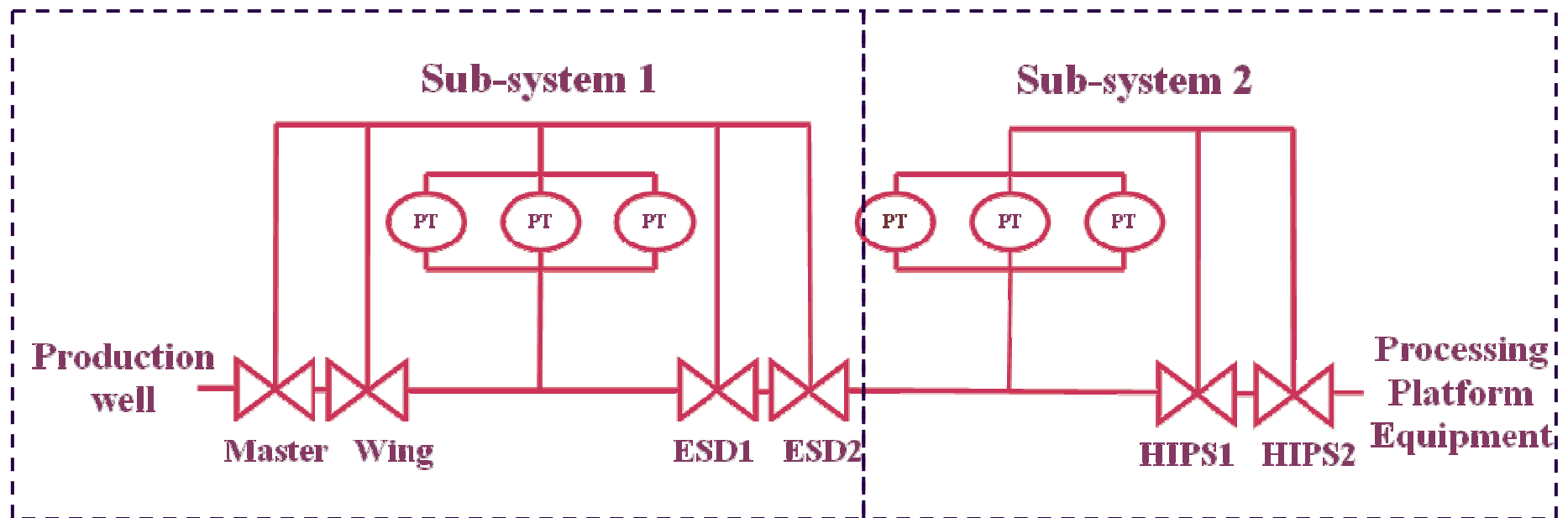
Jelena Borisevic and Lisa M Bartlett

A **safety system** is an essential part of an industrial system as it operates to prevent the occurrence of certain conditions and their future development into a hazardous situation.

To investigate a design **optimisation scheme** which yields an optimal safety system design by fully utilizing available resources.

- Unavailability
- Cost
- Spurious trip frequency
- Maintenance down time

General Structure of the High Integrity Protection System (HIPS):



Variable	Description	Value
θ_1, θ_2	Inspection intervals for subsystems 1 and 2	1 week – 2 years
V	Valve type	1 or 2
P	Pressure transmitter type	1 or 2
$N_1,$ N_2	Number of pressure transmitters fitted in subsystem 1 and 2 respectively	1 – 4 0 – 4
$K_1,$ K_2	Number of pressure transmitters required to trip (activate) for subsystem 1 and 2 respectively	1 – $N_1,$ 0 – N_2
E	Number of ESD valves fitted	0, 1, 2
H	Number of HIPS valves fitted	0, 1, 2

Main HIPS Variables



Limitation	Maximum Value
Total system cost (COST)	< 1000 units
Maintenance down-time (MDT)	< 130 hours
System spurious failure frequency (F_{sys})	1 time per year

