

RAZVOJ REKURENTNE NEURONSKE MREŽE I PRIMENA NA ANALIZI VREMENSKIH SERIJA

SEMINARSKI RAD U OKVIRU KURSA
RAČUNARSKA INTELIGENCIJA

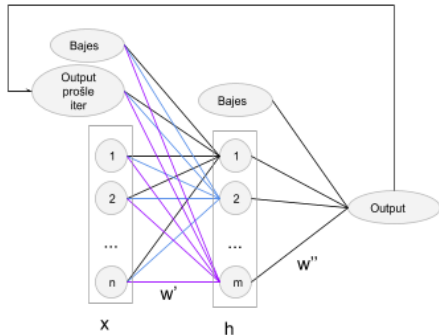
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MATEMATIČKI FAKULTET

20.6.2020.

- Tradicionalna neuronska mreža
 - ▶ ulazi i izlazi nezavisni jedni od drugih
- Rekurentna neuronska mreža
 - ▶ svojstvo pamćenja naučenog znanja iz prethodnih trening instanci
 - ▶ omogućava predikciju u oblasti vremenskih serija
- Jordanova rekurentna neuronska mreža (eng. *Jordan SRNN*)
 - ▶ kopija izlaznog sloja se sprovodi na ulaz

JORDAN SRNN



Legenda:

x - skup ulaznih čvorova

h - skup čvorova skrivenog sloja

Output - količina padavina za 7. dan

Output prošle iter - kopija izlaznog sloja

w' - težine veza ka skrivenom sloju

w'' - težine veza ka izlaznom sloju

Bajes - uvek jednak 1

Figure: Jordanova SRNN sa jednim skrivenim slojem

- **Aktivaciona funkcija** skrivenog i izlaznog sloja:

$$f(x) = (1 + e^{-x})^{-1}$$

- Greška izlaznog sloja neurona k:

$$E_k = \frac{1}{2}(y_k - o_k)^2$$

- Pri ažuriranju vrednosti w''_{jk} , važi $w''_{jk} = w''_{jk} + \Delta w''_{jk}$, gde je

$$\Delta w''_{jk} = -\eta \frac{\partial E_k}{\partial w''_{jk}} + \alpha \Delta w''_{jk}.$$

η uticaj parcijalnog izvoda greške E_k po w''_{jk}

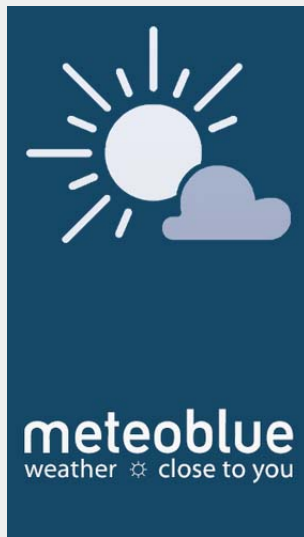
α uticaj prethodne vrednosti $\Delta w''_{jk}$

1. Ulazni podaci $(x_1^{(l)}, x_2^{(l)}, \dots, x_{n+p}^{(l)})$ i (y_1, y_2, \dots, y_p) ,
 $x_0^{(l)} = 1, \forall l$ iz skupa podataka
2. Init η, α i kriterijum zaustavljanja.
Init w'_{ij} i w''_{jk} i $\Delta w'_{ij} = \Delta w''_{jk} = 0$
3. Novi par ulaznog i izlaznog vektora
4. Odrediti u'_j i h_j . Postaviti $h_0^{(l)} = 1, \forall l$ iz skupa podataka.
5. Odrediti u''_k i o_k . Ukoliko je ispunjen kriterijum zaustavljanja, prekinuti izvršavanje.
6. Odrediti $\Delta w''_{jk}$ i ažurirati vrednosti w''_{jk} .
7. Odrediti $\Delta w'_{ij}$ i ažurirati vrednosti w'_{ij} .
8. Preći na korak 3.

