Estimation of energy performance of residential buildings using genetic algorithm

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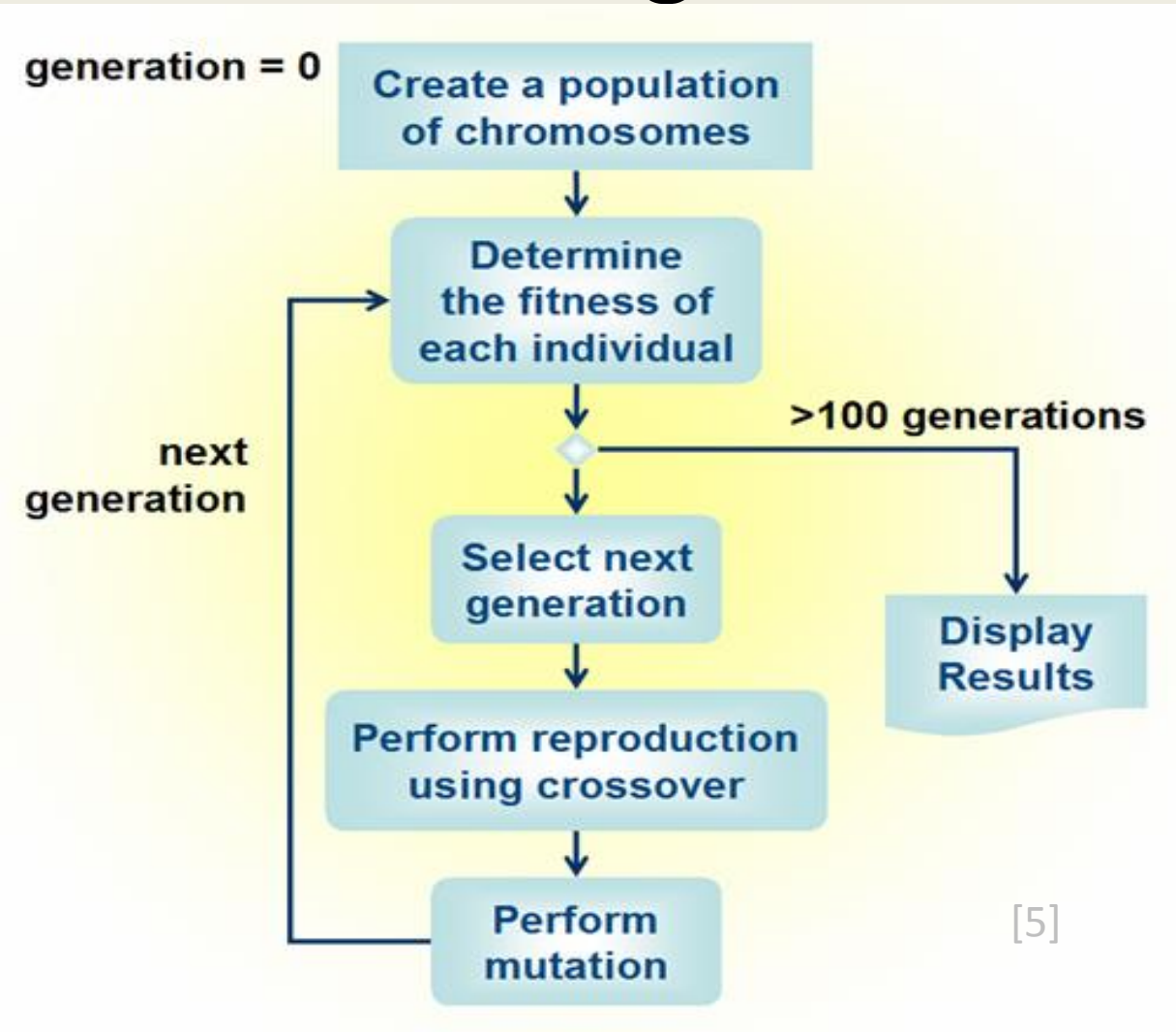
http://www.seiplab.riteh.uniri.hr/

Genetic Algorithm



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Simulation using Ecotec

- 12 different building shapes simulated in **Ecotect**
  - Buildings are composed from 18 elementary cubes
    - 3.5x3.5x3.5 = 771.75 m^3

	U-value
Roofs	1.780
Floors	0.860
Windows	2.260

Internal Design Conditions	
Clothing	0.6 clo
Humidity	60%
Air speed	0.30 m/s
Lighting level	300 Lux

- Thermostat range 19–24 °C, with 15–20 h of operation on weekdays and 10–20 h on weekends
- Glazing areas variations: 10%, 20%, 40% floor area
  1. *uniform*: with 25% glazing on each side,
  2. *north*: 55% - north side, 15% - other sides
  3. *east*: 55% - east side,15% - other sides
  4. *south*: 55% - south side, 15% other sides
  5. *west*: 55% - west side, 15% other sides
- No gazing areas
- Four orientations

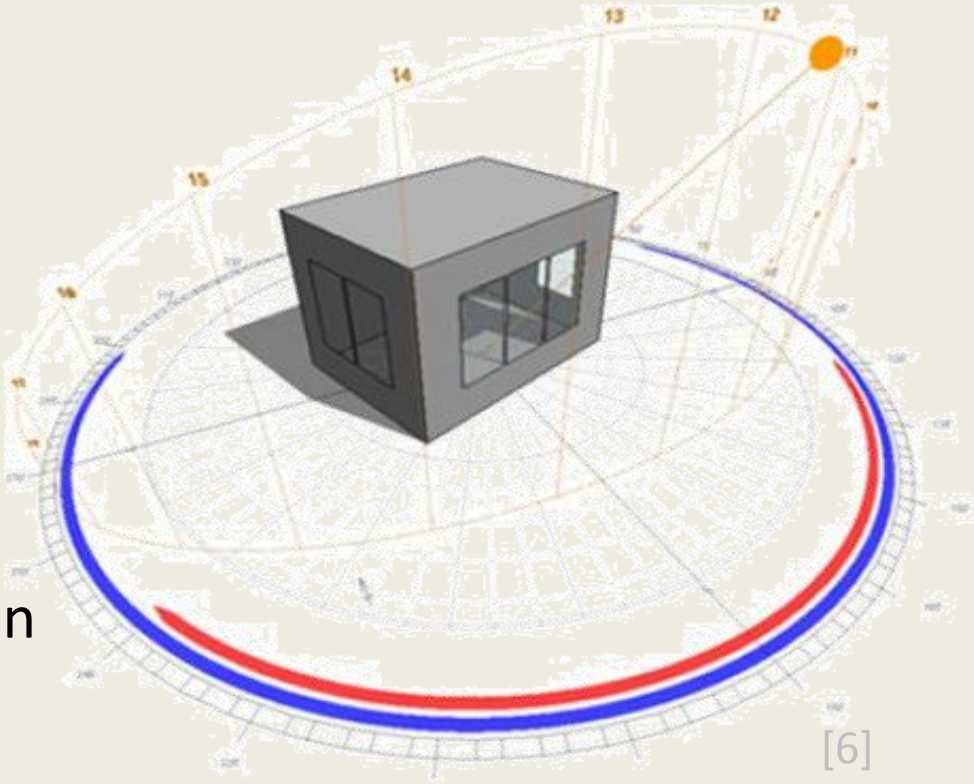
- Samples with glazing areas = 12 building forms * 3 glazing area * 5 glazing area distributions * 4 orientations = 720
- Samples without glazing areas = 12 building forms * 4 orientations

- Total:

12 * 3 * 5 * 4 + 12 * 4 = 768 building samples

Data Set Information

- X1 Relative Compactness
- X2 Surface Area
- X3 Wall Area
- X4 Roof Area
- X5 Overall Height
- X6 Orientation
- X7 Glazing Area
- X8 Glazing Area Distribution
- **Y1 Heating Load**
- **Y2 Cooling Load**