HIPS Design Limitations



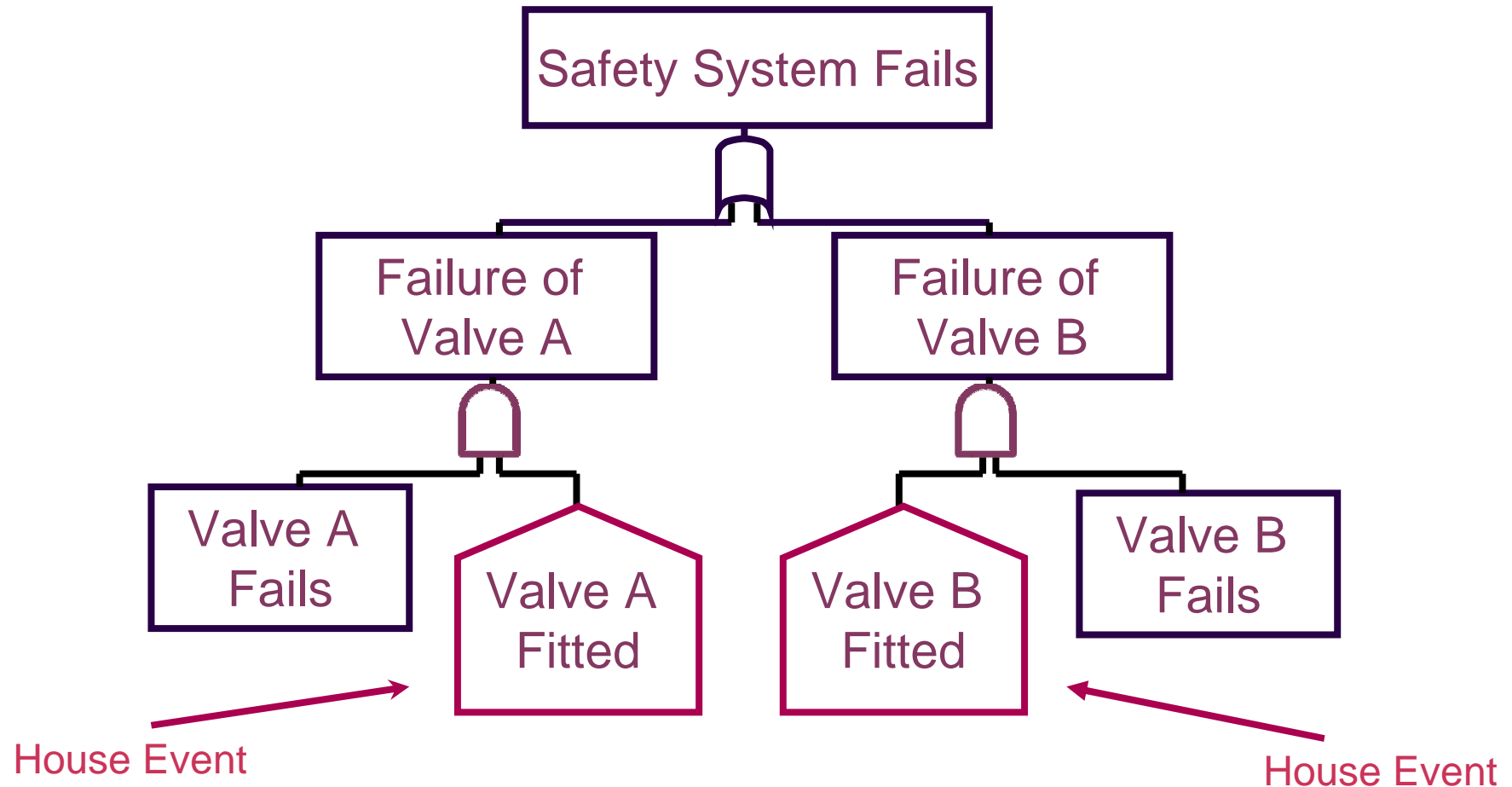
Fault Tree Analysis

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Binary Decision Diagrams