IMPLEMENTACIJA ALGORITMA

- numpy – zeros, array, append, concatenate, multiply, vstack, matrix, around, random
- pandas – DataFrame, Series, read_csv, errors, concat
- sklearn
 - ▶ metrics – mean_absolute_error, mean_squared_error
 - ▶ model_selection – train_test_split
 - ▶ preprocessing – MinMaxScaler
- matplotlib – pyplot

- **Meteo blue**
- Basel, Švajcarska
- 31.12.1990. do 31.12.2019, 11326 uzastopnih dana
- Atributi:
 - ▶ tempMin
 - ▶ tempMax
 - ▶ tempMean
 - ▶ rHumidMean
 - ▶ cloudCoverage
 - ▶ evapor
 - ▶ windSpeedMean
 - ▶ soilTempMean
 - ▶ soilMoistMean
 - ▶ precipitation – ciljni atribut



- `test : train = 3 : 7` → test – 3398 redova, train – 7928 redova
- `sklearn.model_selection - test_train_split`
- `sklearn.preprocessing.MinMaxScaler - [0.1, 0.9]`
- `precipitation : [0, 100] → [0.1, 0.9]`

TRENIRANJE MREŽE

- Aktivaciona funkcija: sigmoidna funkcija
- Broj dana za predikciju: N
- Broj ulaznih čvorova i bias: $n = N * n_attrs + 1$
- Patern: 6 dana + output
- Broj paterna: $\text{len}(x_train) - N$
- Broj atributa za jedan dan: n_attrs
- Broj čvorova skrivenog sloja i bias:
 $m = (\text{int})((N * n_attrs) * 4) + 1$
- $\text{eta} = 0.3$; $\text{alpha} = 0.2$

1	2	3	4	5	6	→	7
2	3	4	5	6	7	→	8
...							
7923	7924	7925	7926	7927	7928	→	7929

- Svaka ćelija je skup atributa za jedan dan
- Jedan patern `input_nodes` predstavlja 6 dana zaredom
`concatenate((bias,`
`(x_train[day:(day+N)]).reshape(-1),`
`output_arr))`

IZRAČUNAVANJE h_1, \dots, h_m ČVOROVA SKRIVENOG SLOJA

```
# Naivan pristup
```

```
h[0] = 1.0
```

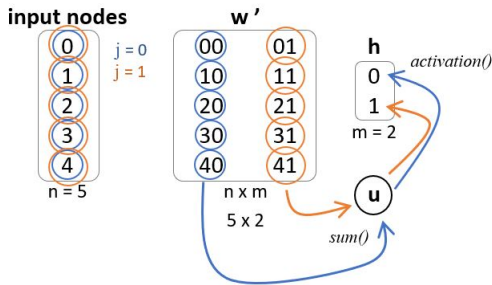
```
for j in range(1, m+1):
```

```
    u = 0
```

```
    for i in range(0, n+1):
```

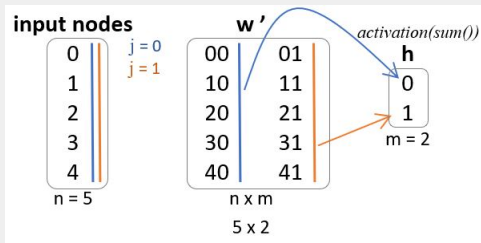
```
        u += input_nodes[i] * w_[i][j]
```

```
    h[j] = activation_f(u)
```



IZRAČUNAVANJE h_1, \dots, h_m ČVOROVA SKRIVENOG SLOJA

```
# Poboľjsan pristup
u = []
for i in w_.T:
    u += [activation_f(
        sum(multiply(i, input_nodes))
    )]
h = array(u)
h[0] = 1 # bias ostaje nepromenjen
```



IZRAČUNAVANJE O_1, \dots, O_P

```
# Naivna implementacija
for k in range(1, p+1):
    u = 0
    for j in range(0, m+1):
        u += h[j] * w__[j][k]
    o[day] = activation_f(u)
```

```
# Poboľjsana implementacija
o[day] = activation_f(sum(multiply(h, w__)))
output_arr = array([o[day]])
```

Račun koji se može izdvojiti:

```
error = (y_train[day+N] - o[day]) * o[day] *  
(1.0 - o[day])
```

Nadalje se samo koristi kao konstantna vrednost u izrazima.

