Seminar class

Optimization Technique for Turbomachinery

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Campus: **Korea Institute of Industrial Technology (KITECH)**

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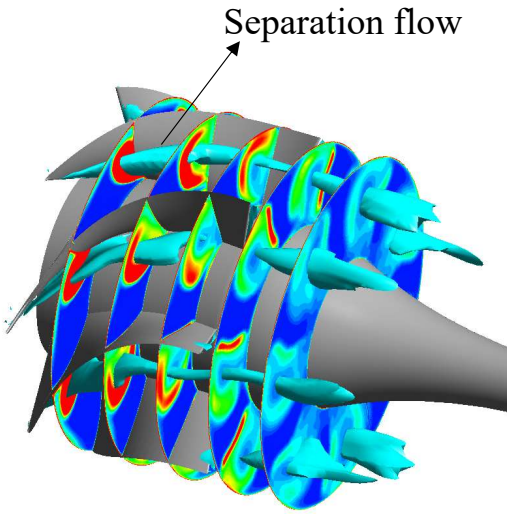
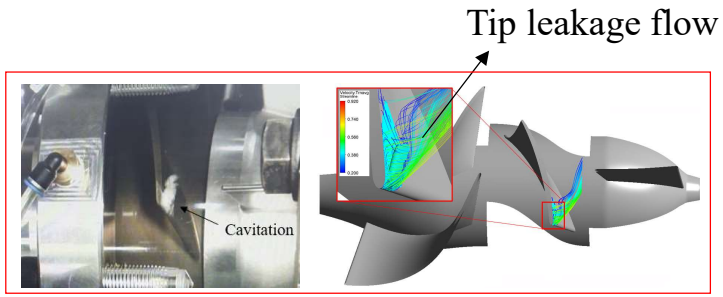
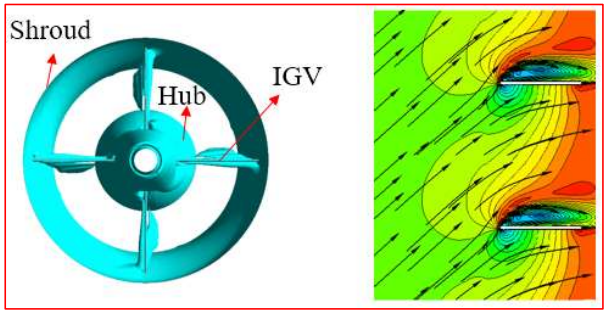
Contents

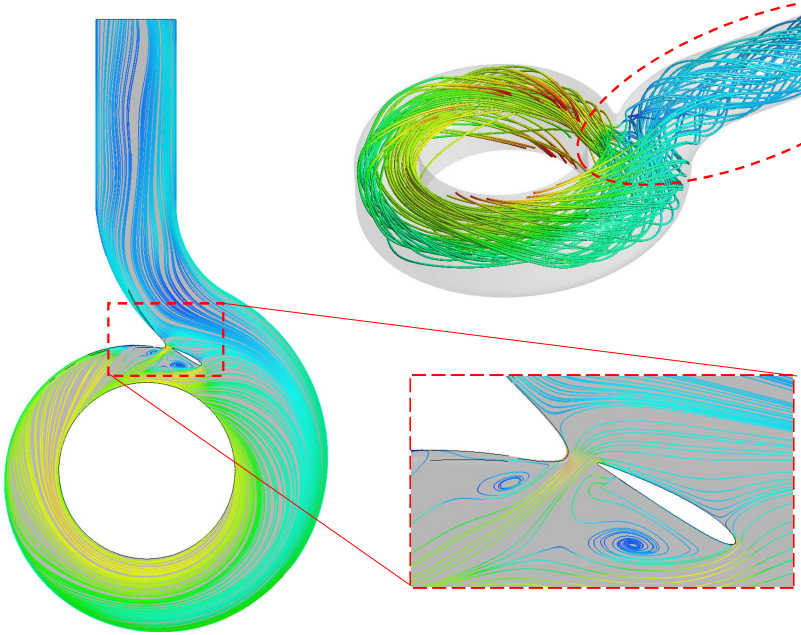
Why optimization? Motivation!