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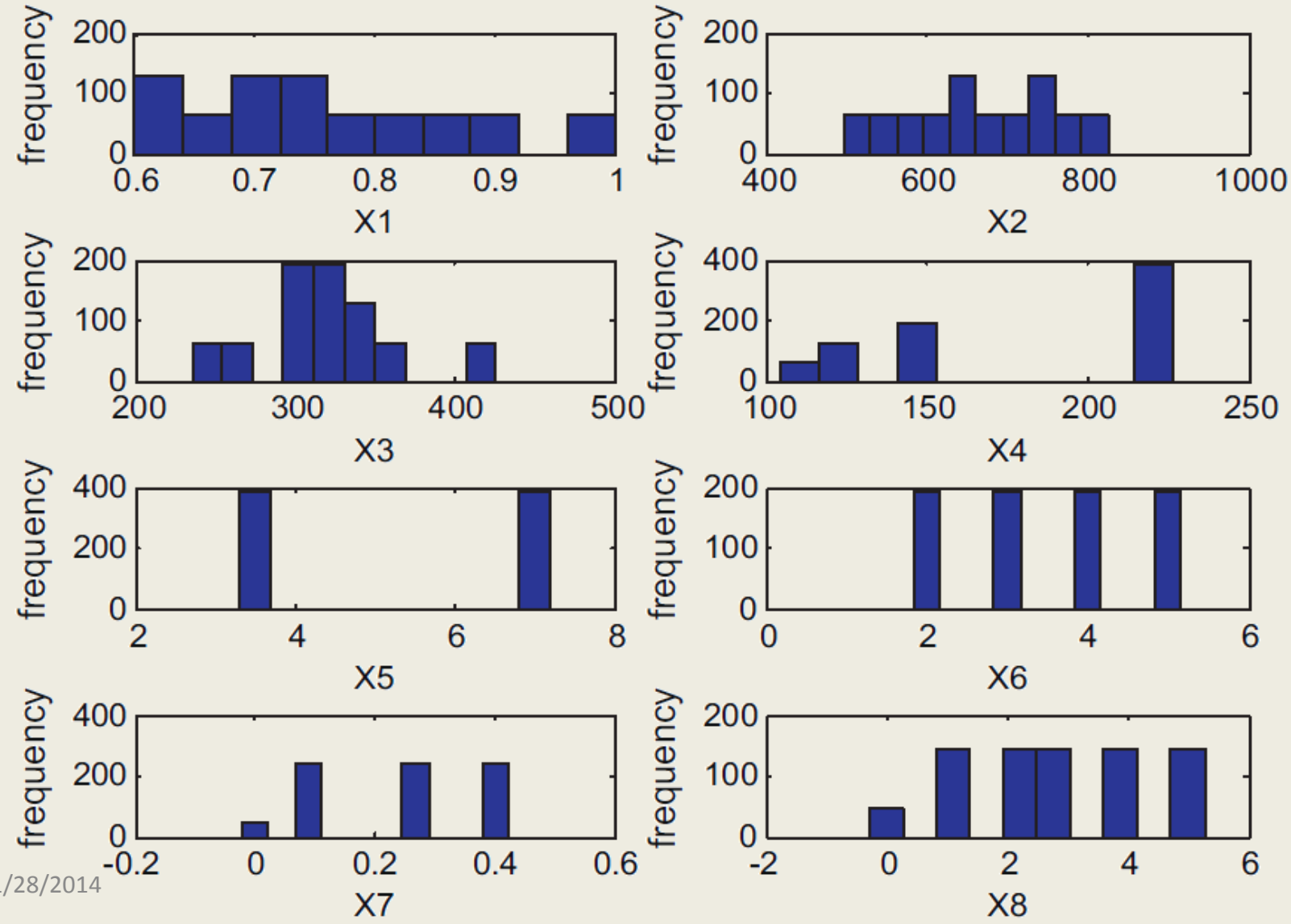
