Fakultet elektrotehnike i računarstva
Zavod za primjenjeno računarstvo

Neizrazito, evolucijsko i neuroračunarstvo

4. laboratorijska vježba

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Funkcija pogreške za k-ti uzorak $E_k = \frac{1}{2}(Y_k - O_k)^2$

Izlaz sustava je $o_k = \dfrac{\sum_{i=1}^{m} \pi_i z_i}{\sum_{i=1}^{m} \pi_i}$

gdje je $\pi_i = \alpha_i \beta_i$

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

$$\beta_i = \frac{1}{1+e^{d_i(x-c_i)}}$$

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

Ažuriranje proizvoljnog parametra ψ: $\psi(t+1) = \psi(t) - \eta \dfrac{\partial E_k}{\partial \psi}$

Odredimo ažuriranja za parametre $a_i, b_i, c_i, d_i, p_i, q_i, r_i$

$$\frac{\partial E_k}{\partial a_i} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial \pi_i} \cdot \frac{\partial \pi_i}{\partial \alpha_i} \cdot \frac{\partial \alpha_i}{\partial a_i}$$

$$= -(Y_k - O_k) \cdot \frac{z_i \sum_{j=1}^{m} \pi_j - \sum_{j=1}^{m} \pi_j z_j}{\left(\sum_{j=1}^{m} \pi_j\right)^2} \cdot \beta_i \cdot \alpha_i (1-\alpha_i) b_i$$

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

$$= -(Y_k - O_k) \cdot \frac{z_i \sum_{j=1}^{m} \pi_j - \sum_{j=1}^{m} \pi_j z_j}{\left(\sum_{j=1}^{m} \pi_j\right)^2} \cdot \beta_i \cdot \alpha_i (1-\alpha_i)(a_i - x)$$

$$\frac{\partial E_k}{\partial c_i} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial \pi_i} \cdot \frac{\partial \pi_i}{\partial B_i} \cdot \frac{\partial B_i}{\partial c_i}$$

$$= -(y_k - o_k) \cdot \frac{z_i \sum_{j=1}^{m} \pi_j - \sum_{j=1}^{m} \pi_j z_j}{\left(\sum_{j=1}^{m} \pi_j\right)^2} \cdot L_i \cdot B_i (1 - B_i)\, d_i$$

$$\frac{\partial E_k}{\partial d_i} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial \pi_i} \cdot \frac{\partial \pi_i}{\partial B_i} \cdot \frac{\partial B_i}{\partial d_i}$$

$$= -(y_k - o_k) \cdot \frac{z_i \sum_{j=1}^{m} \pi_j - \sum_{j=1}^{m} \pi_j \cdot z_j}{\left(\sum_{j=1}^{m} \pi_j\right)^2} \cdot L_i \cdot B_i (1 - B_i)(c_i - y)$$

$$\frac{\partial E_k}{\partial p_i} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial z_i} \cdot \frac{\partial z_i}{\partial p_i}$$

$$= -(y_k - o_k) \cdot \frac{\pi_i}{\sum_{j=1}^{m} \pi_j} \cdot x$$

$$\frac{\partial E_k}{\partial q_i} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial z_i} \cdot \frac{\partial z_i}{\partial q_i}$$

$$= -(y_k - o_k) \cdot \frac{\pi_i}{\sum_{j=1}^{m} \pi_j} \cdot y$$

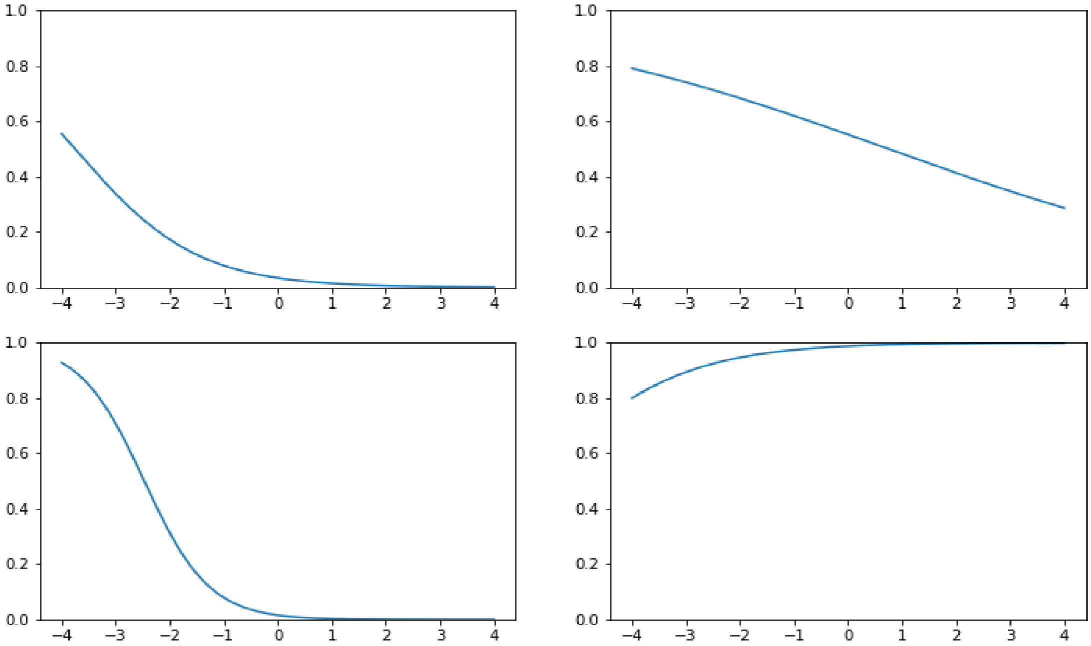
$$\frac{\partial E_k}{\partial r_i} = \frac{\partial E_k}{\partial o_k} \cdot \frac{\partial o_k}{\partial z_i} \cdot \frac{\partial z_i}{\partial r_i}$$

$$= -(y_k - o_k) \cdot \frac{\pi_i}{\sum_{j=1}^{m} \pi_j}$$

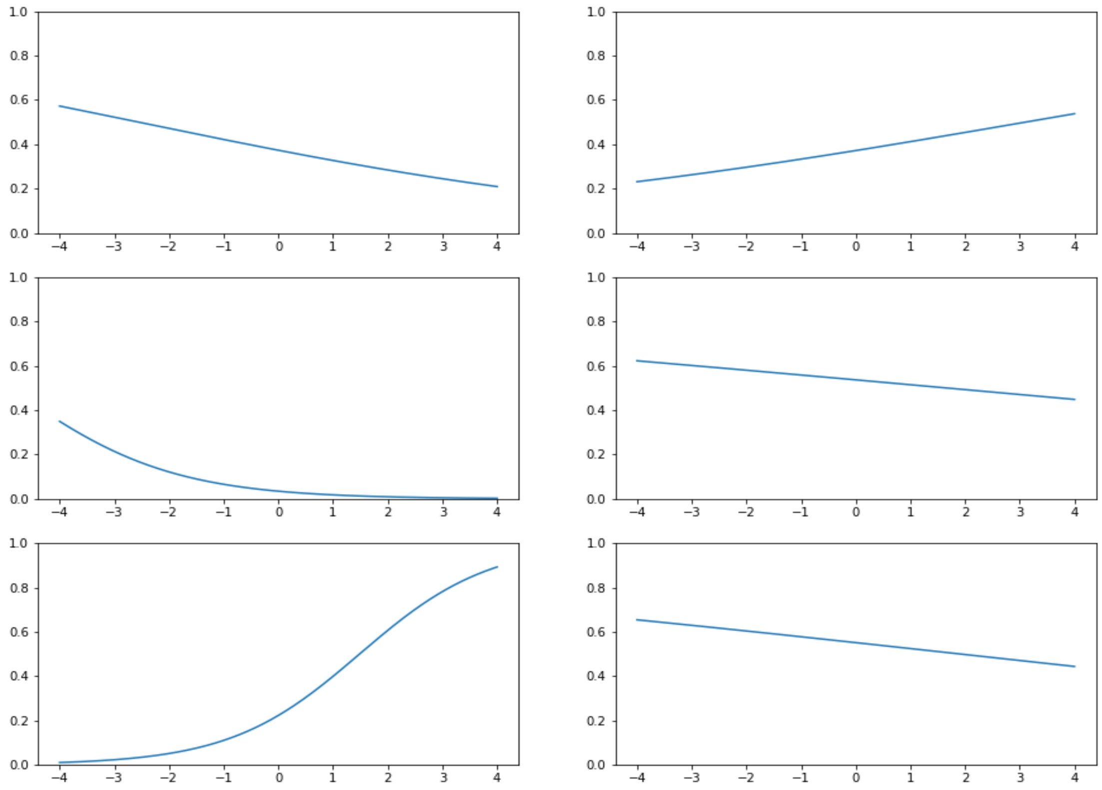
NAPOMENA:

Za gradijentni spust tj. za pravi gradijent ažuriranje radimo sa sumom parcijalnih derivacija za svaki ulazni primjer tj. uzorak što znači da sumiramo prethodne izraze po $\sum_{k=1}^{n}$ pri čemu je n broj uzoraka.

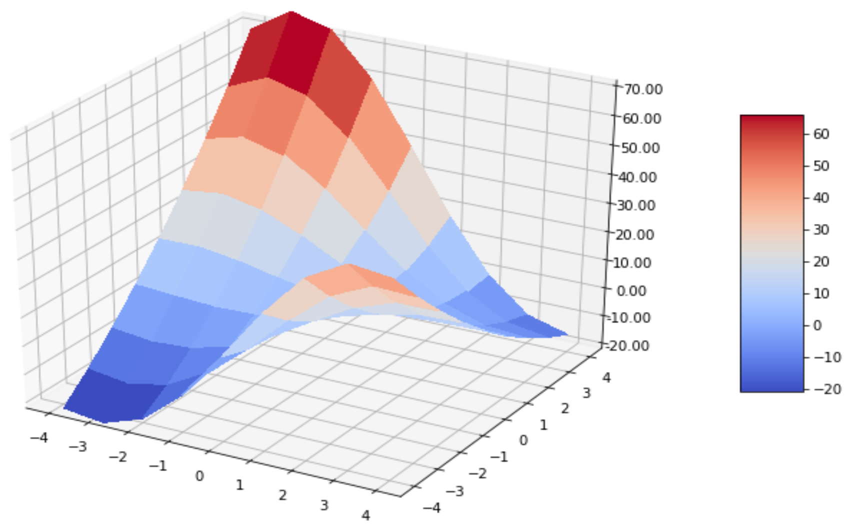
Naučene prijenosne funkcije za dva pravila, prvi stupac je za varijablu *x*, a drugi za varijablu *y.*