IZRAČUNAVANJE DELTAH(j)

Prednosti operacija sa vektorima:

```
# Naivna implementacija
for j in range(1, m+1):
    dh[j] = 0.0
    for k in range(1, p+1):
        dh[j] += w__[j][k] * error

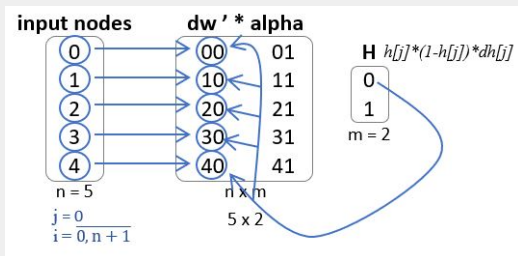
# Poboľjsana implementacija
dh = w__ * error
```

AŽURIRANJE $W'(ij)$ I $\Delta W'(ij)$

```
# Bukvalna interpretacija
for j in range(1,m+1):
    for i in range(0,n+1):
        dw_[i][j] = eta * input_nodes[i] * h[j]
                    * (1 - h[j]) * dh[j]
                    + alpha * dw_[i][j]
        w_[i][j] += dw_[i][j]
```

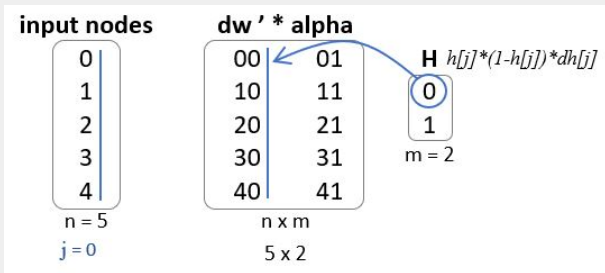
AŽURIRANJE $W'(ij)$ I $\Delta W'(ij)$

```
# Naivna implementacija
for j in range(1, m+1):
    H = h[j] * (1 - h[j]) * dh[j]
    for i in range(0, n+1):
        dw_[i][j] = eta * input_nodes[i] * H
                    + alpha * dw_[i][j]
        w_[i][j] += dw_[i][j]
```



AŽURIRANJE $W'(ij)$ I $\Delta W'(ij)$

```
# Poboljšana implementacija
H = h * (1-h) * dh * eta
dw_ *= alpha
for j in range(0, m):
    dw_.T[j] += (input_nodes * H[j])
w_ += dw_
```



AŽURIRANJE $W''(JK)$ I $\Delta W''(JK)$

```
# Naivna implementacija
for k in range(1, p):
    for j in range(0, m):
        dw__[j][k] = eta * h[j] * error
                    + alpha * dw__[j][k]
        w__[j][k] += dw__[j][k]
```

```
# Poboljsana implementacija
dw__ *= alpha
dw__ += (eta * h * error)
w__ += dw__
```

- Kroz epohe se beleži najbolji model.
- Moguće je učitati neki od postojećih modela kako bi se uštedelo na vremenu.
- Testiranje se sastoji od primene istih operacija korišćenjem postojećih težinskih matrica nad skupom za test.

PRIMERI REZULTATA

Na narednim slajdovima prikazaćemo izlazne vrednosti programa kao i grafike koje smo dobili po epohama za različite vrednosti parametara.

Grafici su radi bolje vidljivosti pravljeni za poslednjih 365 dana svoje epohe.

MODEL n = 54, m = 270, alpha = 0.5, eta = 0.3

broj dana za predikciju= 6; broj ulaznih cvorova= 54; broj cvorova skriveni sloj= 270
alpha = 0.5 eta = 0.3

epoch: 0/20	mse: 0.00230558769024192	mae: 0.030745924289642186	rmse: 0.048016535591834615
epoch: 1/20	mse: 0.0020691819015563008	mae: 0.02903043113699024	rmse: 0.04548826114017001
epoch: 2/20	mse: 0.001938548994169053	mae: 0.027713894391377336	rmse: 0.04402895631478281
epoch: 3/20	mse: 0.0018782308177129618	mae: 0.02718125800641104	rmse: 0.04333856040194416
epoch: 4/20	mse: 0.0018541484309476885	mae: 0.02706152932361909	rmse: 0.04305982386108527
epoch: 5/20	mse: 0.0018472157254949184	mae: 0.02711965092474976	rmse: 0.04297924761434195
epoch: 6/20	mse: 0.001847096882086492	mae: 0.027240328981882785	rmse: 0.04297786502476004
epoch: 7/20	mse: 0.0018484149606793445	mae: 0.02736813761528103	rmse: 0.04299319667900195
epoch: 8/20	mse: 0.001848603137872986	mae: 0.027468230387172166	rmse: 0.04299538507645891
epoch: 9/20	mse: 0.0018466459437720528	mae: 0.027535487234559175	rmse: 0.04297261853520277
epoch: 10/20	mse: 0.0018423689617472	mae: 0.027561658799244805	rmse: 0.04292282564961445
epoch: 11/20	mse: 0.0018360429200479063	mae: 0.027550815717757516	rmse: 0.042849071402399214
epoch: 12/20	mse: 0.0018281416207006791	mae: 0.027509304146725484	rmse: 0.0427567728050268
epoch: 13/20	mse: 0.0018191847531010947	mae: 0.02745052855455493	rmse: 0.042651902104139446
epoch: 14/20	mse: 0.0018096434011468487	mae: 0.02737767645017048	rmse: 0.04253990363349274
epoch: 15/20	mse: 0.0017998957765097856	mae: 0.0272990199920374	rmse: 0.042425178567800814
epoch: 16/20	mse: 0.0017902188217654774	mae: 0.027220601868053973	rmse: 0.04231097755624984
epoch: 17/20	mse: 0.0017808003071023023	mae: 0.027141672344482493	rmse: 0.042199529702382964
epoch: 18/20	mse: 0.0017717585383886071	mae: 0.02706356552362999	rmse: 0.042092262215146
epoch: 19/20	mse: 0.0017631615172861157	mae: 0.02698921856530739	rmse: 0.041990016876468576
epoch: 20/20	mse: 0.001755042129148845	mae: 0.026918010213622875	rmse: 0.041893222950124584

Cuvanje modela: model10_34_23.txt

Uspesno cuvanje modela...

Da li zelite da ucitate neki od postojećih modela? Inace ce se raditi sa trenutnim. (Y/N)

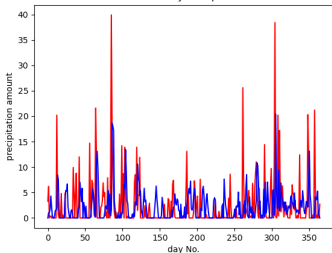
n

MSE - test: 0.007809762722696304

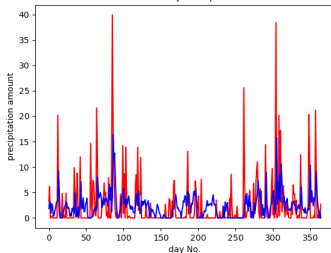
MAE - test: 0.06803416142550417

MODEL $n = 54$, $m = 270$, $\alpha = 0.5$, $\eta = 0.3$

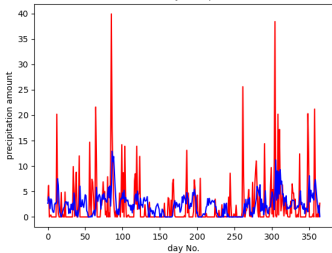
Last 365 days of Epoch: 1



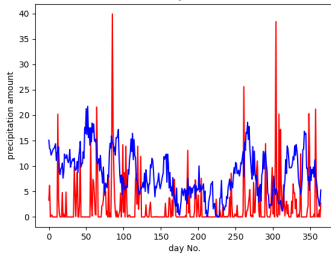
Last 365 days of Epoch: 10



Last 365 days of Epoch: 20



Last 365 days of test data



MODEL n = 54, m = 270, alpha = 0.2, eta = 0.3

broj dana za predikciju= 6; broj ulaznih cvorova= 54; broj cvorova skriveni sloj= 270
alpha = 0.2 eta = 0.3

epoch: 0/20	mse: 0.0020269406544871807	mae: 0.028004053018290072	rmse: 0.045021557663936736
epoch: 1/20	mse: 0.001890504081243114	mae: 0.026942564149147627	rmse: 0.04347992733714161
epoch: 2/20	mse: 0.0018196302392409823	mae: 0.026221842554555657	rmse: 0.04265712413232967
epoch: 3/20	mse: 0.0017822232490548485	mae: 0.025900933803923828	rmse: 0.04221638602550967
epoch: 4/20	mse: 0.0017627793303375927	mae: 0.025788196477321963	rmse: 0.041985465703474015
epoch: 5/20	mse: 0.0017530898416978208	mae: 0.025774947636076753	rmse: 0.04186991571161591
epoch: 6/20	mse: 0.0017484690989736473	mae: 0.025805534939315693	rmse: 0.041814699556180564
epoch: 7/20	mse: 0.0017462094607348239	mae: 0.0258565543824413	rmse: 0.041787671157110726
epoch: 8/20	mse: 0.0017447740486098808	mae: 0.02591221237660181	rmse: 0.04177049255886122
epoch: 9/20	mse: 0.0017433371103788757	mae: 0.02596884453143699	rmse: 0.04175328861753138
epoch: 10/20	mse: 0.0017415055255598313	mae: 0.02601497775557538	rmse: 0.041731349433727055
epoch: 11/20	mse: 0.0017391416649945803	mae: 0.02604763713138203	rmse: 0.041703017456709054
epoch: 12/20	mse: 0.001736249819904523	mae: 0.02606718475596866	rmse: 0.04166833113894199
epoch: 13/20	mse: 0.0017329051905294111	mae: 0.02607708128901555	rmse: 0.04162817784301171
epoch: 14/20	mse: 0.0017292112152060485	mae: 0.02608050394965929	rmse: 0.041583785484321276
epoch: 15/20	mse: 0.0017252751760931007	mae: 0.026076631202983366	rmse: 0.041536431913358915
epoch: 16/20	mse: 0.0017211952721594226	mae: 0.026067270878615822	rmse: 0.041487290489491145
epoch: 17/20	mse: 0.001717054744560637	mae: 0.026055096018513333	rmse: 0.041437359285560624
epoch: 18/20	mse: 0.0017129202224039387	mae: 0.026042036435217755	rmse: 0.04138744039444743
epoch: 19/20	mse: 0.0017088424555715819	mae: 0.026028215969460994	rmse: 0.041338147703683846
epoch: 20/20	mse: 0.0017048582457663906	mae: 0.026013956321552966	rmse: 0.04128992910827519

Cuvanje modela: model11_20_22.txt

Uspesno cuvanje modela...

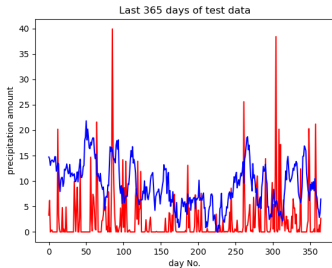
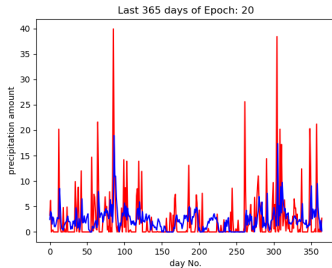
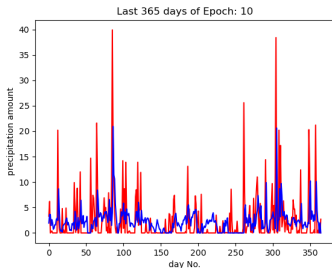
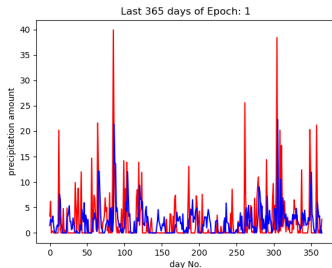
Da li zelite da ucitate neki od postojećih modela? Inace ce se raditi sa trenutnim. (Y/N)

n

MSE - test: 0.008091158261669746

MAE - test: 0.07069133506849452

MODEL $n = 54$, $m = 270$, $\alpha = 0.2$, $\eta = 0.3$



MODEL n = 54, m = 108, alpha = 0.2, eta = 0.3

broj dana za predikciju= 6; broj ulaznih cvorova= 54; broj cvorova skriveni sloj= 108

alpha = 0.2 eta = 0.3

Ucitati model? (Y/N)

n

Zapoceto treniranje...

epoch: 0/20	mse: 0.0018333969136350868	mae: 0.026933730168636608	rmse: 0.0428181843804135
epoch: 1/20	mse: 0.0016754780687101315	mae: 0.025783809351965038	rmse: 0.04093260398154668
epoch: 2/20	mse: 0.0016590487256534369	mae: 0.02568695221407384	rmse: 0.040731421846695176
epoch: 3/20	mse: 0.0016544457597040723	mae: 0.025708908399360842	rmse: 0.04067487873004752
epoch: 4/20	mse: 0.0016543808344862826	mae: 0.02576578925655835	rmse: 0.040674080622508026
epoch: 5/20	mse: 0.001655983693567097	mae: 0.025823072251350093	rmse: 0.04069377954389463
epoch: 6/20	mse: 0.001657923819381214	mae: 0.02587356628509388	rmse: 0.040717610678688086
epoch: 7/20	mse: 0.001659587624372455	mae: 0.025915958927055307	rmse: 0.04073803657974271
epoch: 8/20	mse: 0.0016607316316972973	mae: 0.025948983750714708	rmse: 0.0407520751827106
epoch: 9/20	mse: 0.001661298631963185	mae: 0.025973995917623664	rmse: 0.04075903129323837
epoch: 10/20	mse: 0.0016613203279609002	mae: 0.025990148196568922	rmse: 0.04075929744194446
epoch: 11/20	mse: 0.0016608669737958744	mae: 0.02599940101815533	rmse: 0.04075373570356311
epoch: 12/20	mse: 0.0016600215298744568	mae: 0.026002650164185535	rmse: 0.04074336178906273
epoch: 13/20	mse: 0.0016588664753508535	mae: 0.026000842992122776	rmse: 0.040729184565258036
epoch: 14/20	mse: 0.001657477297276228	mae: 0.025995562091115195	rmse: 0.04071212716043738
epoch: 15/20	mse: 0.0016559196408595365	mae: 0.025987549434830667	rmse: 0.04069299252770109
epoch: 16/20	mse: 0.0016542485113777163	mae: 0.02597756267861766	rmse: 0.040672453963065916
epoch: 17/20	mse: 0.0016525086452444057	mae: 0.02596627872154472	rmse: 0.040651059583292605
epoch: 18/20	mse: 0.0016507354798691062	mae: 0.025954102295667428	rmse: 0.04062924414592408
epoch: 19/20	mse: 0.0016489563946454236	mae: 0.025941314477399502	rmse: 0.04060734409740957
epoch: 20/20	mse: 0.001647192008298528	mae: 0.02592846928388935	rmse: 0.040585613316771844

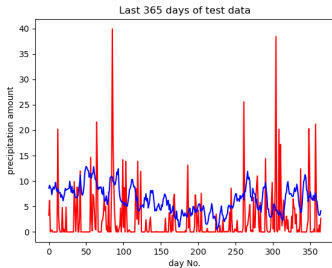
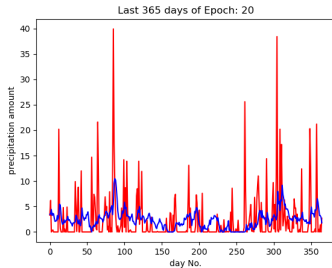
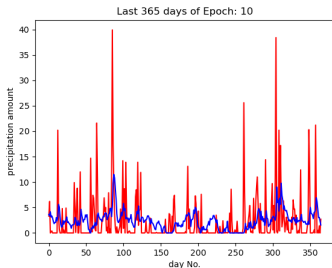
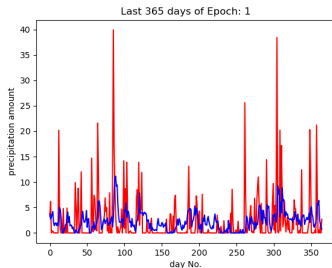
Cuvanje modela: model14_14_49.txt

Uspesno cuvanje modela...

MSE - test: 0.003506690181926135

MAE - test: 0.04771320812085592

MODEL $n = 54$, $m = 108$, $\alpha = 0.2$, $\eta = 0.3$



MODEL n = 54, m = 108, alpha = 0.9, eta = 0.5

broj dana za predikciju= 6; broj ulaznih cvorova= 54; broj cvorova skriveni sloj= 108

alpha = 0.9 eta = 0.5

Ucitati model? (Y/N)

n

Zapoceto treniranje...

epoch: 0/20	mse: 0.016278322555309498	mae: 0.12094758357319745	rmse: 0.1275865296781345
epoch: 1/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 2/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 3/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 4/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 5/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 6/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 7/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 8/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 9/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 10/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 11/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 12/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 13/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 14/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 15/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 16/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 17/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 18/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 19/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633
epoch: 20/20	mse: 0.01623426739833596	mae: 0.12088270642205709	rmse: 0.12741376455601633

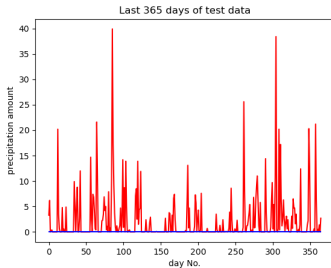
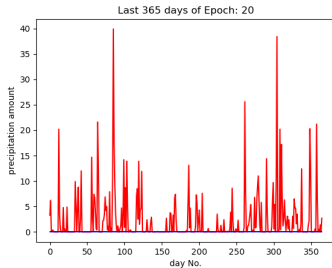
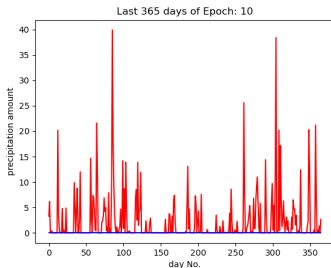
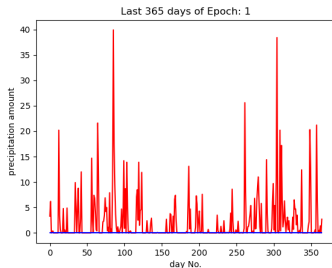
Cuvanje modela: model14_26_29.txt

Uspesno cuvanje modela...

MSE - test: 0.016415549855460915

MAE - test: 0.12109056609589977

MODEL $n = 54$, $m = 108$, $\alpha = 0.9$, $\eta = 0.5$



MODEL n = 54, m = 216, alpha = 0.2, eta = 0.3

broj dana za predikciju= 6; broj ulaznih cvorova= 54; broj cvorova skriveni sloj= 216

alpha = 0.2 eta = 0.3

Ucitati model? (Y/N)

n

Zapoceto treniranje...

epoch: 0/20	mse: 0.0021575027163934207	mae: 0.02652431359427752	rmse: 0.046448925890631966
epoch: 1/20	mse: 0.0017313560050236467	mae: 0.02581874779568006	rmse: 0.04160956626815097
epoch: 2/20	mse: 0.0016980976950275693	mae: 0.02556963193327894	rmse: 0.041207980962764595
epoch: 3/20	mse: 0.0016852775891562715	mae: 0.025536138780498437	rmse: 0.04105213257744683
epoch: 4/20	mse: 0.0016834115936480711	mae: 0.025610076577534314	rmse: 0.041029399138277314
epoch: 5/20	mse: 0.0016864911263050693	mae: 0.025723452596539614	rmse: 0.041066910357428515
epoch: 6/20	mse: 0.0016908278668649722	mae: 0.025836977136316	rmse: 0.04111967736820137
epoch: 7/20	mse: 0.0016944480036495896	mae: 0.02593223751307915	rmse: 0.04116367334980674
epoch: 8/20	mse: 0.0016965760280770999	mae: 0.026000441221906062	rmse: 0.041189513569318825
epoch: 9/20	mse: 0.0016971200202701494	mae: 0.026043706717404472	rmse: 0.041196116567828935
epoch: 10/20	mse: 0.0016963014217072916	mae: 0.026067881692874308	rmse: 0.04118617998439879
epoch: 11/20	mse: 0.0016944406496029875	mae: 0.026076416048813448	rmse: 0.04116358402281059
epoch: 12/20	mse: 0.001691851396522331	mae: 0.026073081517814237	rmse: 0.041132121225659284
epoch: 13/20	mse: 0.0016887977037938406	mae: 0.02606213812282413	rmse: 0.04109498392497363
epoch: 14/20	mse: 0.0016854834230127954	mae: 0.026046374292068134	rmse: 0.04105463948219245
epoch: 15/20	mse: 0.001682056578389527	mae: 0.026028069265398295	rmse: 0.04101288307824173
epoch: 16/20	mse: 0.0016786192645684816	mae: 0.026008373142093383	rmse: 0.04097095635408675
epoch: 17/20	mse: 0.0016752384087034553	mae: 0.02598816921477992	rmse: 0.04092967638161161
epoch: 18/20	mse: 0.0016719553351191461	mae: 0.025967897216678644	rmse: 0.040889550439191014
epoch: 19/20	mse: 0.0016687934545317527	mae: 0.025948199550662257	rmse: 0.040850868467289074
epoch: 20/20	mse: 0.0016657640735455374	mae: 0.025929346769125082	rmse: 0.04081377308636801

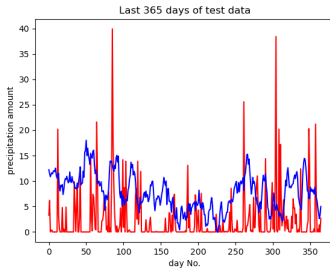
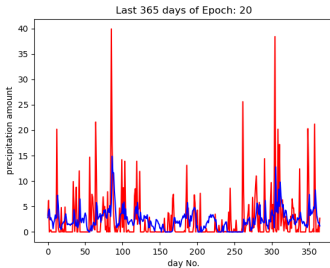
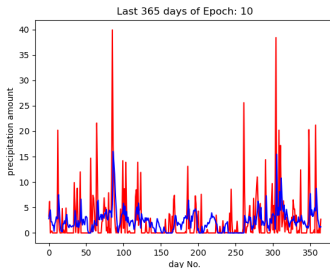
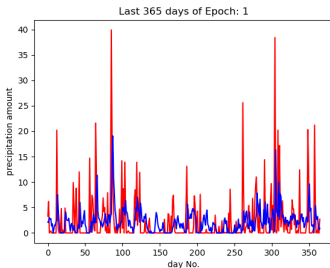
Cuvanje modela: model14_34_23.txt

Uspesno cuvanje modela...

MSE - test: 0.005802880771351822






MAE - test: 0.06029731664924966

MODEL $n = 54$, $m = 216$, $\alpha = 0.2$, $\eta = 0.3$



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