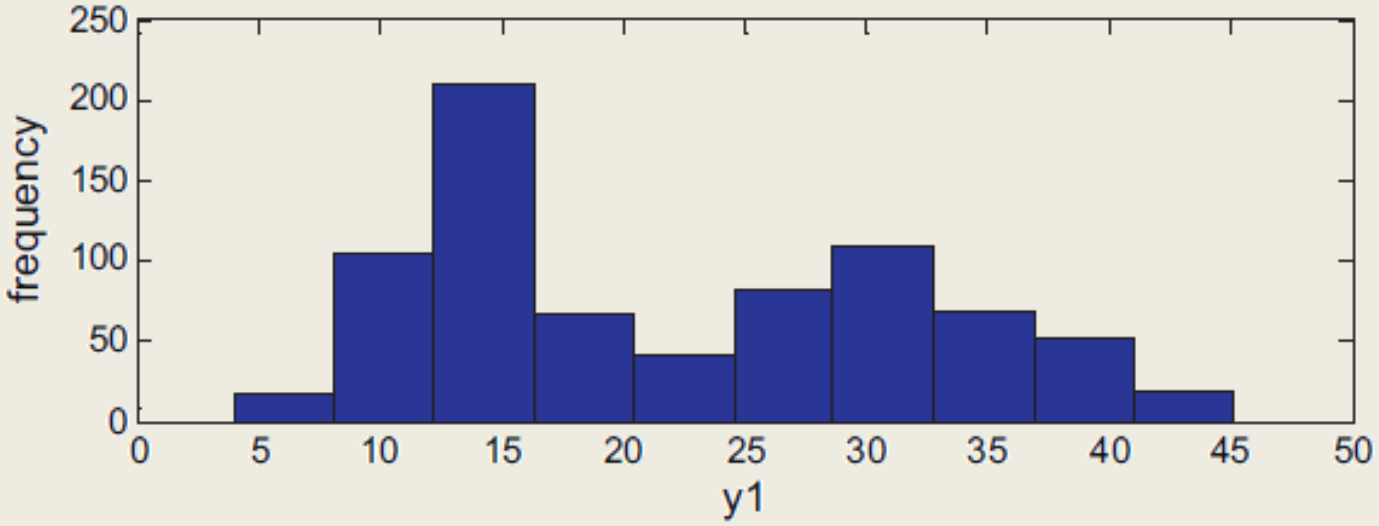
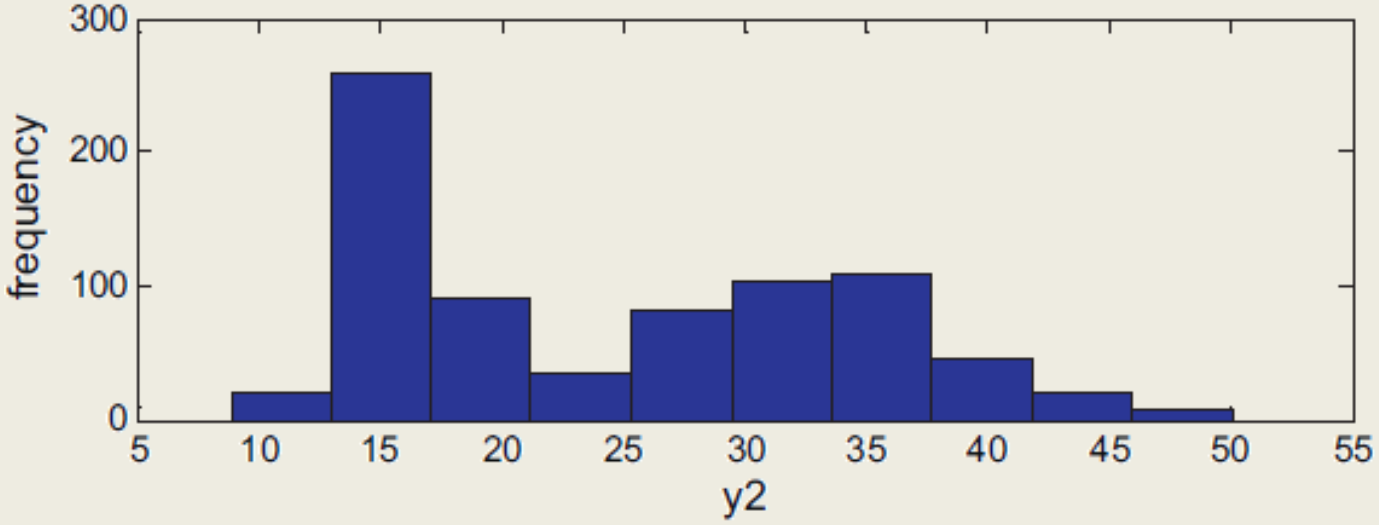


[1]


frequency
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
y1


frequency
300
200
100
0
5
10
15
20
25
30
35
40
45
50
55
y2

[1]

Prediction algorithm explained

1. Choose training and learning from Data Set
   - Learning group = 90% Data Set
   - Training group = 10% Data Set
2. Define Fitness Function
3. Run genetic algorithm
4. Collect Results

Define Fitness Function

predicted

$$W1*X1 + W2*X2 + \ldots + Wn*Xn = Y'$$

$$fitnessFun = (Y' - Y)^2$$

actual

$$fitnessFun = \{ (W1*X1 + W2*X2 + \ldots + Wn*Xn) - Y \}^2$$

$$fitnessFun \gg 0$$

$$\begin{bmatrix} X11 & X12 & \dots & X1n \\ X21 & X22 & \dots & X2n \\ \dots & \dots & \dots & \dots \\ Xm1 & Xm2 & \dots & Xmn \end{bmatrix} \begin{bmatrix} W1 \\ W2 \\ \dots \\ Wn \end{bmatrix} = \begin{bmatrix} Y1' \\ Y2' \\ \dots \\ Yn' \end{bmatrix}$$

$$\textit{fitnessFcn} \rightarrow \begin{bmatrix} Y1' \\ Y2' \\ \dots \\ Yn' \end{bmatrix} - \begin{bmatrix} Y1 \\ Y2 \\ \dots \\ Yn \end{bmatrix} \approx \begin{bmatrix} 0 \\ 0 \\ \dots \\ 0 \end{bmatrix}$$

[7]

$$\textit{fitnessFun} \gg 0$$

$$fitnessFcn(1) = \frac{1}{m}\sum\left(\begin{bmatrix} X11 & X12 & \dots & X1n \\ X21 & X22 & \dots & X2n \\ \dots & \dots & \dots & \dots \\ Xm1 & Xm2 & \dots & Xmn \end{bmatrix}\begin{bmatrix} W1 \\ W2 \\ \dots \\ Wn \end{bmatrix} - \begin{bmatrix} Y1 \\ Y2 \\ \dots \\ Y \end{bmatrix}\right)^2$$

MSE

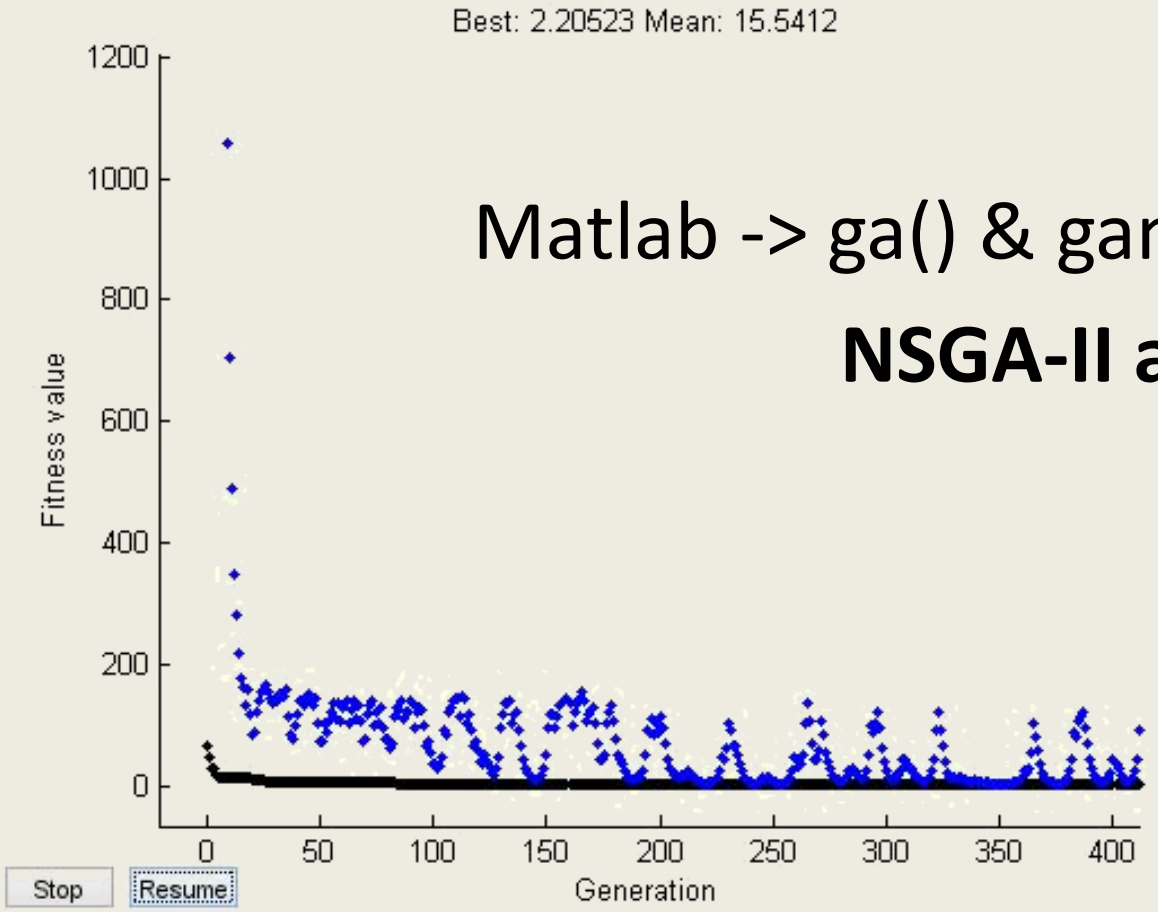
$$fitnessFcn(2) = \frac{1}{m}\sum\left|\left(\begin{bmatrix} X11 & X12 & \dots & X1n \\ X21 & X22 & \dots & X2n \\ \dots & \dots & \dots & \dots \\ Xm1 & Xm2 & \dots & Xmn \end{bmatrix}\begin{bmatrix} W1 \\ W2 \\ \dots \\ Wn \end{bmatrix} - \begin{bmatrix} Y1 \\ Y2 \\ \dots \\ Y \end{bmatrix}\right)\right|$$