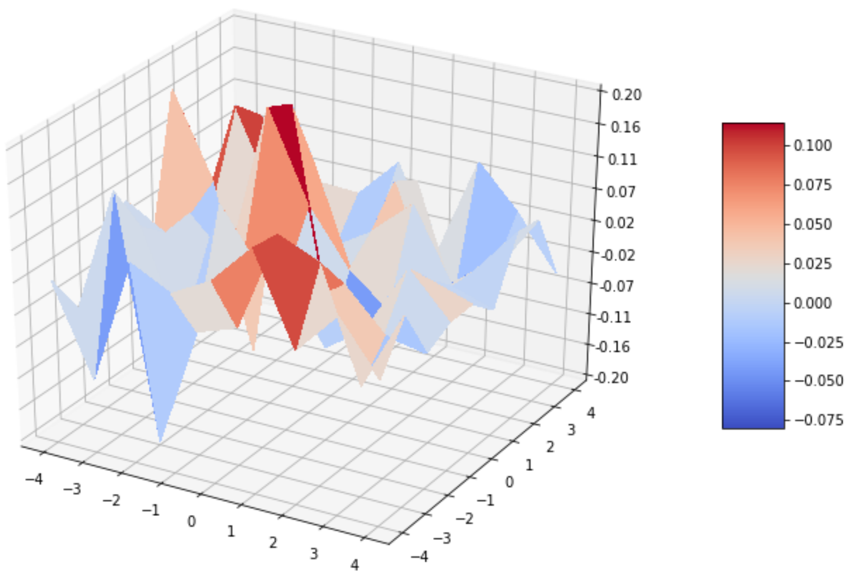
Naučene prijenosne funkcije za tri pravila, prvi stupac je za varijablu x, a drugi za varijablu y.



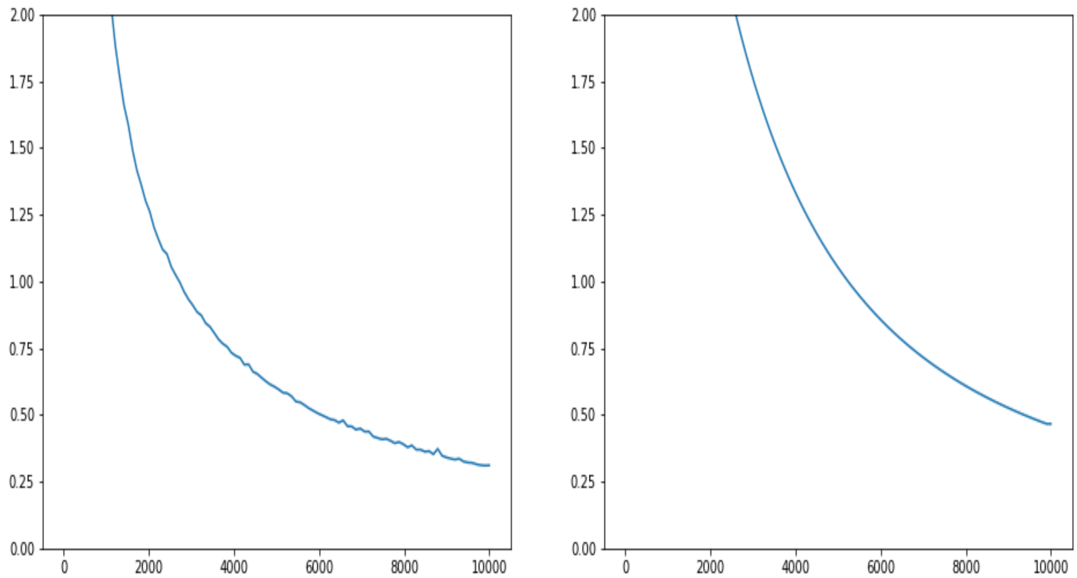
Prikaz svih uzoraka kojima pomoću kojih smo aproksimirali funkciju.



Prikaz razlika tj. grešaka za svaki uzorak.



Prikaz kretanja pogreške kroz deset tisuća epoha uzorkovano sa sto točaka. Prvi graf prikazuje greške kroz epohe za online-verziju algoritma, a drugi za potpuni gradijent. Mogu se uočiti na prvom grafu nestabilnost greške tj. alterniranje.



Prikaz kretanja greške kroz prvih 100 epoha. Prvi graf prikazuje online verziju algoritma, a drugi verziju s potpunim gradijentom. Za slučaj velike stope učenja algoritam divergira, na optimalnu konvergira, dok za jako malu stopu učenja konvergira, ali jako sporo.