1.

$E_k = \frac{1}{2}(y_k - o_k)^2$ F-JA POGREŠKE ZA UZORAK

$$o = \frac{\sum_{i=1}^{m} w_i z_i}{\sum_{i=1}^{m} w_i} \qquad w_i = \alpha_i \cdot \beta_i$$

$$\alpha_i = \frac{1}{1+e^{b_i(x-a_i)}} \qquad \beta_i = \frac{1}{1+e^{d_i(y-c_i)}}$$

$$z_i = p_i x + q_i y + r_i$$

$$\frac{\partial E_k}{\partial o_k} = \frac{\partial}{\partial o_k}\left(\frac{1}{2}(y_k - o_k)^2\right) = \frac{\cancel{2}}{\cancel{2}}(y_k - o_k)\cdot(-1) = -(y_k - o_k)$$

$$\frac{\partial o_k}{\partial z_i} = \frac{\partial}{\partial z_i}\left(\frac{\sum_{i=1}^{m} w_i z_i}{\sum_{i=1}^{m} w_i}\right) = \frac{w_i}{\sum_{i=1}^{m} w_i} \qquad \frac{\partial z_i}{\partial p_i} = x \qquad \frac{\partial z_i}{\partial q_i} = y \qquad \frac{\partial z_i}{\partial r_i} = 1$$

$$\boxed{\frac{\partial E_k}{\partial p_i}} = \frac{\partial E_k}{\partial o_k}\cdot\frac{\partial o_k}{\partial z_i}\cdot\frac{\partial z_i}{\partial p_i} = \boxed{-(y_k - o_k)\cdot\frac{w_i}{\sum_{i=1}^{m} w_i}\cdot x}$$

$$\boxed{\frac{\partial E_k}{\partial q_i}} = \frac{\partial E_k}{\partial o_k}\cdot\frac{\partial o_k}{\partial z_i}\cdot\frac{\partial z_i}{\partial q_i} = \boxed{-(y_k - o_k)\cdot\frac{w_i}{\sum_{i=1}^{m} w_i}\cdot y}$$

$$\boxed{\frac{\partial E_k}{\partial r_i}} = \frac{\partial E_k}{\partial o_k}\cdot\frac{\partial o_k}{\partial z_i}\cdot\frac{\partial z_i}{\partial r_i} = -(y - o_k)\cdot\frac{w_i}{\sum_{i=1}^{m} w_i}\cdot 1 = \boxed{-(y_k - o_k)\cdot\frac{w_i}{\sum_{i=1}^{m} w_i}}$$

$$\boxed{\frac{\partial E_k}{\partial a_i}} = \frac{\partial E_k}{\partial o_k}\cdot\boxed{\frac{\partial o_k}{\partial w_i}}\,\frac{\partial w_i}{\partial \alpha_i}\,\frac{\partial \alpha_i}{\partial a_i} = \boxed{-(y_k - o_k)\cdot\frac{\sum_{j=1}^{m} w_j(z_i - z_j)}{\left(\sum_{j=1}^{m} w_j\right)^2}\cdot \beta_i\cdot b_i\alpha_i(1-\alpha_i)}$$

$$\frac{\partial o_k}{\partial w_i} = \frac{z_i\cdot\sum_{i=1}^{m} w_i - \sum_{j=1}^{m} w_i z_i\cdot 1}{\left(\sum_{j=1}^{m} w_i\right)^2} = \boxed{\frac{\sum_{j=1}^{m} w_j(z_i - z_j)}{\left(\sum_{j=1}^{m} w_i\right)^2}}$$

$$\frac{\partial w_i}{\partial \alpha_i} = \beta_i \qquad \frac{\partial \alpha_i}{\partial a_i} = \frac{\partial\left(\left(1+e^{b_i(x-a_i)}\right)^{-1}\right)}{\partial a_i} = -1\left(1+e^{b_i(x-a_i)}\right)^{-2}\cdot e^{-a_i b_i}\cdot(-b_i)$$

$$= b_i\frac{e^{-a_i b_i}}{\left(1+e^{b_i(x-a_i)}\right)^2} = b_i\,\frac{e^{-a_i b_i}}{1+e^{b_i(x-a_i)}}\cdot\underbrace{\frac{1}{1+e^{b_i(x-a_i)}}}_{\alpha_i}$$

$$= b_i\cdot\alpha_i\cdot(1-\alpha_i)$$

$$\frac{\partial E_k}{\partial b_i} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial w_i} \cdot \frac{\partial w_i}{\partial \alpha_i} \cdot \frac{\partial \alpha_i}{\partial b_i}$$

$$= -(y_k - o_k) \frac{\sum_{j=1}^{m} w_j (z_i - z_j)}{\left(\sum_{j=1}^{m} w_j\right)^2} \cdot \beta_i \cdot (a_i - x)\, \alpha_i (1 - \alpha_i)$$

$$\frac{\partial \alpha_i}{\partial b_i} = -1\left(1 + e^{b_i(x - a_i)}\right)^{-2} \cdot e^{b_i(x-a_i)} \cdot (x - a_i)$$

$$= (a_i - x) \underbrace{\frac{1}{1 + e^{b_i(x-a_i)}}}_{\alpha_i} \cdot \frac{e^{b_i(x-a_i)}}{1 + e^{b_i(x-a_i)}} = (a_i - x)\, \alpha_i (1 - \alpha_i)$$

$$\boxed{\frac{\partial E_k}{\partial c_i}} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial w_i} \cdot \frac{\partial w_i}{\partial \beta_i} \cdot \frac{\partial \beta_i}{\partial c_i}$$

analogno kao $\frac{\partial \alpha_i}{\partial a_i}$

$$\boxed{= -(y_k - o_k) \frac{\sum_{j=1}^{m} w_j (z_i - z_j)}{\left(\sum_{j=1}^{m} w_j\right)^2} \cdot \alpha_i \cdot d_i \cdot \beta_i (1 - \beta_i)}$$