MAE

$$fitnessFcn(33) = \frac{100}{m}\sum\frac{\left|\left(\begin{bmatrix} X11 & X12 & \dots & X1n \\ X21 & X22 & \dots & X2n \\ \dots & \dots & \dots & \dots \\ Xm1 & Xm2 & \dots & Xmn \end{bmatrix}\begin{bmatrix} W1 \\ W2 \\ \dots \\ Wn \end{bmatrix} - \begin{bmatrix} Y1 \\ Y2 \\ \dots \\ Y \end{bmatrix}\right)\right|}{\begin{bmatrix} Y1 \\ Y2 \\ \dots \\ Y \end{bmatrix}}$$

MRE

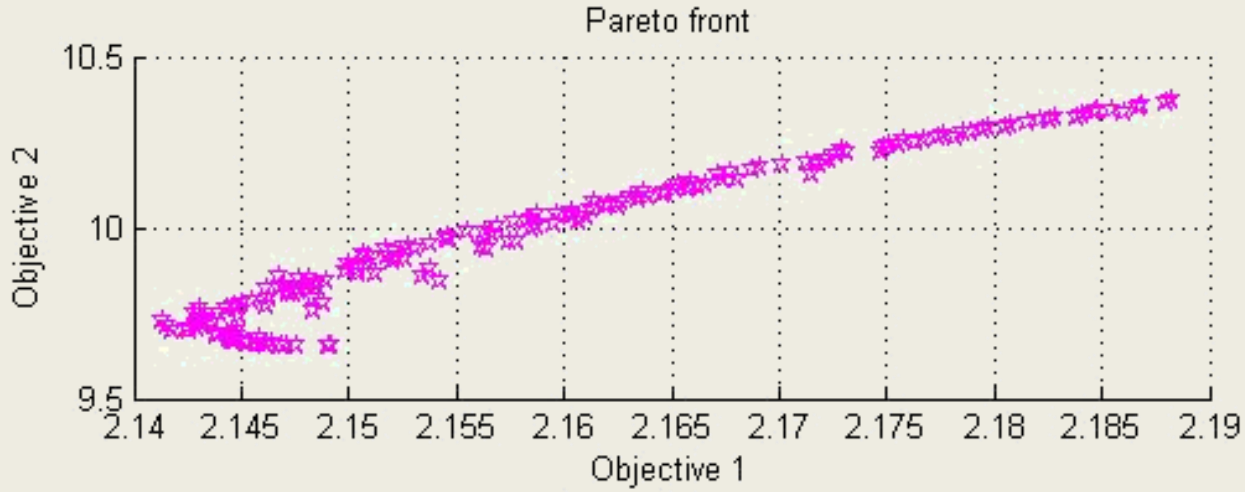
Run genetic algorithm

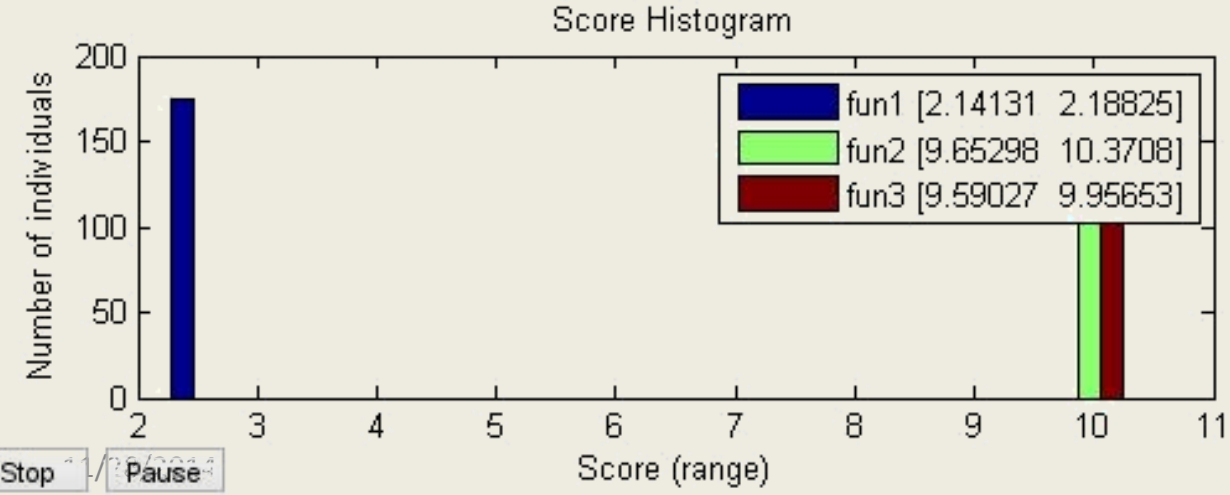


Matlab -> ga() & gamultiobj()

NSGA-II algorithm

Gamultiobj()





Y1

MAE [2.141 2.228]

MSE [9.653 10.994]

MRE [9.322 10.001]

Y2

MAE [2.207 2.344]

MSE [10.346 11.927]

MRE [9.001 10.421]

Conclusion

- Using genetic algorithm we can estimate
  - HL with 2.2 points deviation
  - CL with 2.3 points deviation
- We explore the statistical relationship between eight input variables and the two output variables
  - Glazing area has most impact on HL and CL

Literature

[1] A.Tsanasa, A. Xifarab, Accurate quantitative estimation of energy performance of residential buildings using statistical machine learning tools, Energy and Buildings 49 (2012) 560–567, 3 March 2012

[2] K. Deb, Multiobjective Optimization Using Evolutionary Algorithms: An Introduction, Department of Mechanical Engineering, Indian Institute of Techonology Kanpur, PIN 208016, India, February 10,2011

[3] K. Deb, Associate Member, IEEE, A. Pratap, S. Agarwal, and T. Meyarivan, A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II, IEEE TRANSACTIONS ON EVOLUTIONARY COMPUTATION, VOL. 6, NO. 2, APRIL 2002

[4] Edin Salković, Genetički algoritmi i njihova praktična primjena, Univerzitet Crne gore, Elektrotehnički fakultet, Podgorica, septembar 2005.

Images

[5] http://thundaxsoftware.blogspot.com/2010/11/genetic-algorithms-ga.html

[6]http://www.frangiluce.com/wpcontent/uploads/2013/09/ECOTECT.jpg

[7]http://st.depositphotos.com/1768142/1987/v/950/depositphotos_19875345-Bodybuilder-Fitness-Model-Illustration-Sign-Symbol-Button-Badge-Icon-Logo-for-Family-Baby-Children-Teenager--Tattoo.jpg