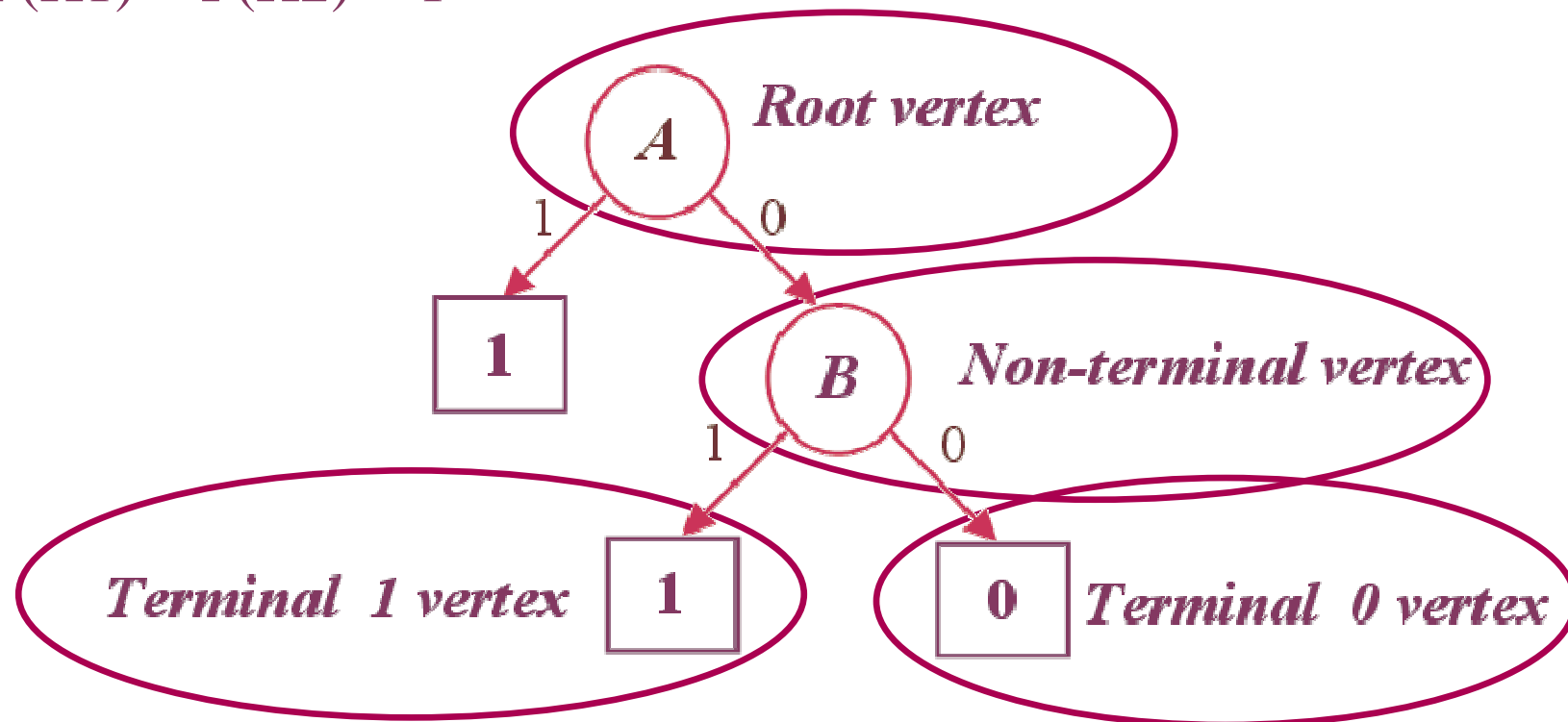
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Improved Strength Pareto Evolutionary Approach
(SPEA2)

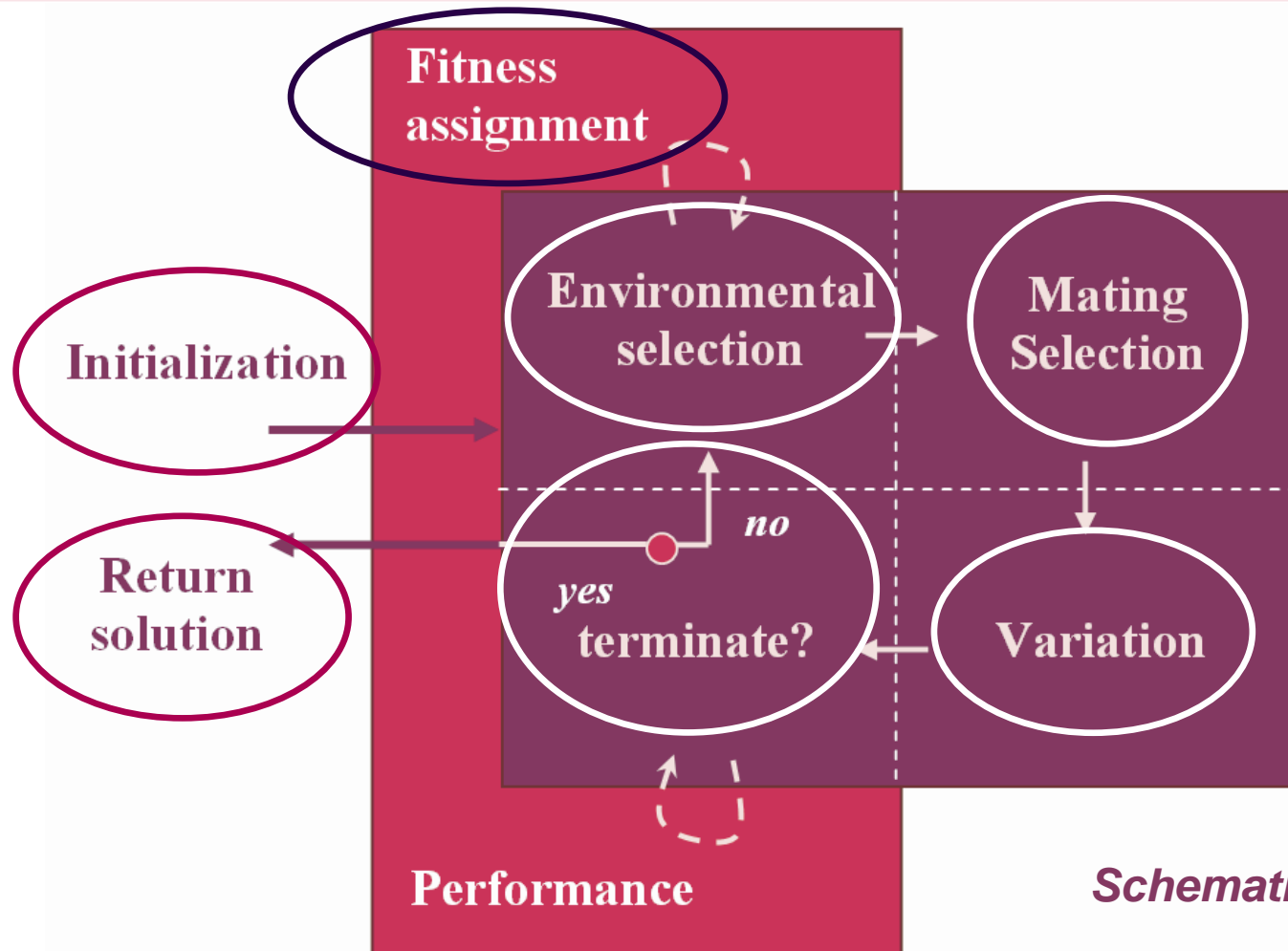


Example of the Fault Tree with House Events

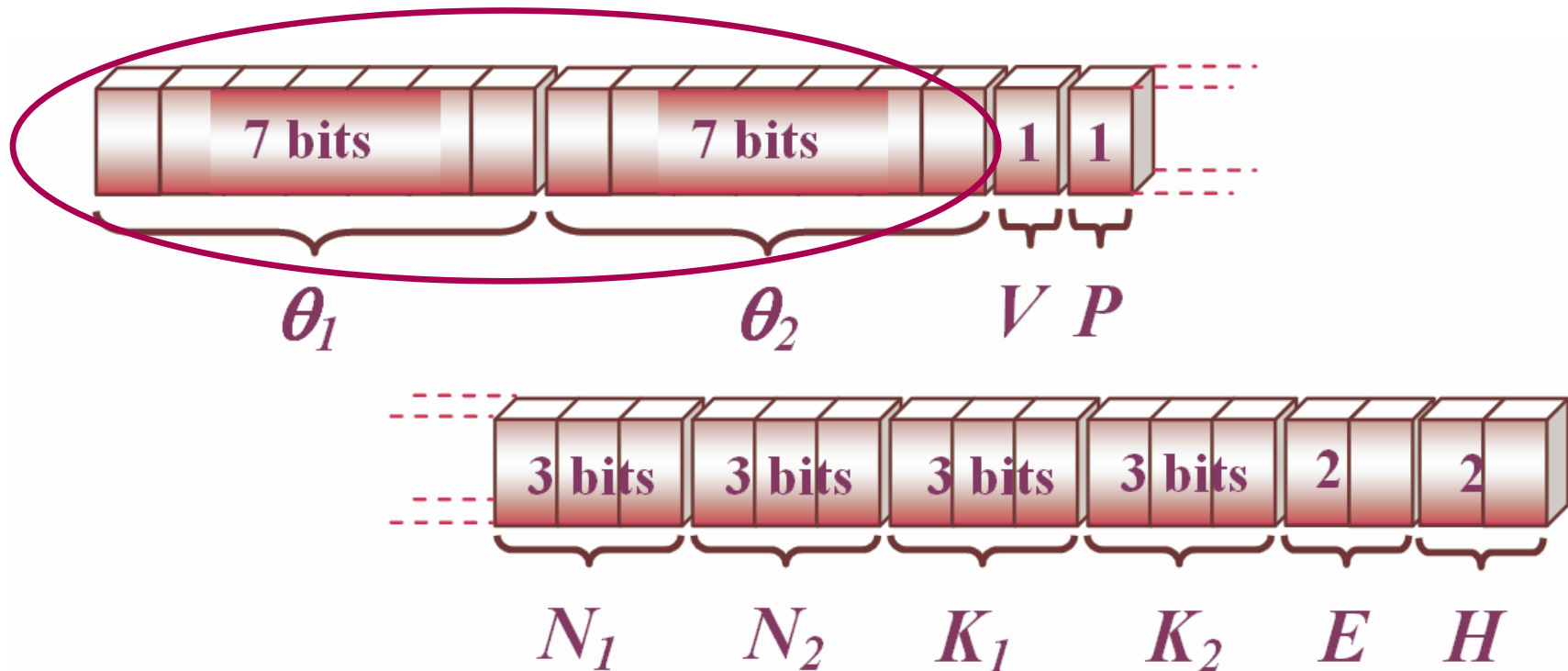
If $P(H1) = P(H2) = 1$



Example BDD

*Schematic of the SPEA2*

Coding and Initializing the Population:



Total length = 32 bits

Optimization Parameters Evaluation:

$$\blacksquare \text{ Cost} = \text{Cost}(\text{subsystem1}) + \text{Cost}(\text{subsystem2}) < 1000 \quad (1)$$

$$\blacksquare \text{ MDT} = \text{MDT}(\text{subsystem1}) + \text{MDT}(\text{subsystem2}) < 130 \quad (2)$$

$$\blacksquare \text{ Penalized Qsys} = \text{Qsys} + \text{Penalties} \quad (3)$$

where

$$\text{Penalties} = \text{Cost_pen} + \text{MDT_pen} + \text{Spurious_trip_pen}$$

Run No.	Cost	MDT	F_{sys}	Q_{sys}
1	592	129.7008	0.455	4.5e-7
2	512	129.6974	0.332	8.33e-4
3	582	128.7361	0.324	6.8e-4
4	922	128.2273	0.718	1e-6
5	882	129.1590	0.166	1e-6
6	992	129.2523	0.552	1e-6
7	852	128.3286	0.245	6.55e-4
8	542	128.9881	0.324	8.45e-4
9	872	129.9032	0.377	1e-6
10	862	129.7309	0.999	1e-6
Average values	761	129.1724	0.449	3.01e-4

Fittest Designs after 10 Runs of SPEA2 Program (100 generations each)



		GAs	SPEA2
Subsystem 1	No. of ESD valves (E)	0	0
	No. of PTs (N_1)	2	1
	No. of PTs to trip system (K_1)	1	1
	Maintenance test interval (θ_1)	29	25
Subsystem 2	No. of HIPS valves (H)	2	1
	No. of PTs (N_2)	3	3
	No. of PTs to trip system (K_2)	2	3
	Maintenance test interval (θ_2)	32	73
	Valve type (V)	2	1
	PT type (P)	1	2
	MDT	128.43	129.7008
	Cost	822	592
	Spurious trip occurrence (F_{sys})	0.717	0.455
	System unavailability (Q_{sys})	7.6e-4	4.5e-7

Results Comparison

- The proposed technique has been successfully applied to a high integrity protection system (HIPS) and produced better results for system design optimization comparing to those obtained by the simple GAs.
- Important advantage of the SPEA2 is that it is faster and requires less memory resources.

- Application of the technique to the larger and more detailed safety system.
- Testing the effectiveness of the technique on the system with dependencies.

Thank You Very Much!