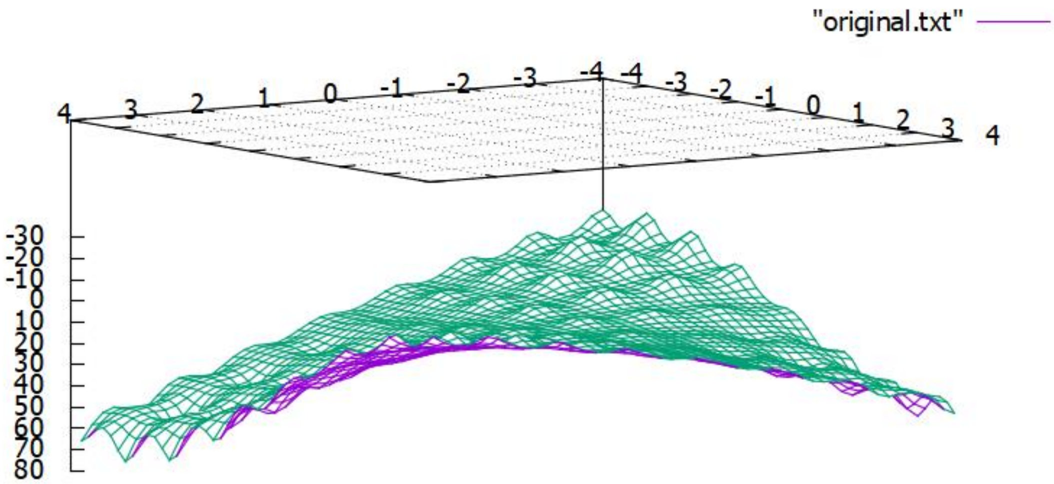
$$\boxed{\frac{\partial E_k}{\partial d_i}} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial w_i} \cdot \frac{\partial w_i}{\partial \beta_i} \cdot \frac{\partial \beta_i}{\partial d_i}$$

$$\boxed{= -(y_k - o_k) \frac{\sum_{j=1}^{m} w_j (z_i - z_j)}{\left(\sum_{j=1}^{m} w_j\right)^2}\, \alpha_i\, (c_i - y)\, \beta_i (1 - \beta_i)}$$

Napomena: kod mene nema razlike kod računanja pravog gradijenta i stohastičke varijante, jedina razlika je koliki mi je m (broj primjera s kojima radim) koji je kod stohastičke varijante m = 1, a kod pravog gradijenta je jednak m = 81 (koliko se primjera tražilo da imamo).

3.

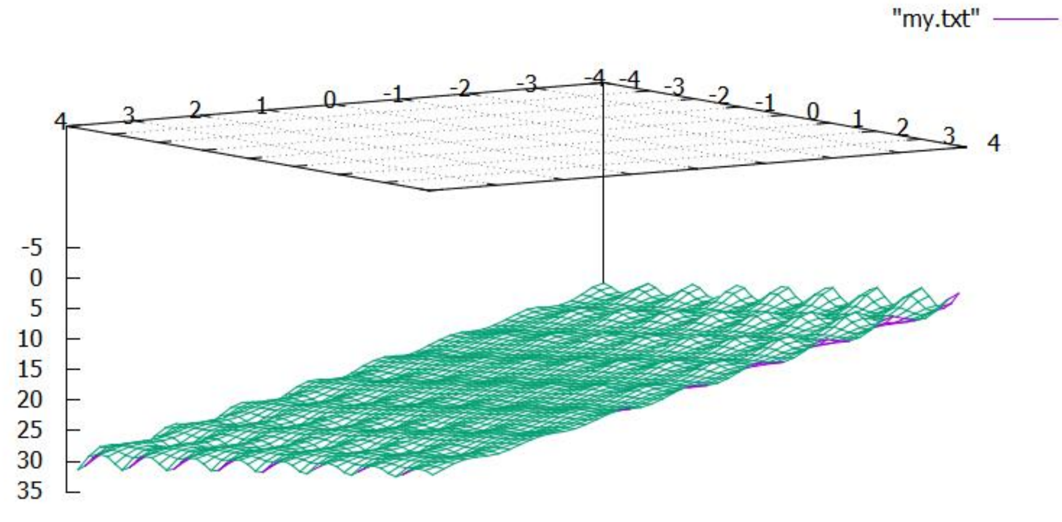
Zadana funkcija nad zadanom domenom:



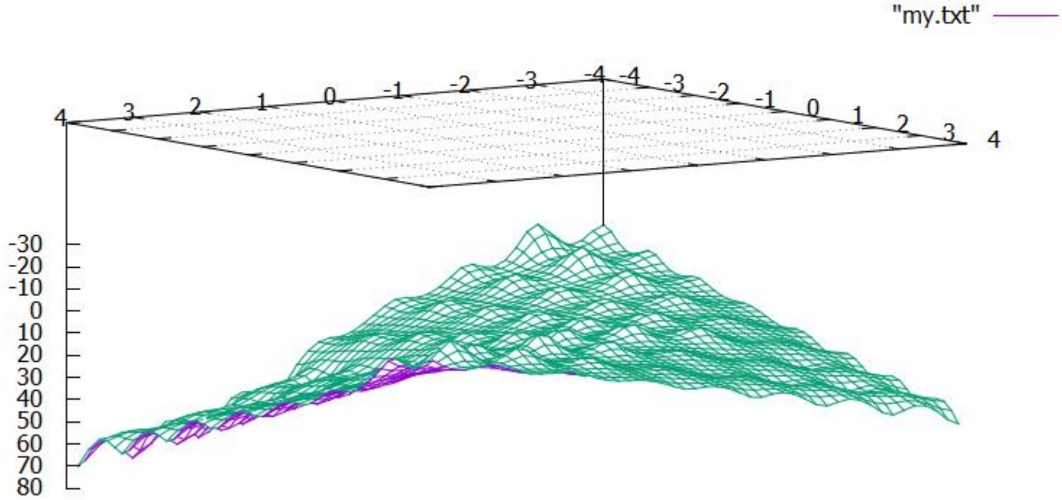
4.

a) funkcija koju je ANFIS naučio za:

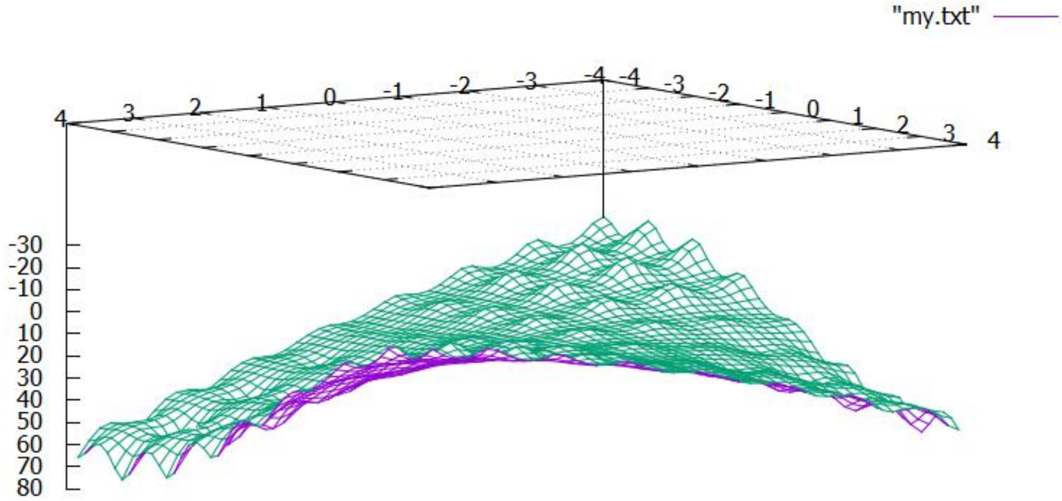
- 1 pravilo:



- 2 pravila:

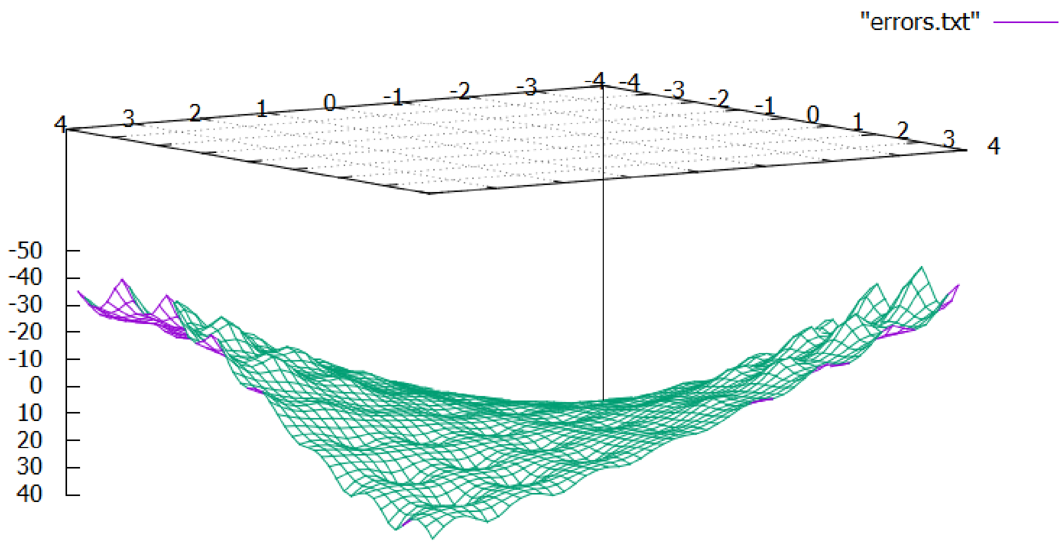


- 7 pravila:

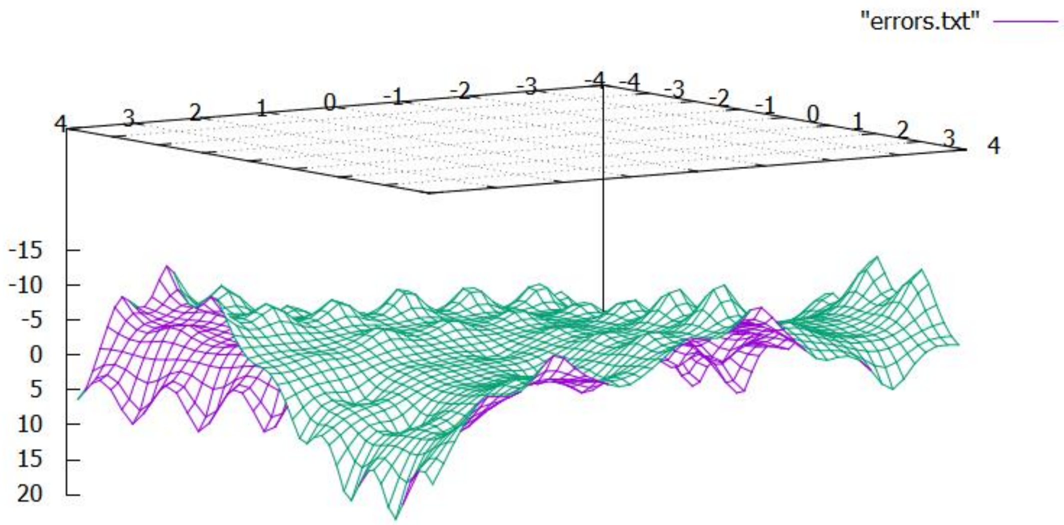


b) odstupanja naučene funkcije i uzoraka za učenje nad svim uzorcima za učenje

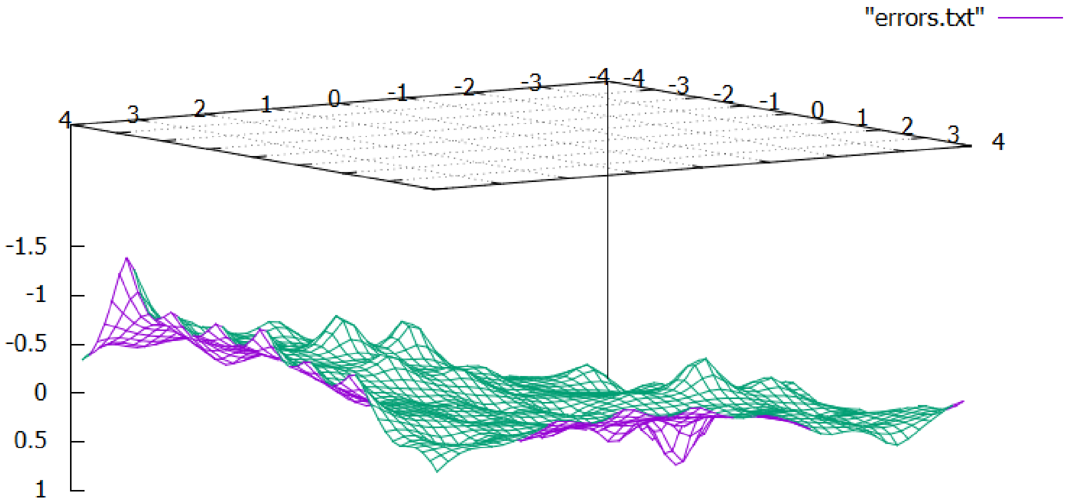
- 1 pravilo:



- 2 pravila:



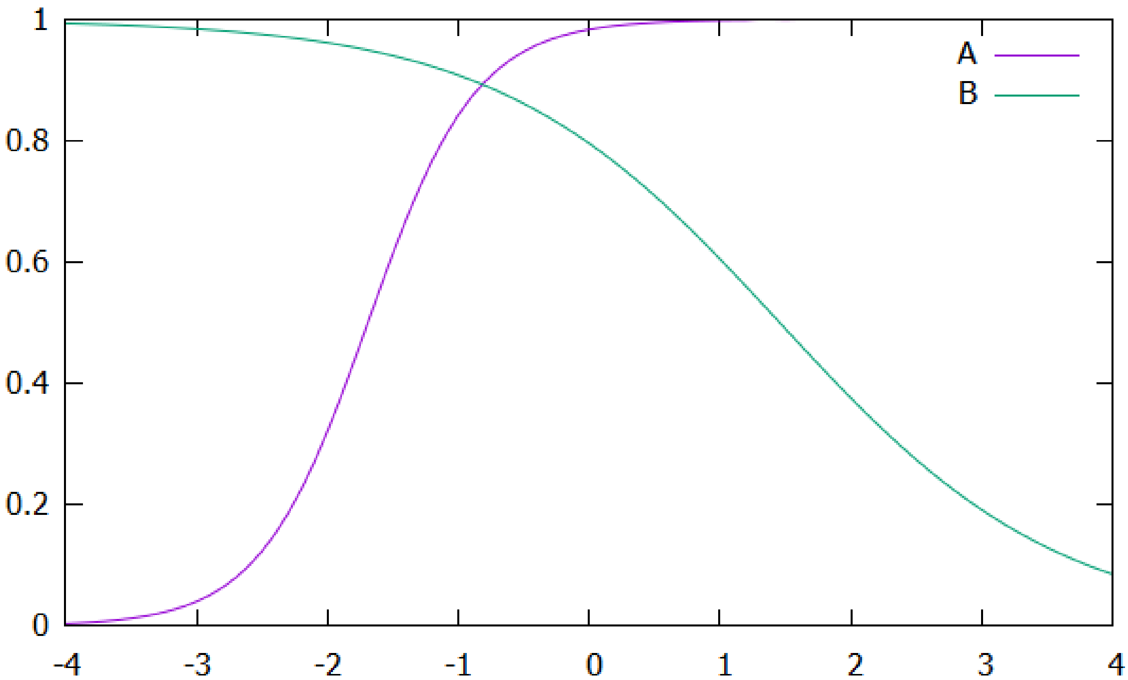
- 7 pravila:



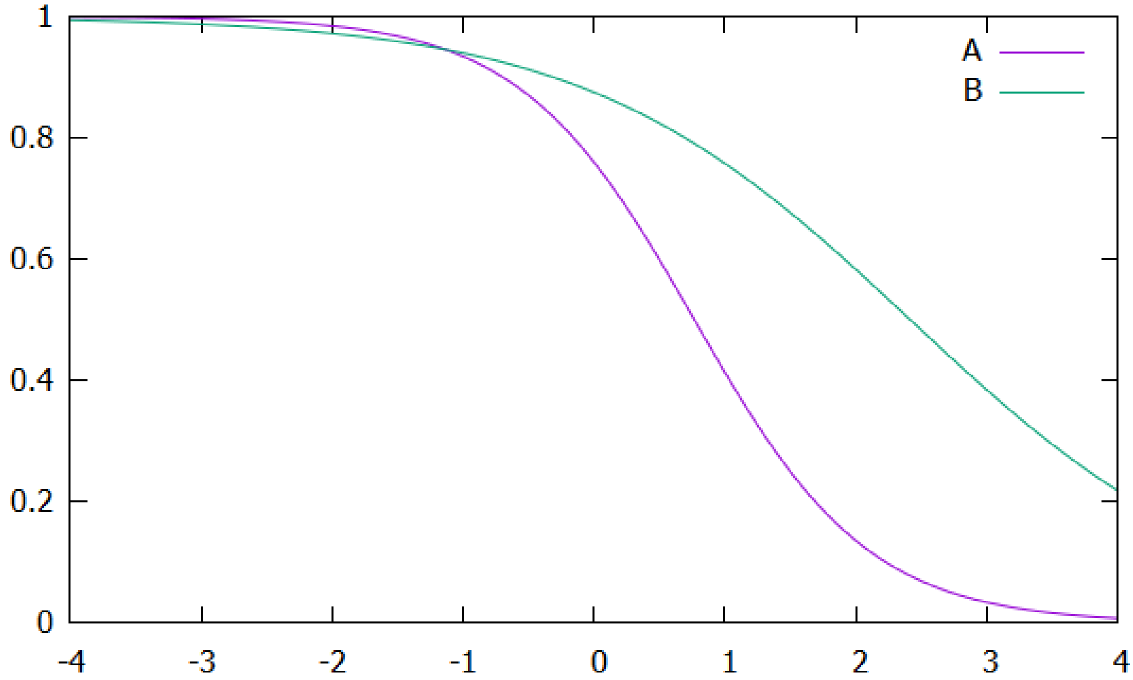
5.

fje pripadnosti za:

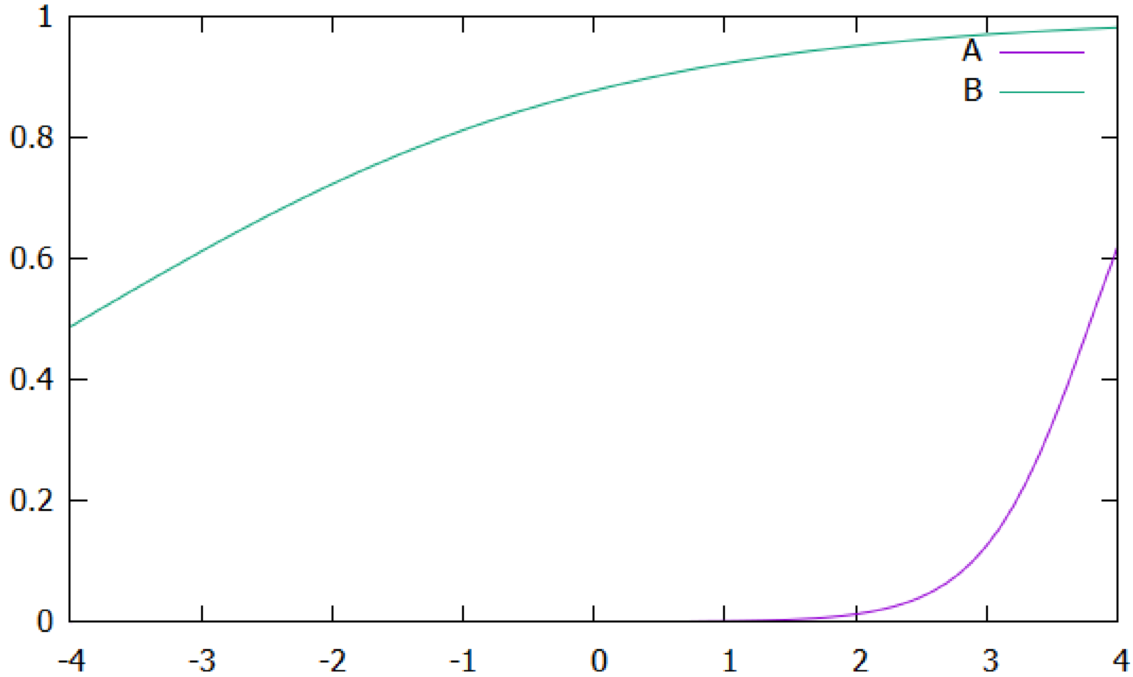
- 1. pravilo:



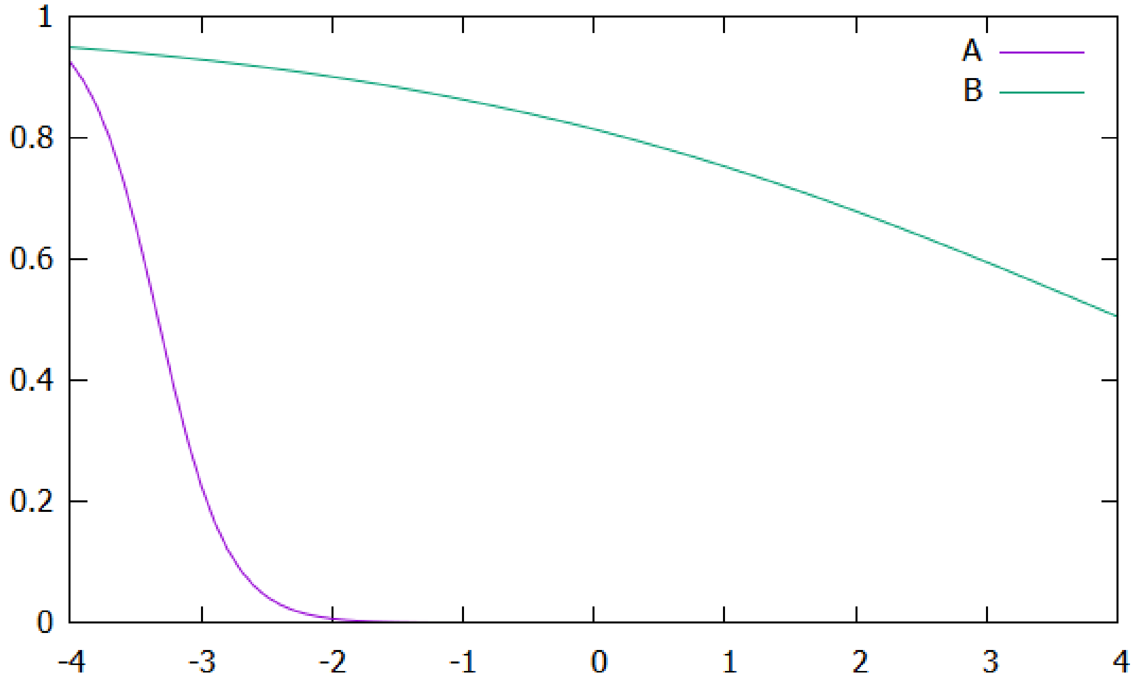
- 2. pravilo:



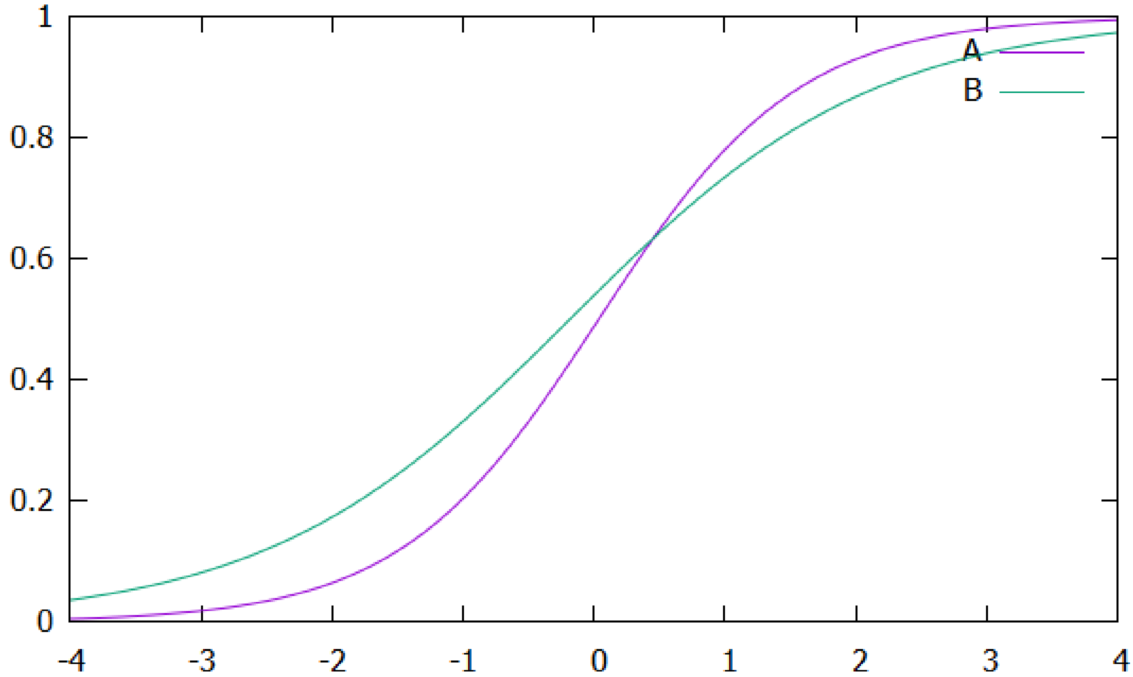
- 3. pravilo:



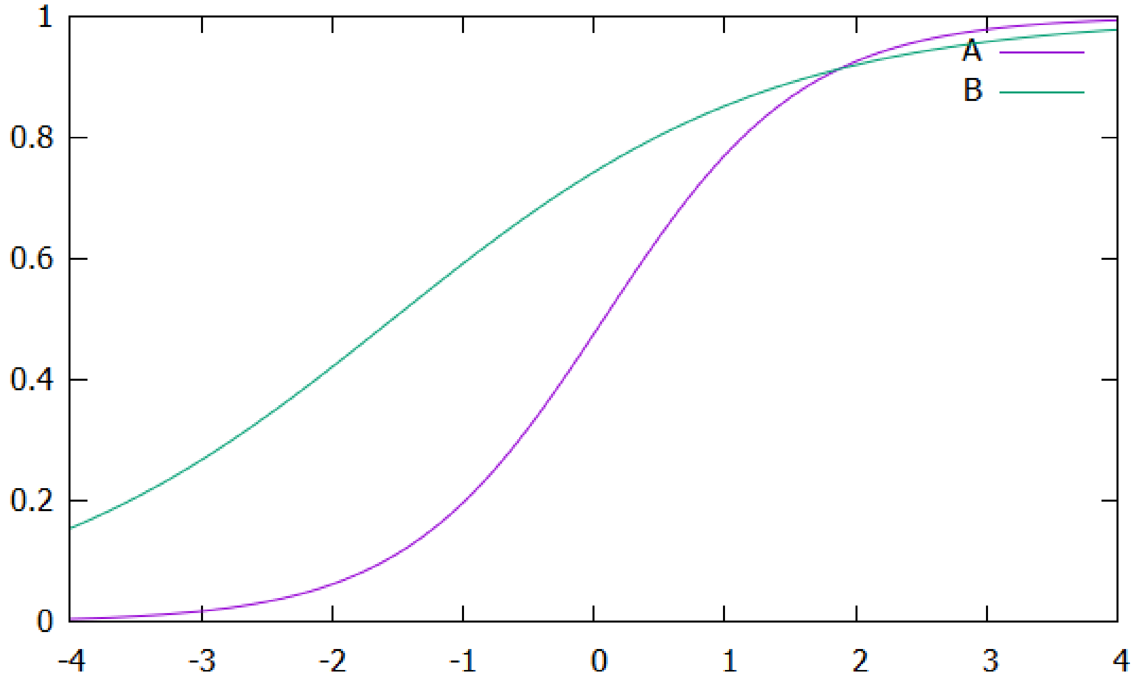
- 4. pravilo:



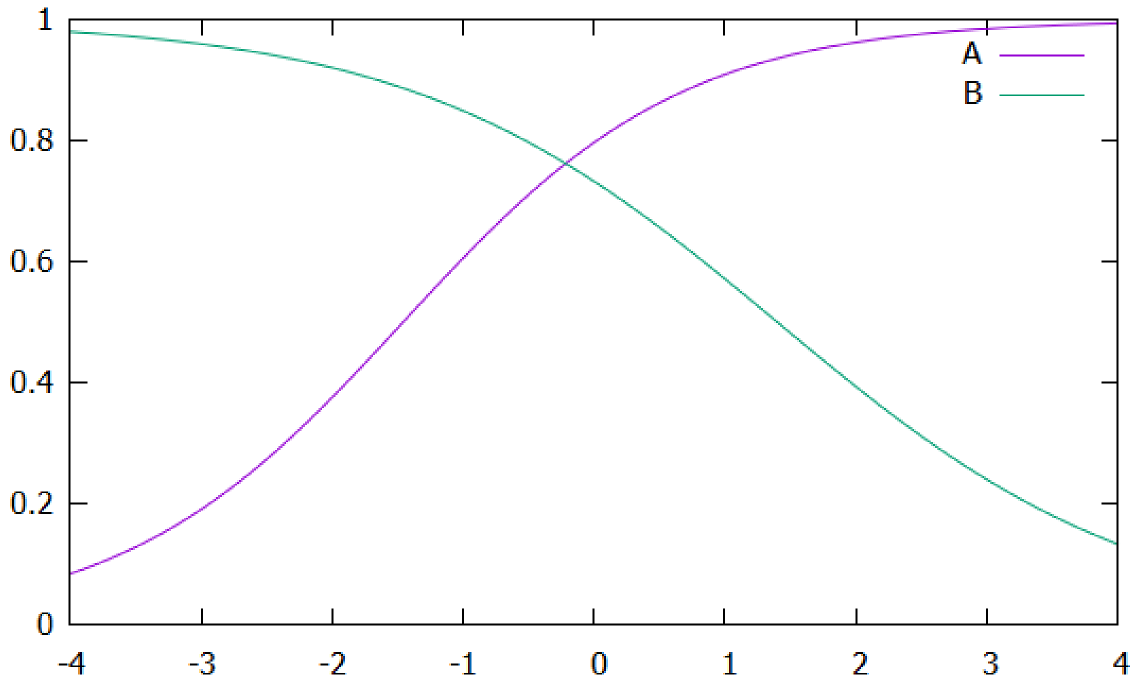
- 5. pravilo:



- 6. pravilo:

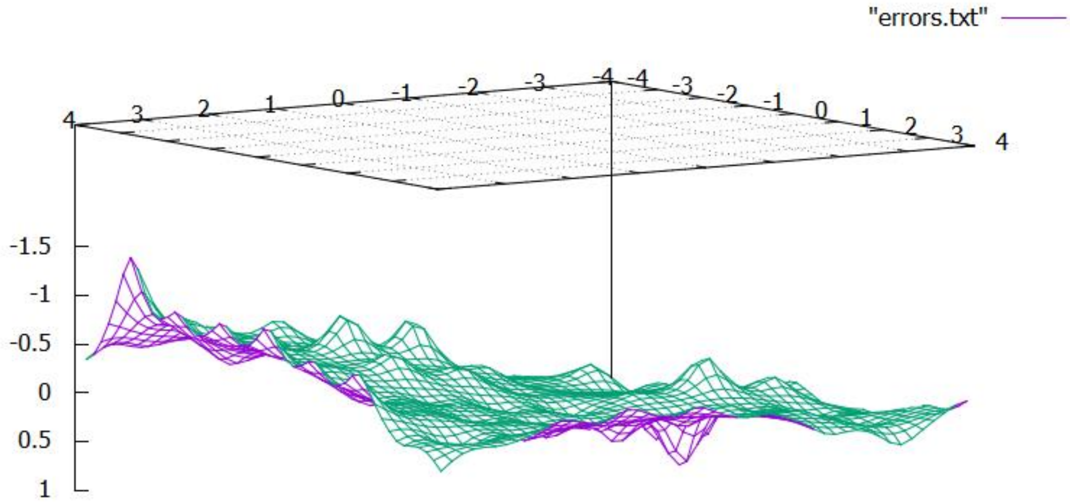


- 7. pravilo:



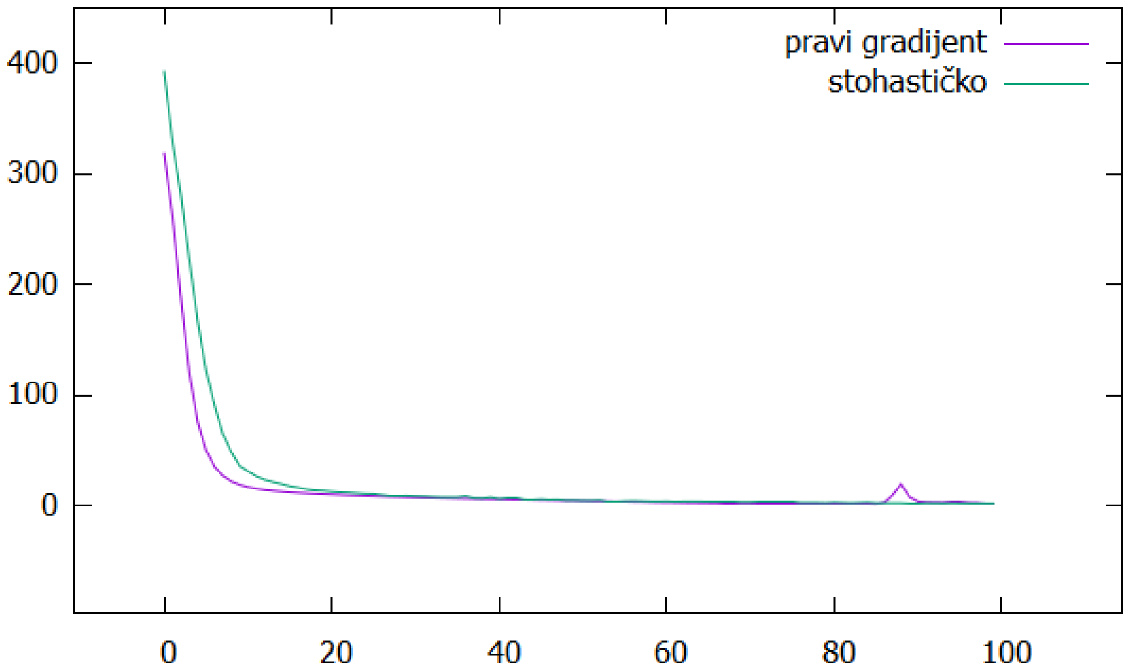
6.