- Bad phenomena



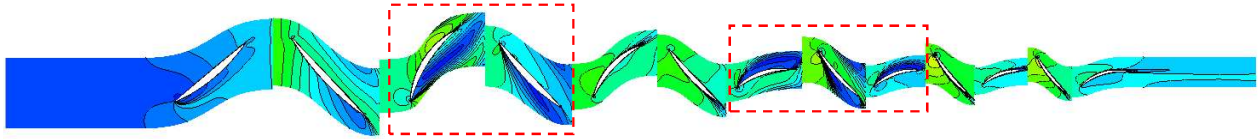






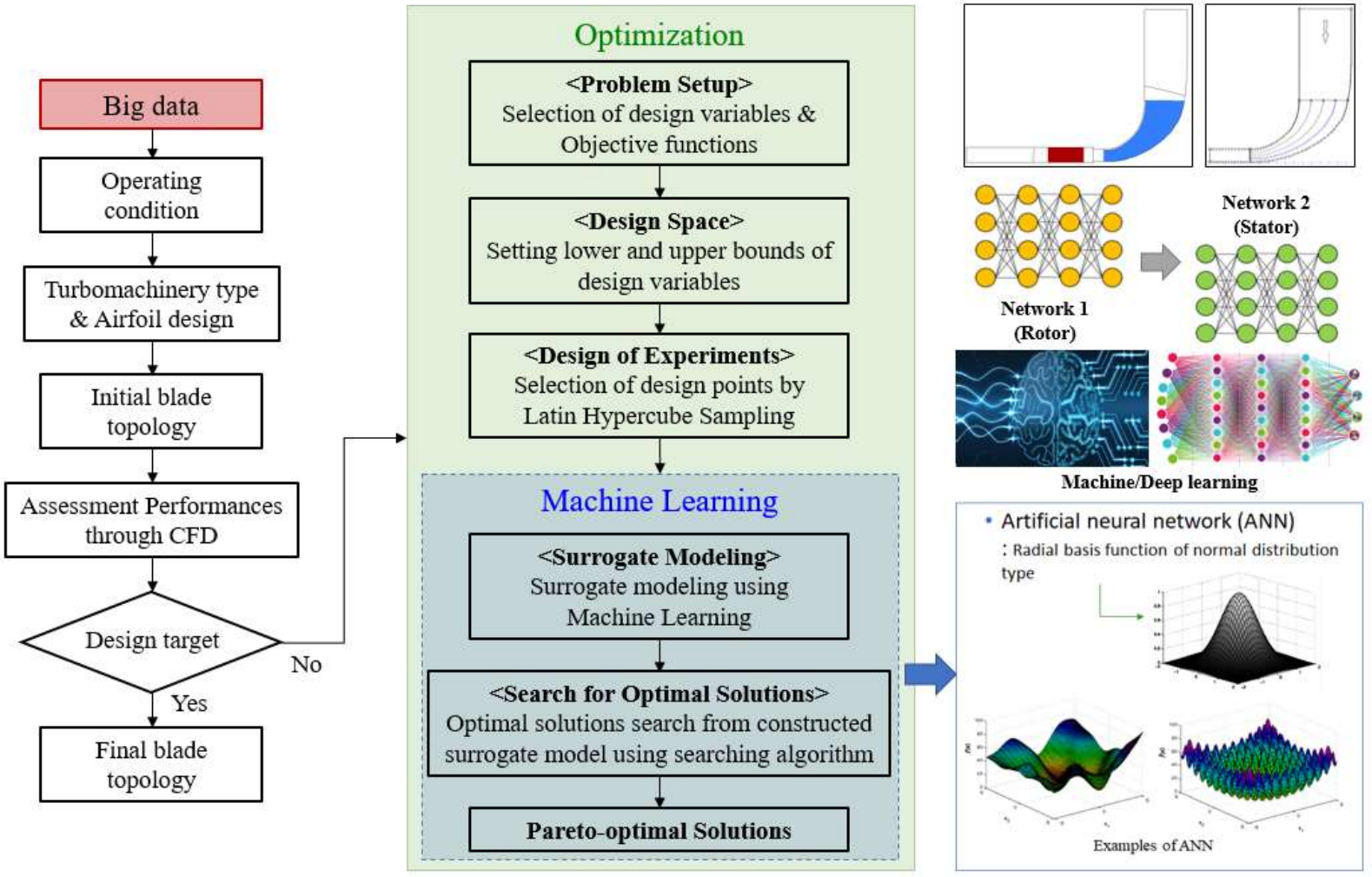
Improving Performance!

Flow Separation

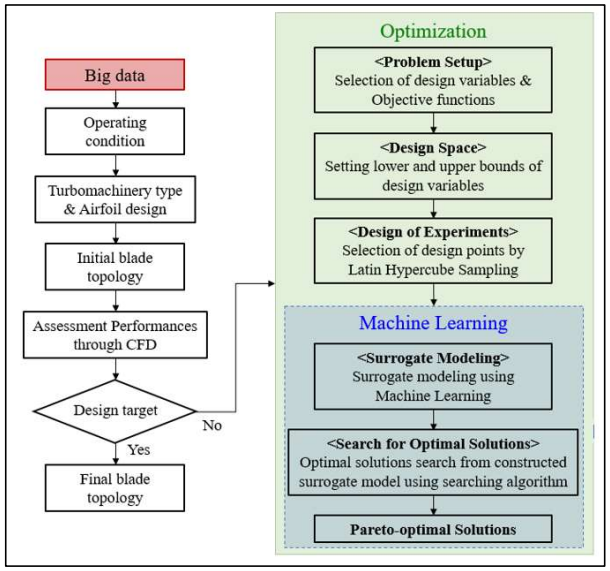


Turbulence

Research Process

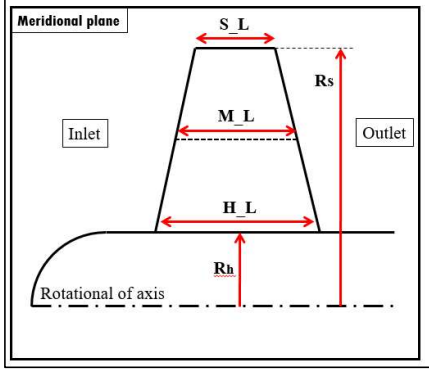


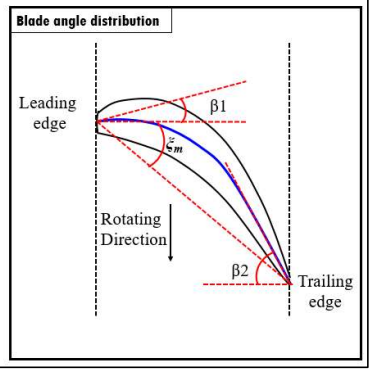
Research Process



Step 1

➢ **Design variables of impeller**

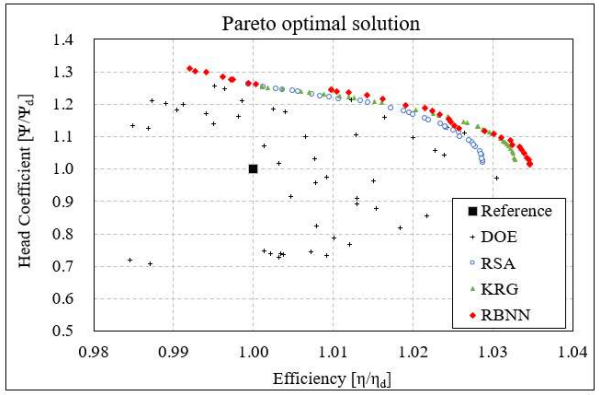




Step 2

➢ **DOE (2^k factorial design)**

Design variable	Low	Reference	High	Unit
Imp_H_ratio	49	54	59	(mm)
Imp_H_L	49	54	59	mm
Imp_M_L	35	39	43	mm
Imp_S_L	27	30	33	mm
Imp_β1_h	59	62	65	degree
Imp_β2_h	28	31	34	degree
Imp_Set_β_h	42	46	50	degree
Imp_β1_m	74	77	80	degree
Imp_β2_m	55	58	61	degree
Imp_Set_β_m	62	66	70	degree
Imp_β1_s	78	81	84	degree
Imp_β2_s	62	65	68	degree
Imp_Set_β_s	68	72	76	degree
Imp_LE_θ_m	1	3	5	degree
Imp_LE_θ_s	-2	-1	0	degree



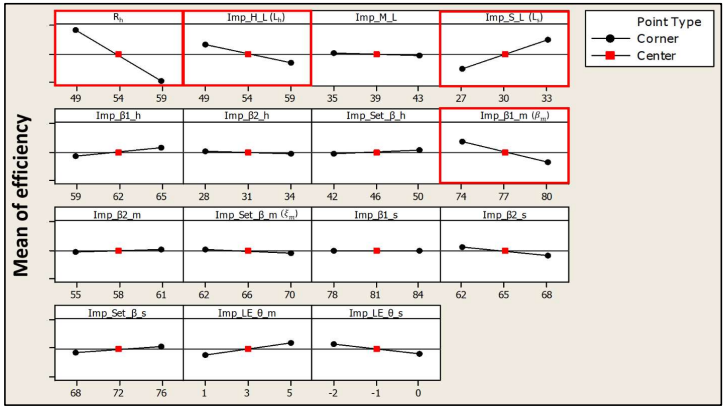
Step 4

➢ **Latin Hypercube Sampling method for DOE**

	L_s	L_h	ξ_m	$\beta_{1,m}$	Efficiency (%)	H_1 (m)	H_2 (m)	Power (kW)
1	30.000	44.000	62.000	74.000	74.442	6.823	9.731	14.925
2	36.000	44.000	62.000	74.000	75.741	7.054	10.164	15.321
3	30.000	54.000	62.000	74.000	74.614	7.174	10.386	15.892
4	30.000	44.000	70.000	74.000	75.726	4.529	6.352	9.576
5	30.000	44.000	62.000	80.000	74.301	6.856	9.789	15.042
6	36.000	54.000	62.000	74.000	75.164	7.368	10.778	16.371
7	36.000	44.000	70.000	74.000	76.128	4.543	6.329	9.491
8	36.000	44.000	62.000	80.000	75.629	7.091	10.230	15.443
9	30.000	54.000	70.000	74.000	74.464	4.313	6.104	9.359
10	30.000	54.000	62.000	80.000	74.477	7.208	10.445	16.012
11	30.000	44.000	70.000	80.000	75.538	4.601	6.447	9.744
12	36.000	54.000	70.000	74.000	75.680	4.445	6.283	9.479
13	36.000	54.000	62.000	80.000	75.070	7.400	10.839	16.484
14	36.000	44.000	70.000	80.000	75.985	4.622	6.433	9.665
15	30.000	54.000	70.000	80.000	74.274	4.389	6.202	9.533
16	36.000	54.000	70.000	80.000	75.603	4.523	6.390	9.650
17	30.194	47.548	64.581	76.323	75.545	6.573	9.262	13.997
18	33.484	45.935	69.484	76.903	76.201	4.876	6.809	10.202
19	32.710	49.806	63.548	74.581	75.065	6.894	9.837	14.961
20	31.548	51.097	63.290	79.806	75.301	6.982	10.035	15.215
21	34.645	45.290	65.871	78.065	77.244	6.403	9.019	13.331
22	34.258	48.839	69.742	75.742	76.351	4.723	6.620	9.898
23	35.226	46.258	69.226	77.290	76.830	5.079	7.077	10.516
24	32.323	45.613	68.194	80.000	76.421	5.536	7.715	11.526
25	35.419	53.032	65.355	74.774	76.944	6.668	9.466	14.046

	L_s	L_h	ξ_m	$\beta_{1,m}$	Efficiency (%)	H_1 (m)	H_2 (m)	Power (kW)
26	30.387	50.129	67.161	78.839	76.029	5.917	8.261	12.406
27	31.161	47.226	65.613	74.968	76.022	6.349	8.916	13.390
28	36.000	46.581	64.323	77.871	77.266	6.827	9.750	14.407
29	32.129	48.516	70.000	78.452	75.696	4.546	6.390	9.638
30	31.935	44.645	66.903	74.387	76.570	5.955	8.322	12.409
31	32.903	54.000	67.935	75.355	76.421	5.612	7.862	11.746
32	35.032	53.677	63.032	76.516	76.366	7.209	10.468	15.650
33	30.968	44.323	68.968	77.484	76.040	5.112	7.122	10.694
34	33.097	44.000	64.065	78.645	75.930	6.687	9.493	14.274
35	34.065	53.355	65.097	79.613	76.410	6.752	9.551	14.271
36	33.871	49.484	62.000	75.548	75.334	7.217	10.445	15.829
37	30.000	51.419	67.677	76.129	75.795	5.666	7.901	11.900
38	34.839	50.774	66.387	79.032	77.153	6.481	9.141	13.527
39	35.613	47.871	64.839	75.161	77.432	6.734	9.588	14.137
40	30.581	44.968	66.645	79.226	76.129	6.022	8.414	12.619
41	33.677	52.387	63.806	74.000	76.681	6.973	10.022	14.922
42	30.774	51.742	62.774	76.710	74.994	7.035	10.122	15.409
43	31.742	49.161	62.258	78.258	74.718	7.072	10.215	15.609
44	31.355	52.710	66.129	75.935	75.681	6.292	8.795	13.267
45	34.452	46.903	68.710	74.194	77.075	5.298	7.386	10.940
46	33.290	48.194	68.452	79.419	76.602	5.438	7.591	11.314
47	32.516	52.065	62.516	77.097	74.778	7.129	10.349	15.800
48	35.806	50.452	67.419	77.677	77.742	5.984	8.390	12.322
Ref	30.000	54.000	66.000	77.000	75.439	6.163	8.636	13.069

Step 3



Screening Process

Design of Experiments

Available Factorial Designs (with Resolution)

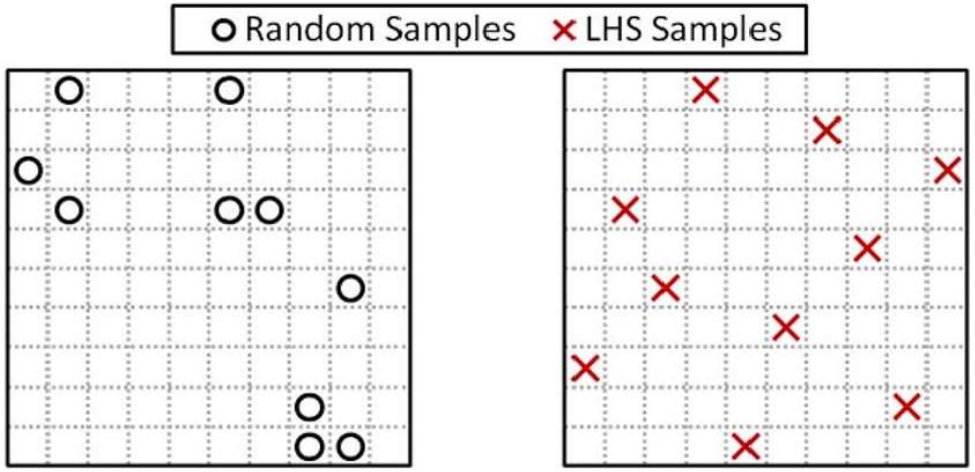
Run	Factors													
	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	Full	III												
8		Full	IV	III	III	III								
16			Full	V	IV	IV	IV	III	III	III	III	III	III	III
32				Full	VI	IV	IV	IV	IV	IV	IV	IV	IV	IV
64					Full	VII	V	IV	IV	IV	IV	IV	IV	IV
128						Full	VIII	VI	V	V	IV	IV	IV	IV

Available Resolution III Plackett-Burman Designs

Factors	Runs	Factors	Runs	Factors	Runs
2-7	12,20,24,28,...,48	20-23	24,28,32,36,...,48	36-39	40,44,48
8-11	12,20,24,28,...,48	24-27	28,32,36,40,44,48	40-43	44,48
12-15	20,24,28,36,...,48	28-31	32,36,40,44,48	44-47	48
16-19	20,24,28,32,...,48	32-35	36,40,44,48		

Help OK

Latin Hypercube Sampling



➢ DOE (2^k factorial design)

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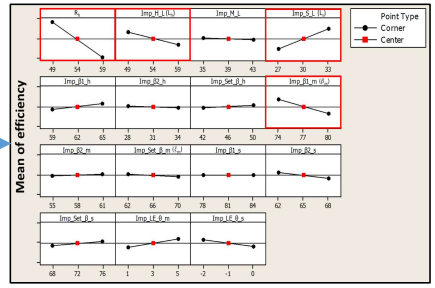

➢ Latin Hypercube Sampling method for DOE

	L_T	L_R	ξ_m	$\beta_{1,m}$	Efficiency (%)	H_1 (m)	H_{11} (m)	Power (kW)
1	30.000	44.000	62.000	74.000	74.442	6.823	9.731	14.925
2	36.000	44.000	62.000	74.000	75.741	7.054	10.164	15.321
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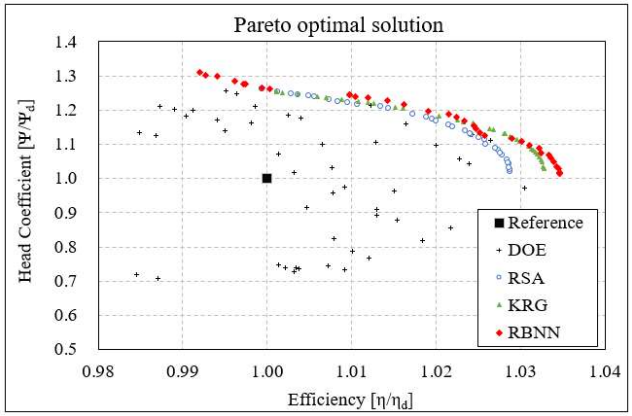
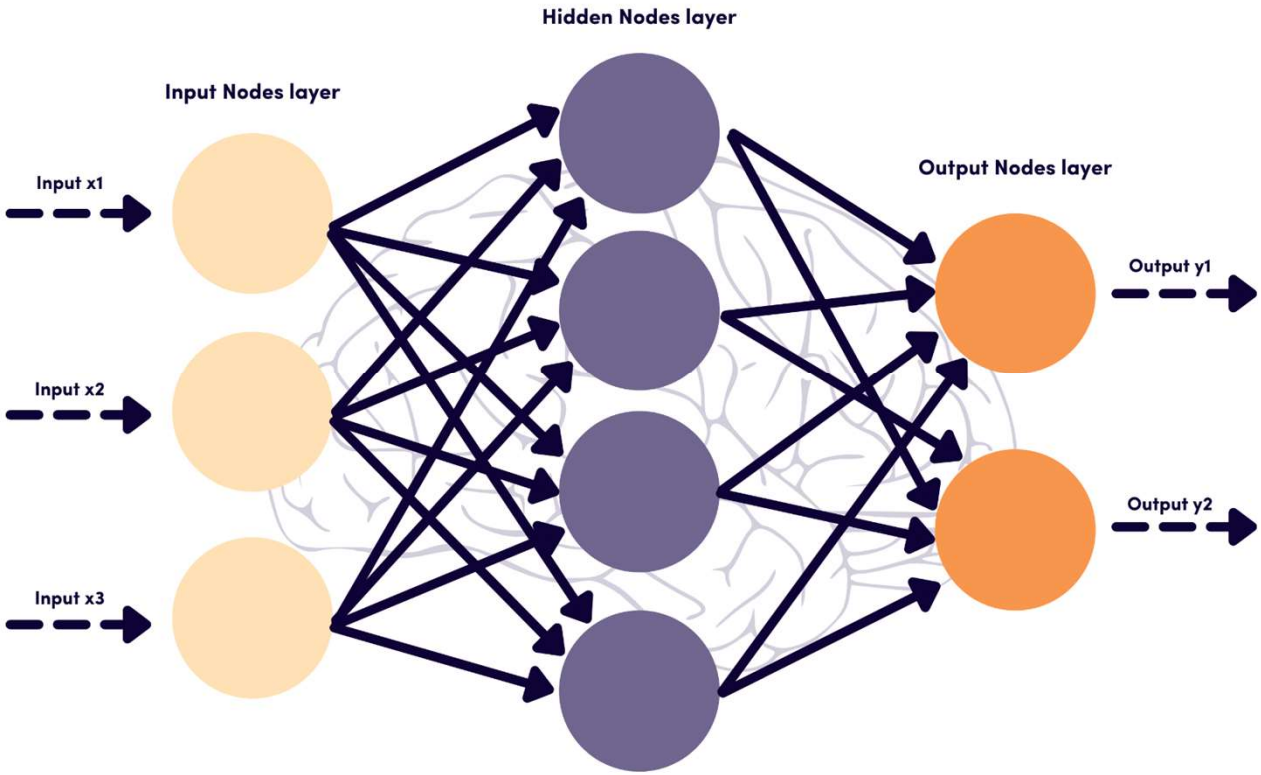


Radial Basic Neural Network (RBNN)

➢ **Introduction**

✓ **Features**

- Two-layer feed-forward networks.
- Hidden nodes implement a set of radial basis functions (e.g. Gaussian fuctions).
- Output nodes implement linear summation functions as in an MLP.
- Training/learning is very fast.
- Networks are very good at interpolation.

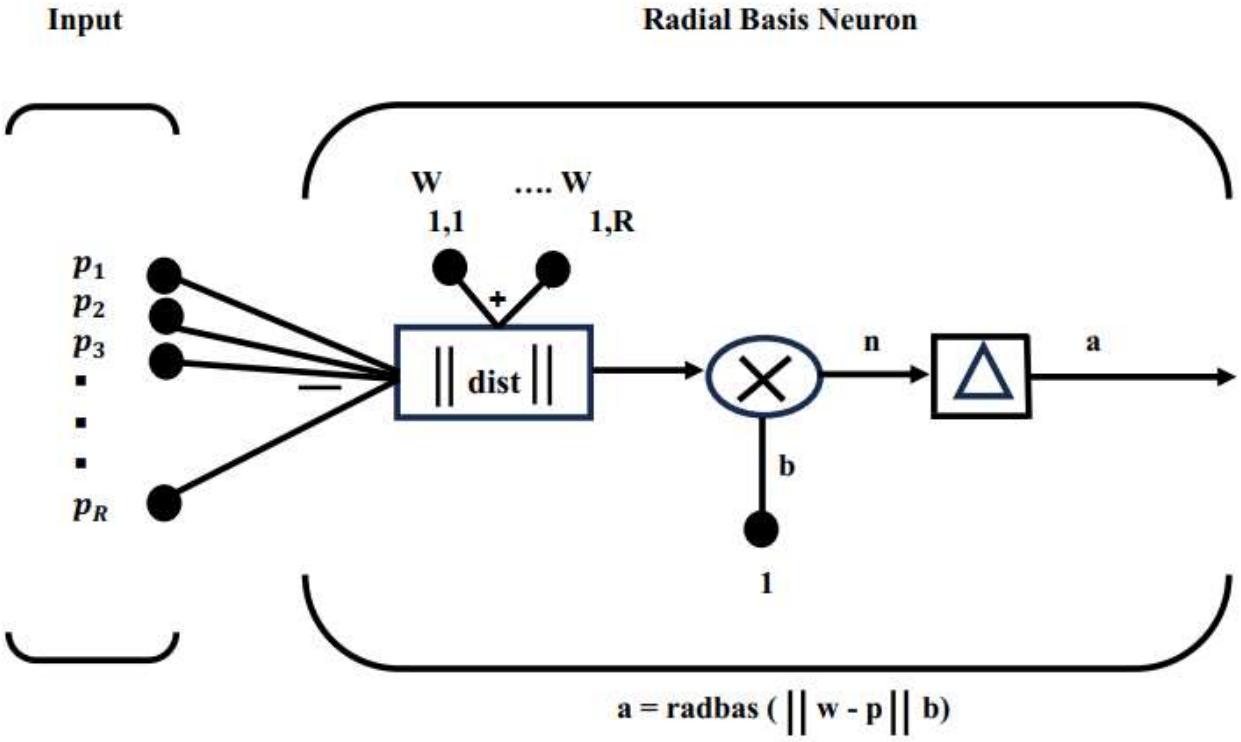


Radial Basic Neural Network (RBNN)

➢ **Commonly Functions**

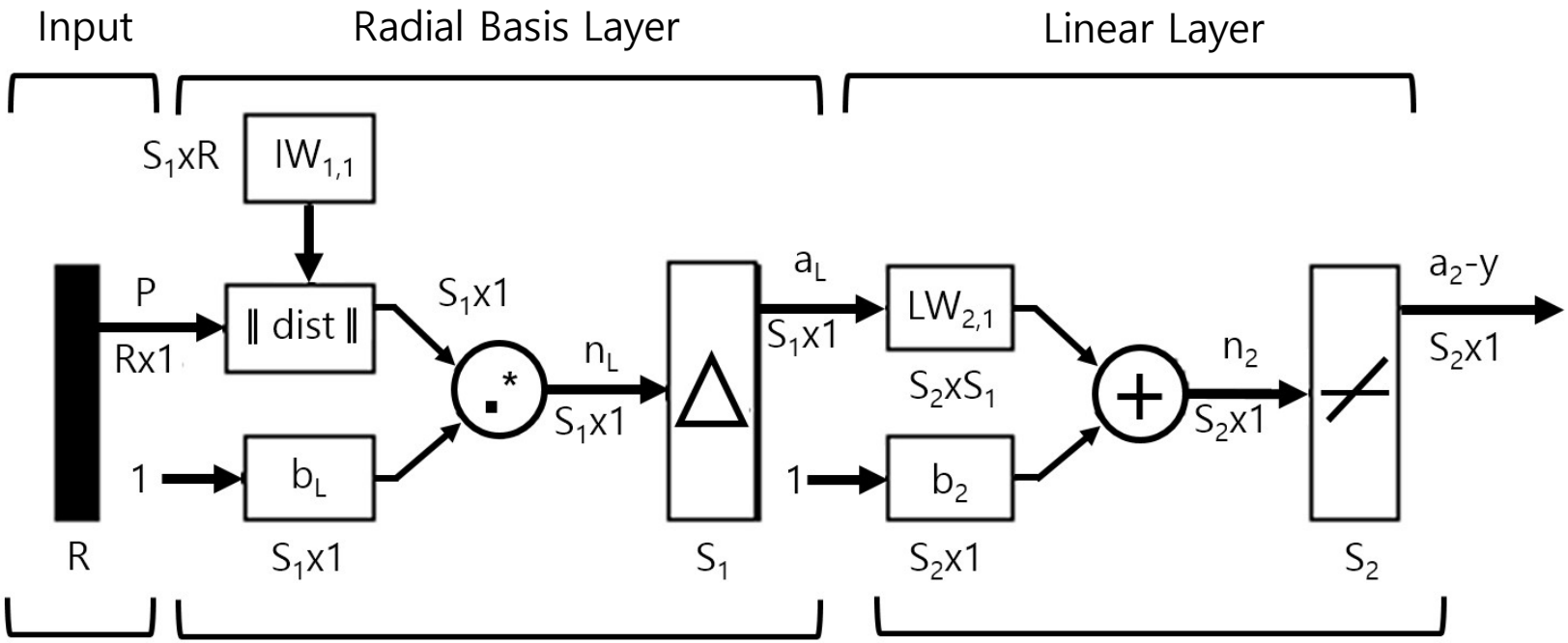
- Gaussian Functions
- Multi-Quadric Gaussian Functions
- Generalized Multi-Quadric Gaussian
- Inverse Multi-Quadric Functions
- Generalized Inverse Multi-Quadric
- Thin Plate Spline Functions
- Cubic Functions
- Linear Functions

➢ **Neuron Model**



Radial Basic Neural Network (RBNN)

➢ **Network Architecture**



a_i^L = radbas ($\left|\left|{}_i IW_{1,1} - p\right|\right|$ $b_i L$) $a_2 = purelin(LW_{2,1}a_L + b_2)$

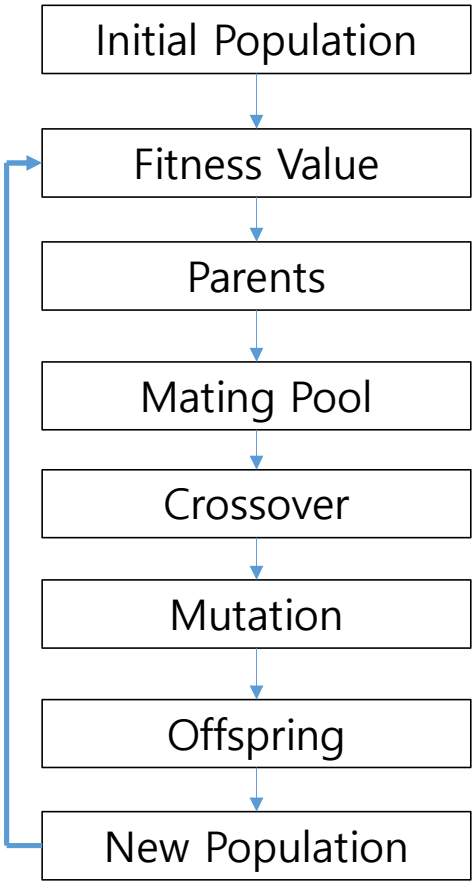
a_i^L is i^{th} element of a^L where ${}_jIW_{1,1}$ is a vector made of the i^{th} row of $IW_{1,1}$

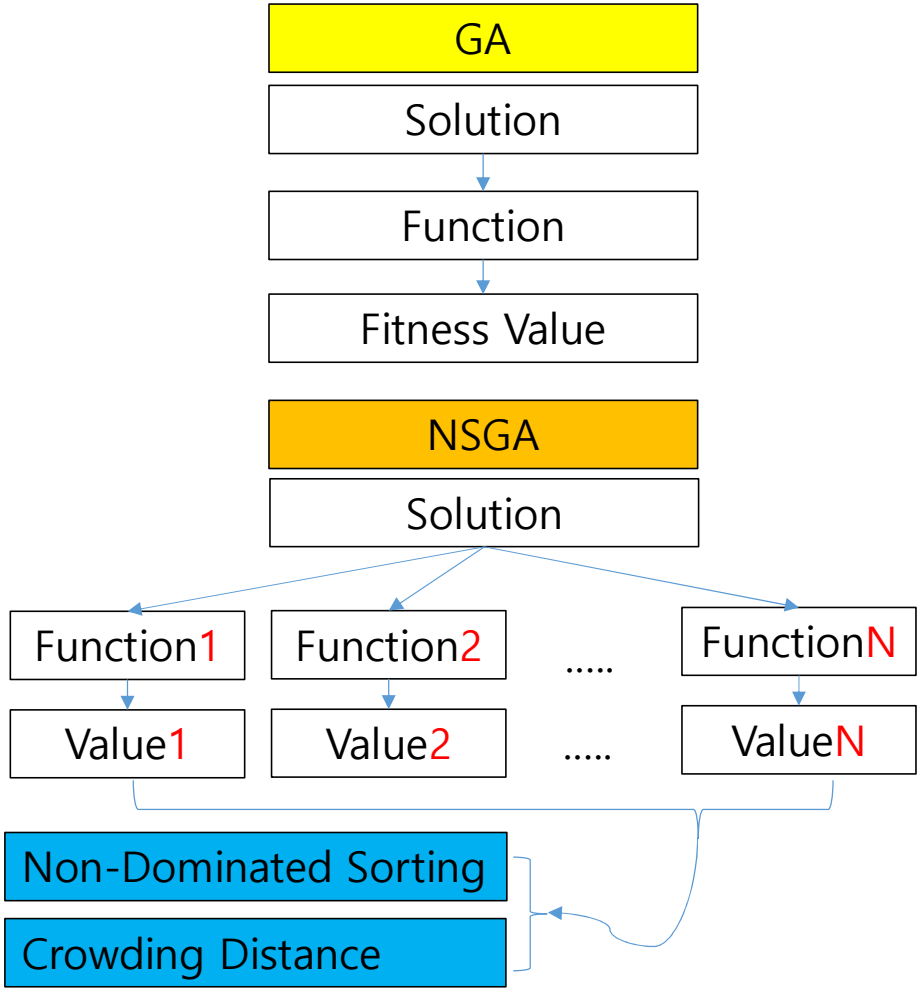
Where R is number of elements in input vector, S_1 is number of neurons in layer 1,
S_2 is number of neurons in layer 2

NSGA-II: Non-dominated Sorting Genetic Algorithm

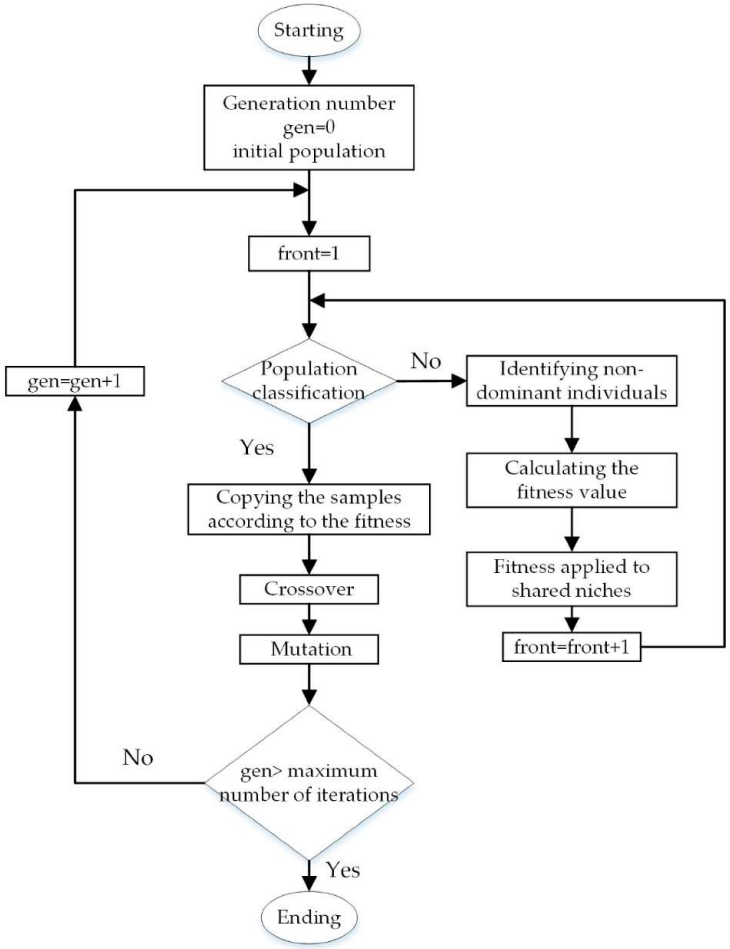
➢ GA and NSGA-II

✓ Steps



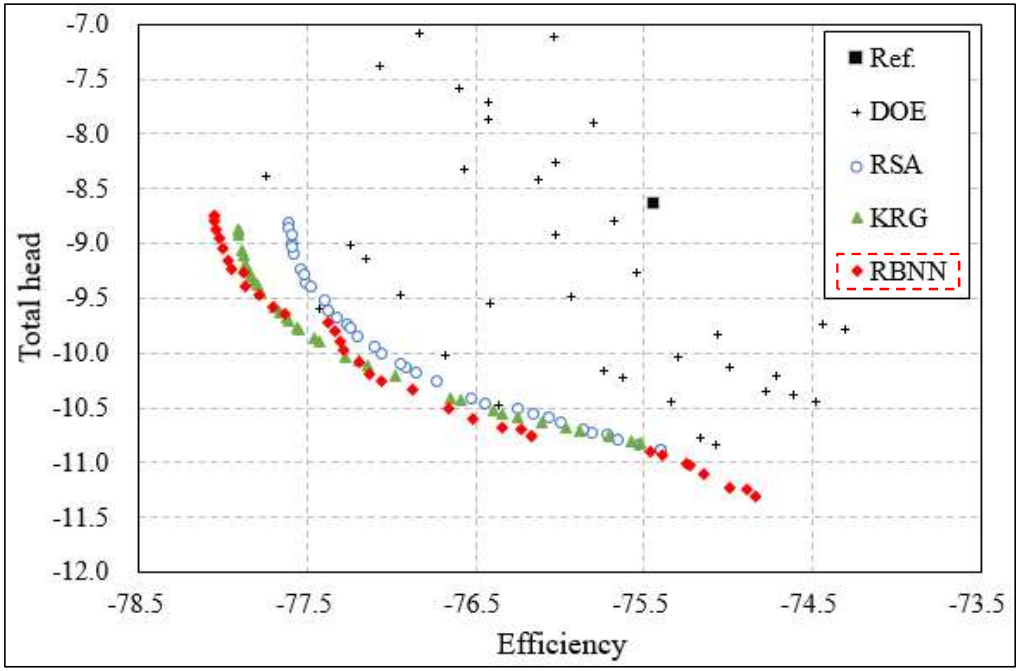


✓ NSGA-II schematic



Prediction and Pareto Optimal Solution

	Design variables				*Predicted values*		*Calculation*	
	L_s	L_h	ξ_m	$\beta_{1,m}$	η_t (%)	H_t (m)	η_t (%)	H_t (m)
Case 1	35.447	48.539	65.783	77.226	-77.886	-9.191	77.405	9.202
Case 2	34.925	52.711	63.251	75.384	-76.792	-10.347	76.397	10.331
Case 3	35.831	48.623	62.335	79.890	-75.149	-11.092	75.894	10.489



- **Next Presentation:**
  - ✓ Prediction error
  - ✓ Analysis of optimized geometry

Thank You For Listening!