Funkcija pogreške uzorka na ANFIS-u s 7 pravila:



7.

Prikaz kako greška pada u ovisnosti o broju epoha:

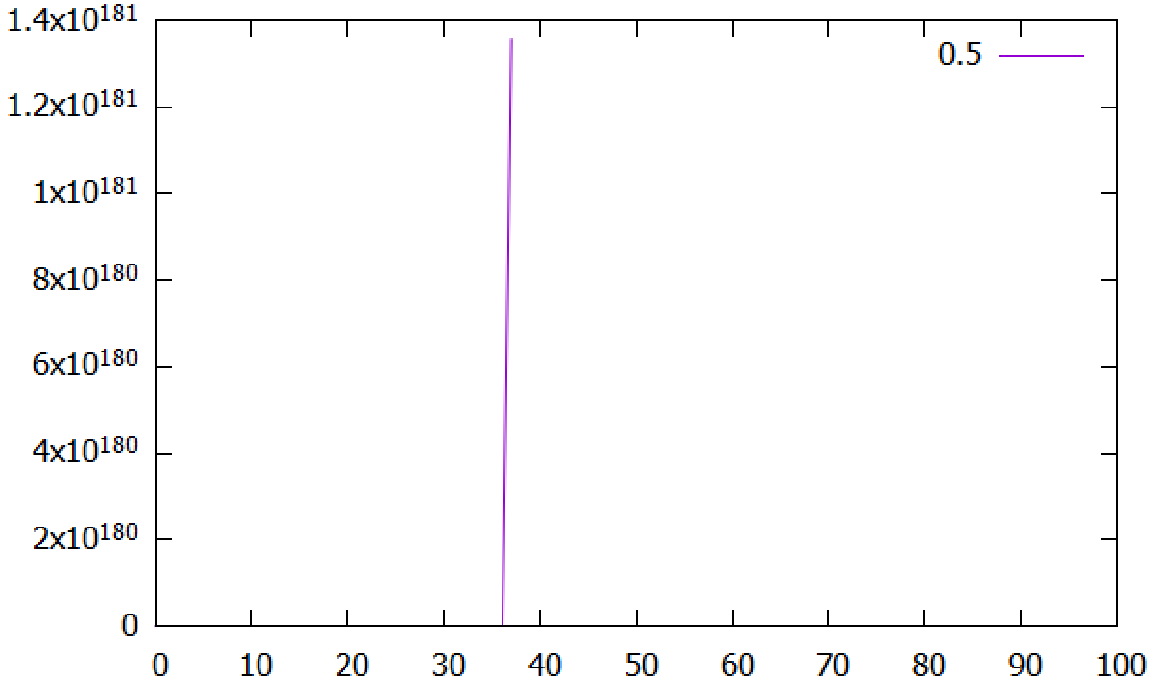


8.

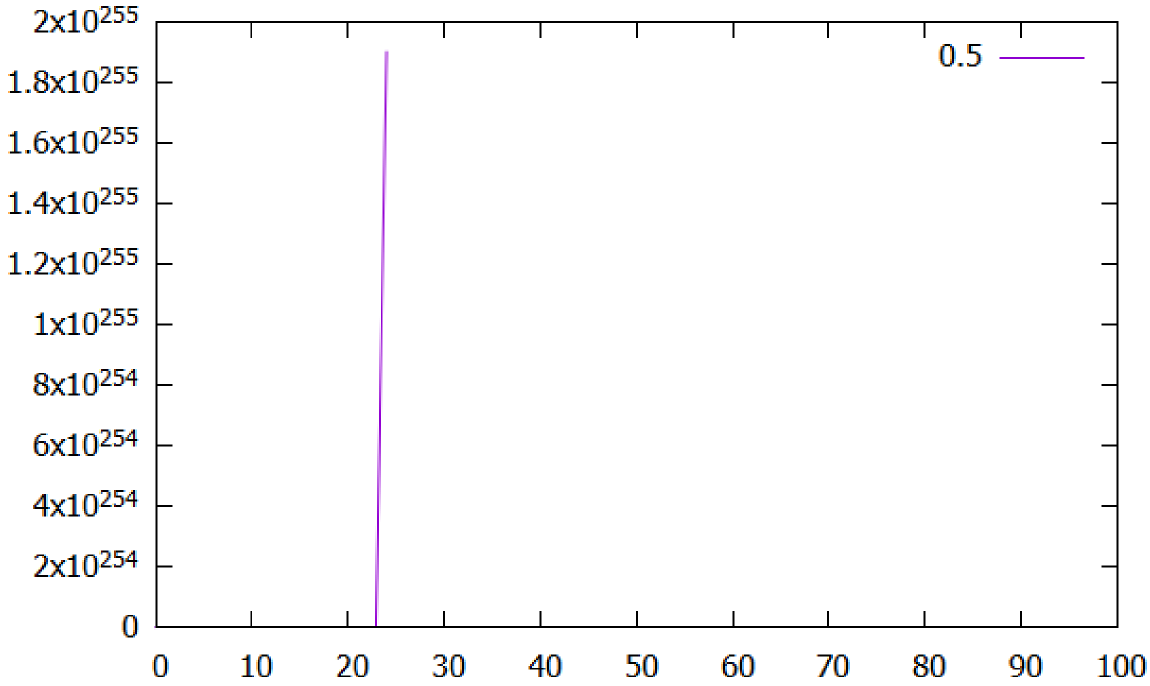
Graf srednje kvadratne pogreške ovisan o broju epoha:

- Za eta = 0.5:

Gradijentni:

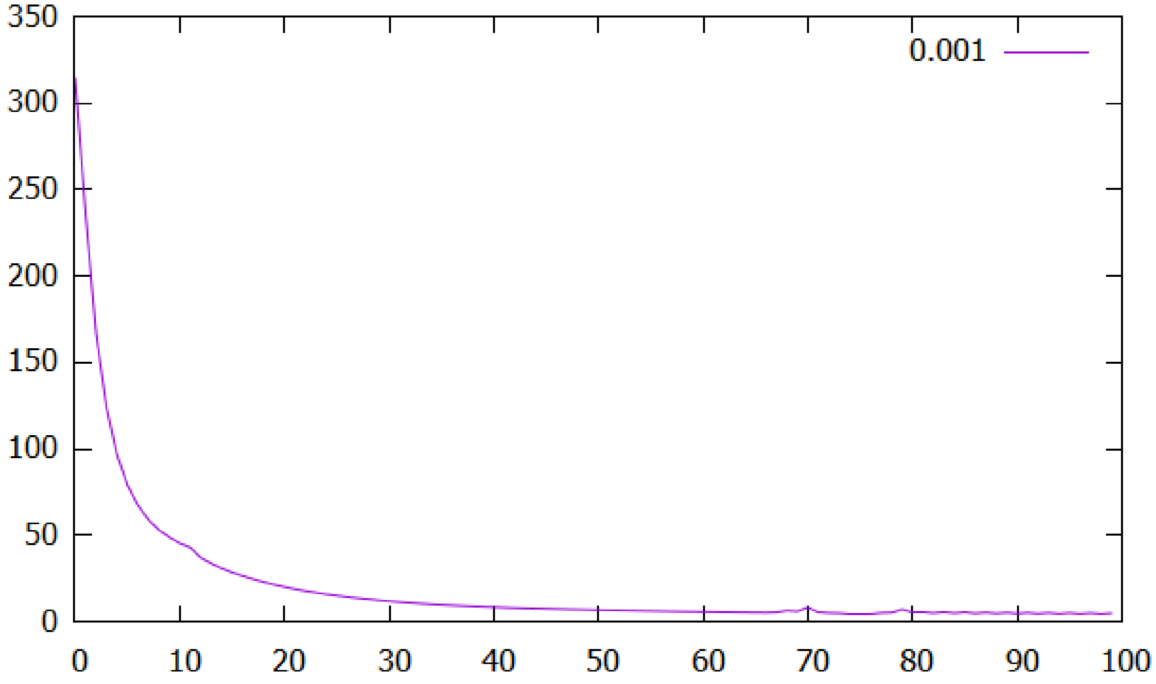


Stohastički:

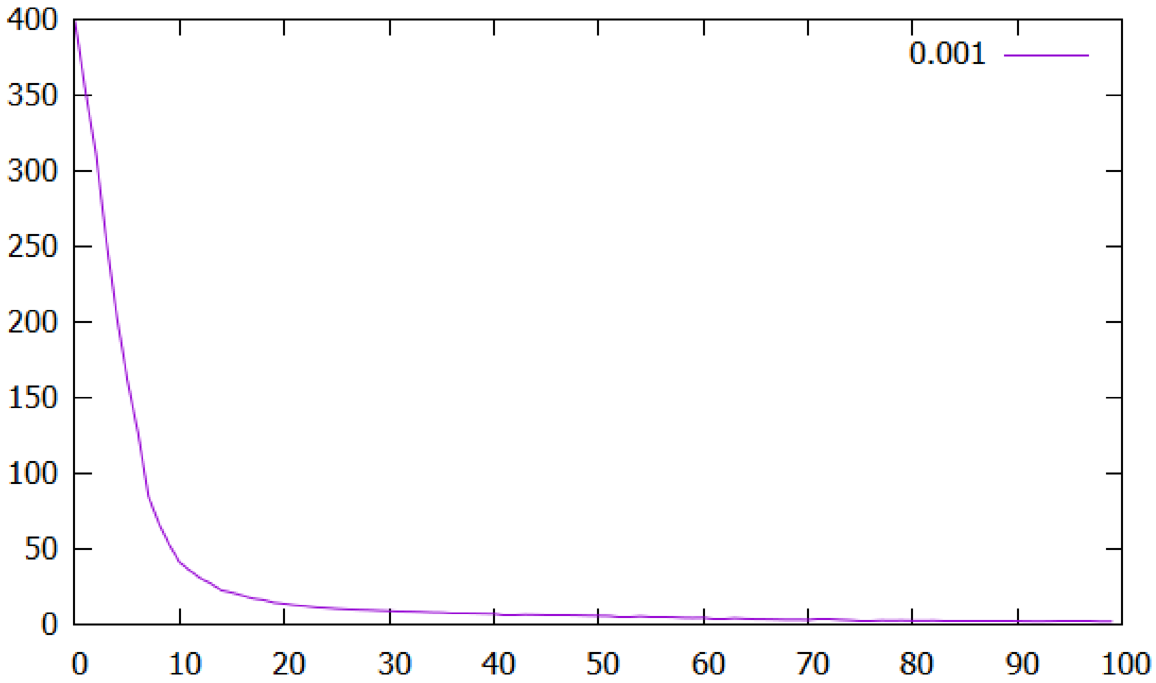


- Za eta je 0.001:

Gradijentni:

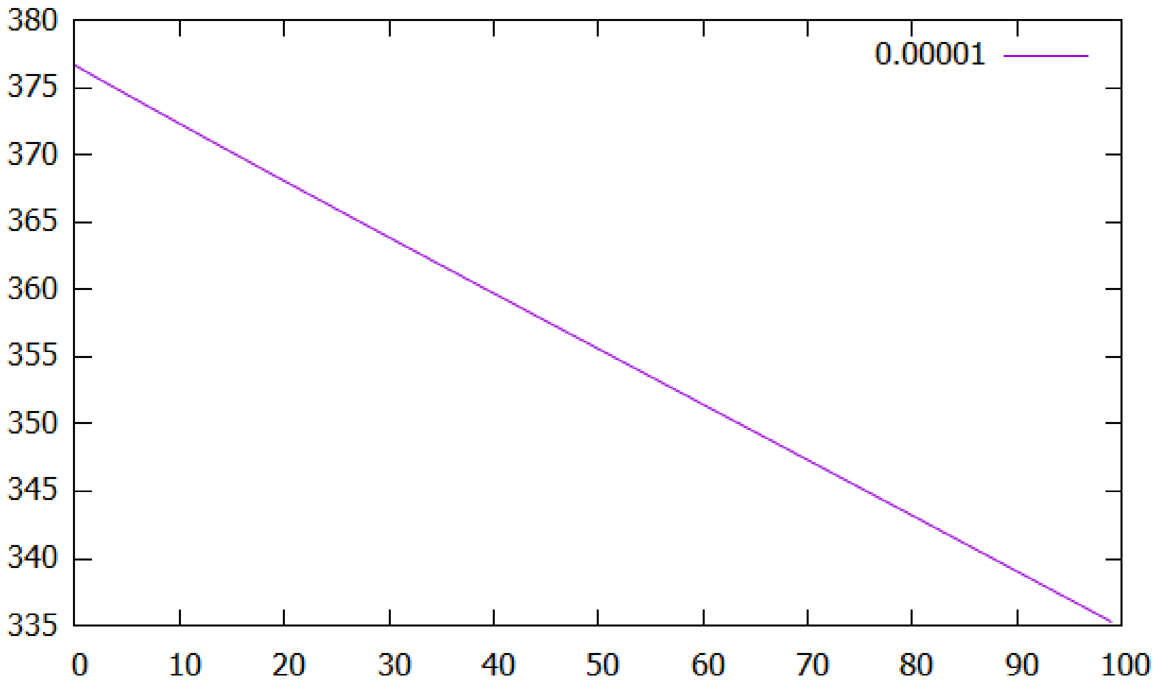


Stohastički:



- Za eta je 0.00001:

Gradijentni:



Stohastički: