Invatare Automata
Tema - Etapa 1

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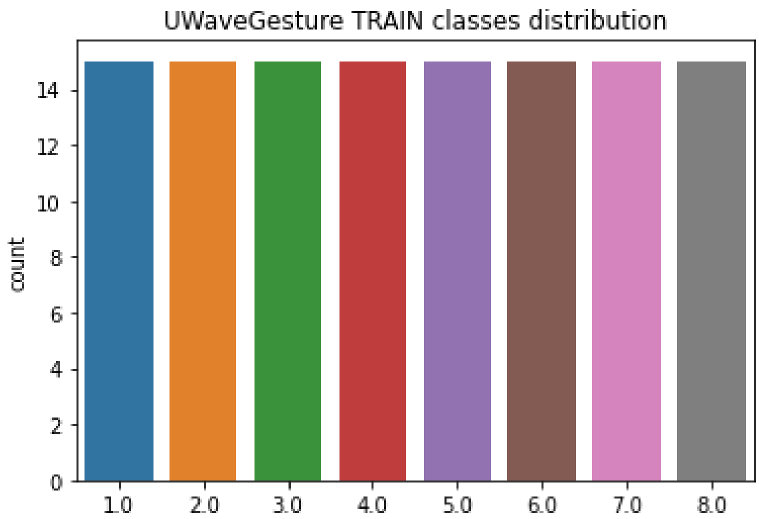
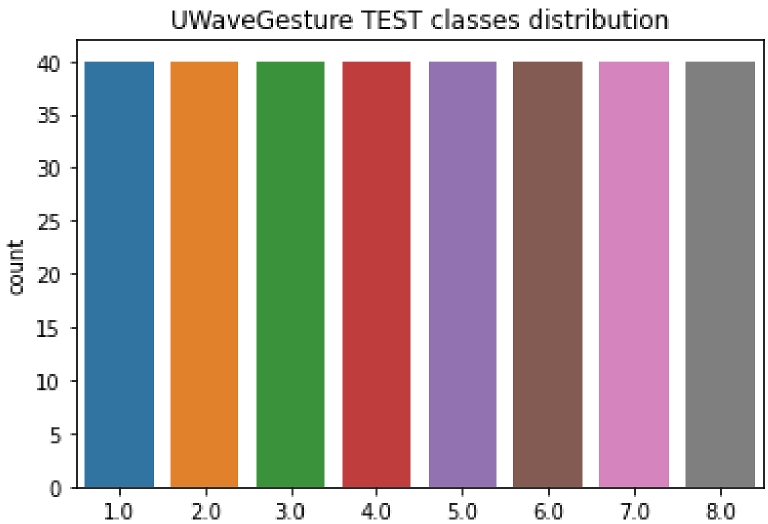
Codul sursa al acestei lucrari poate fi gasit in Google Colab la acest link.

Cerinta 1. Exploratory Data Analysis

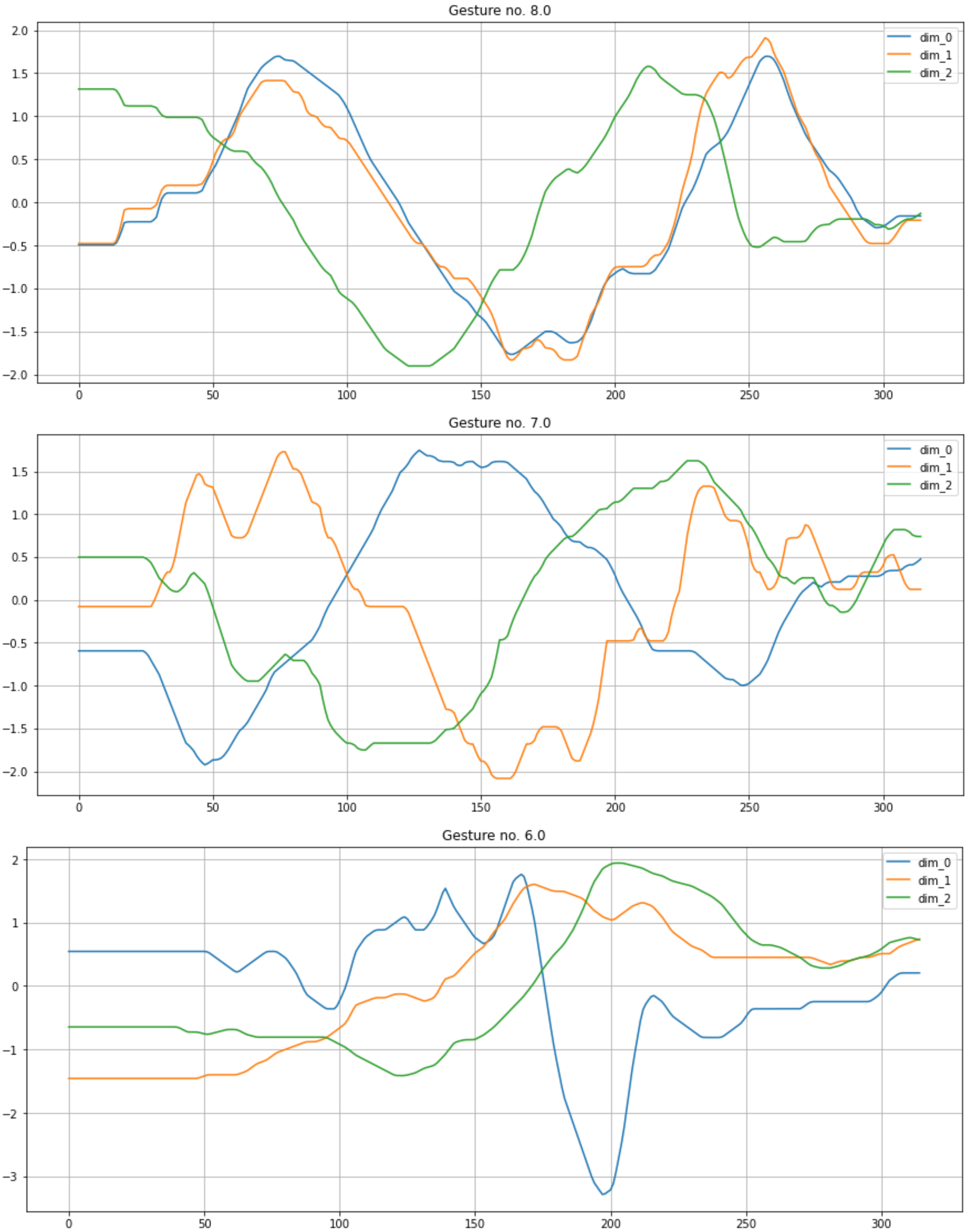
Frecventa de aparitie a claselor in setul de date pentru UWaveGesture



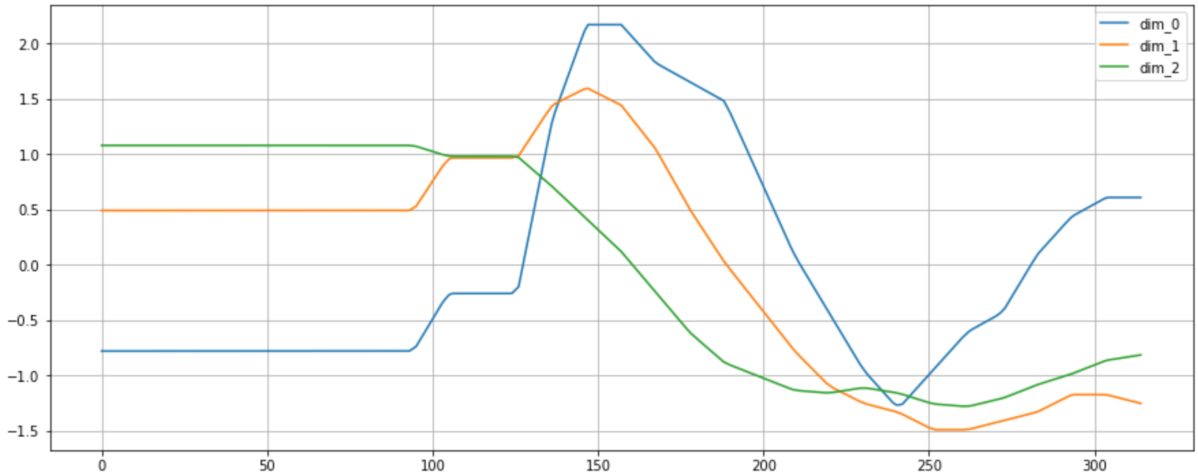


Observam ca setul de date UWaveGesture contine un numar egal de clase atat in setul de antrenare, cat si in cel de testare.

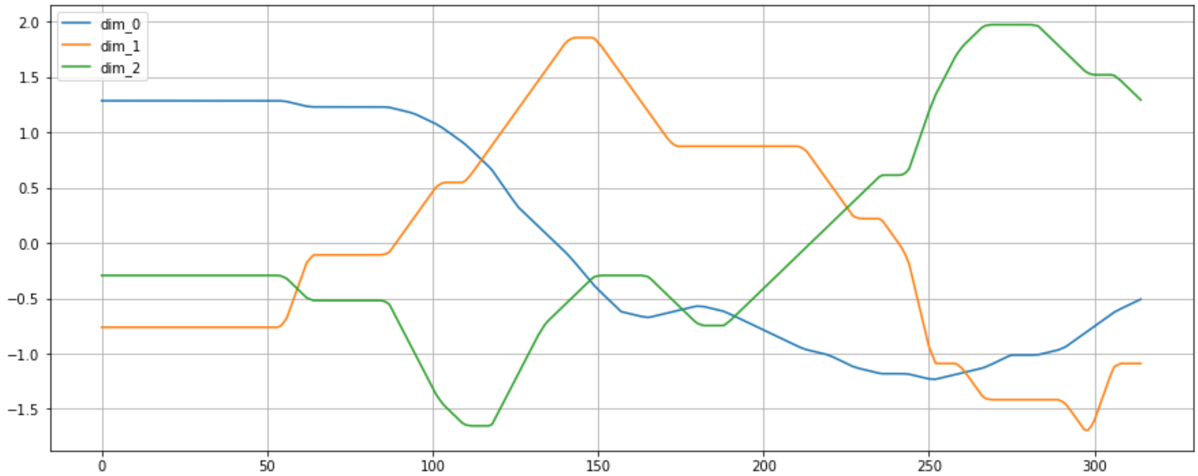
Afisarea unei serii temporale pentru fiecare gest



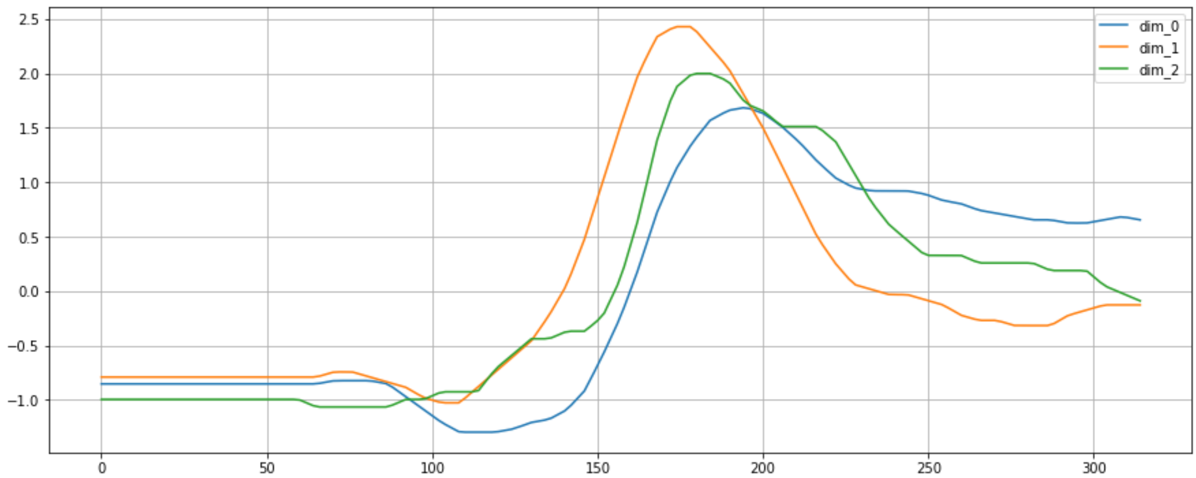
Gesture no. 5.0

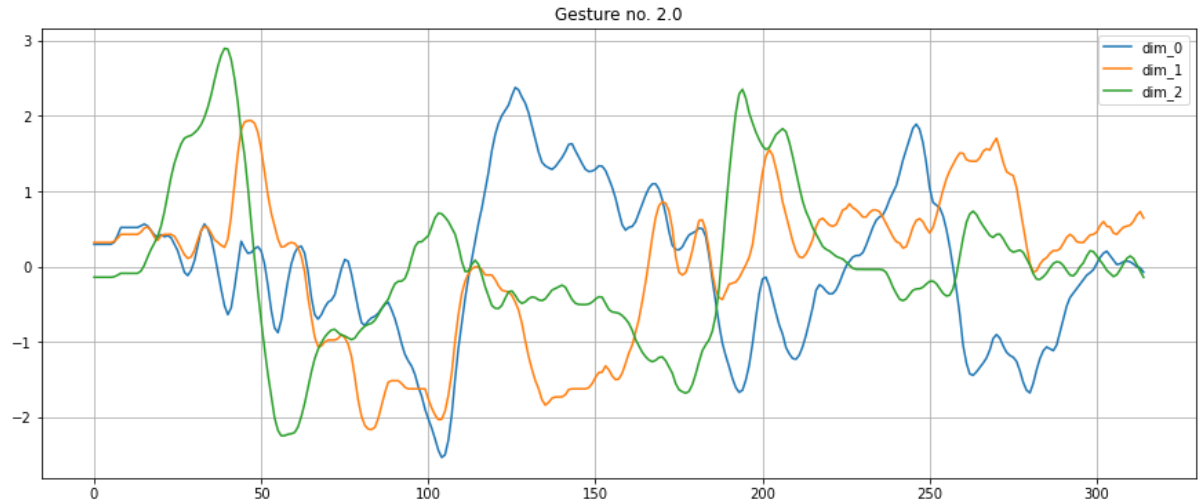


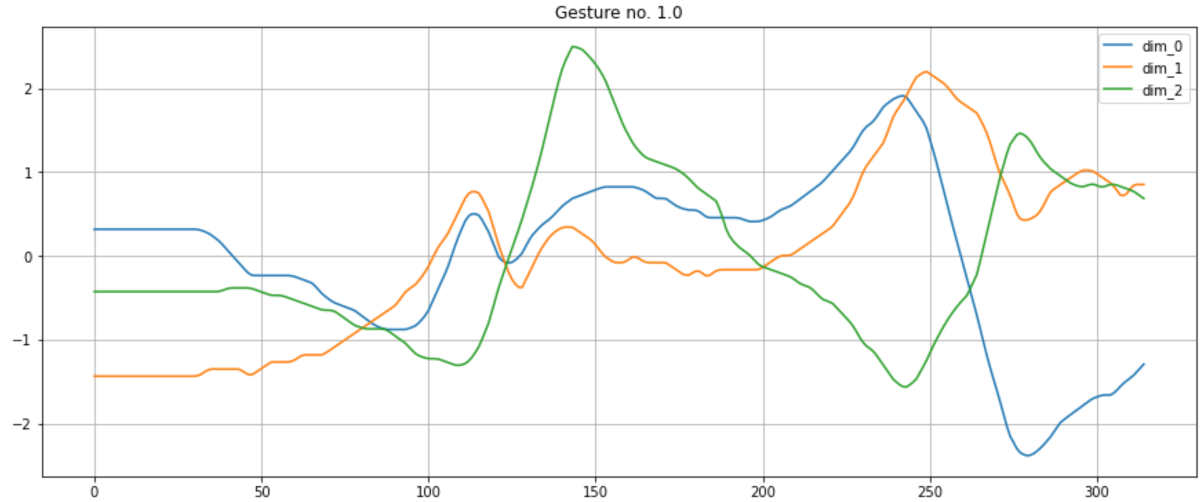
Gesture no. 4.0



Gesture no. 3.0

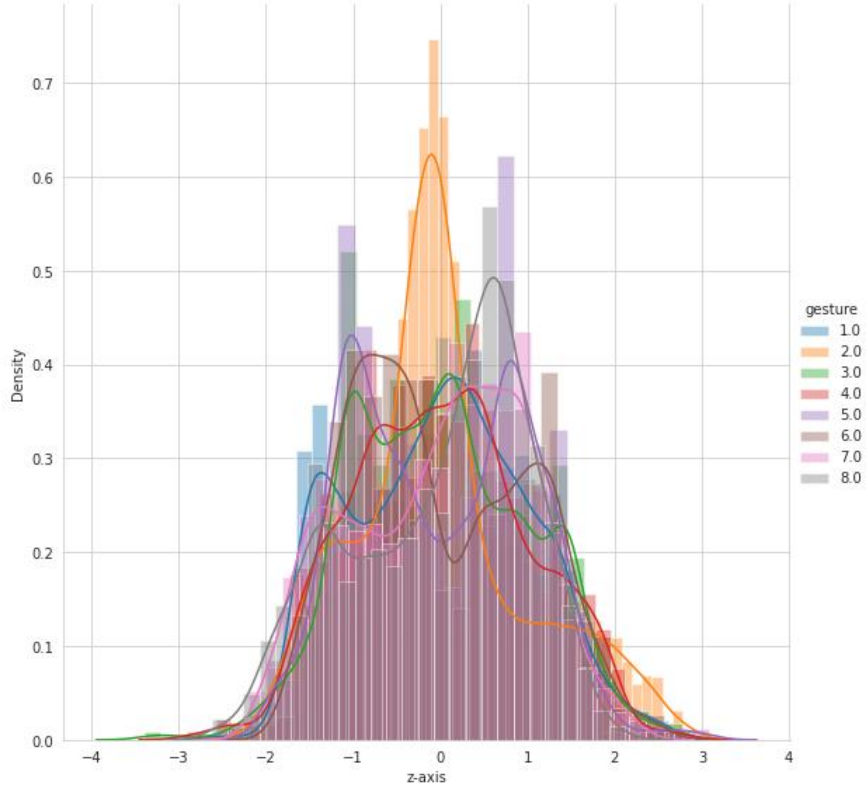


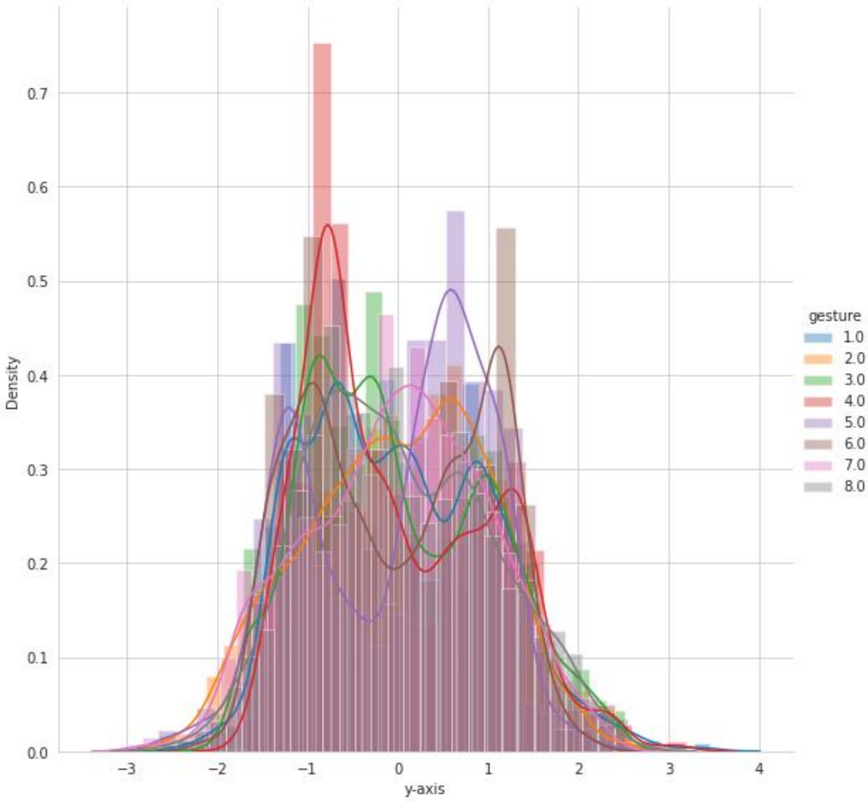


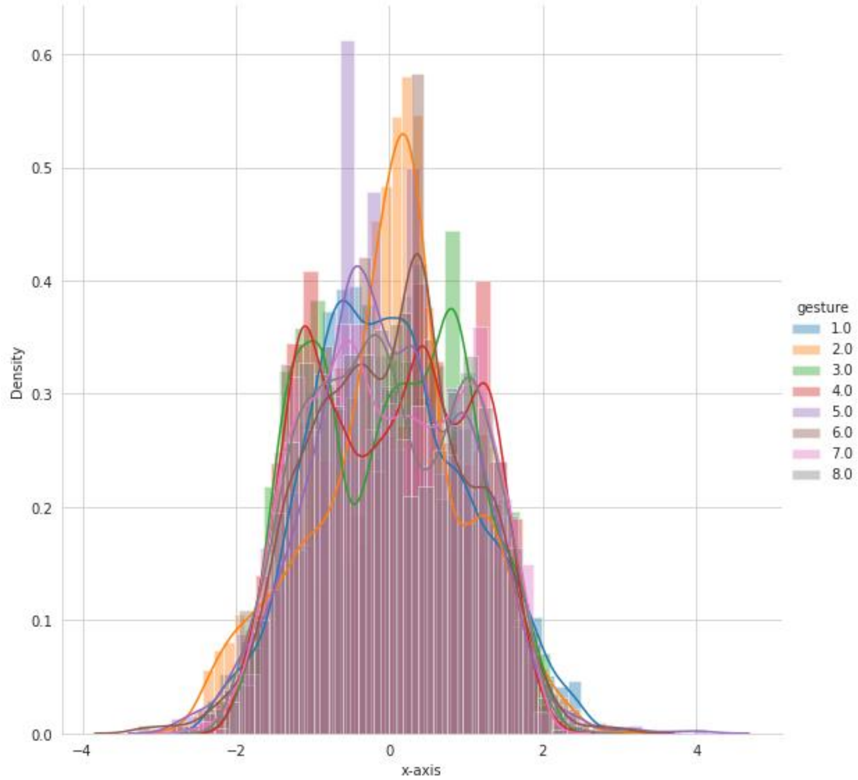


Pentru fiecare serie temporala am luat din setul de antrenare primul exemplu din clasa respectiva.

Distributia valorilor per fiecare axa, per gest

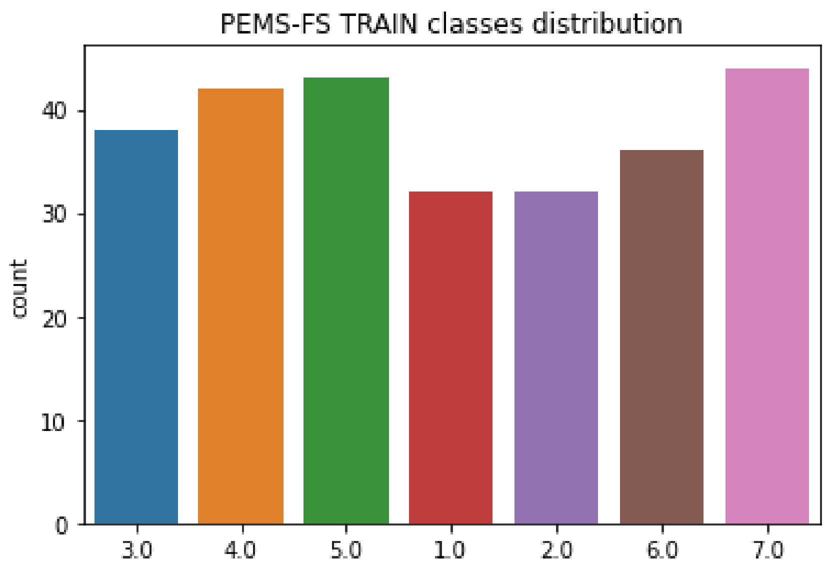


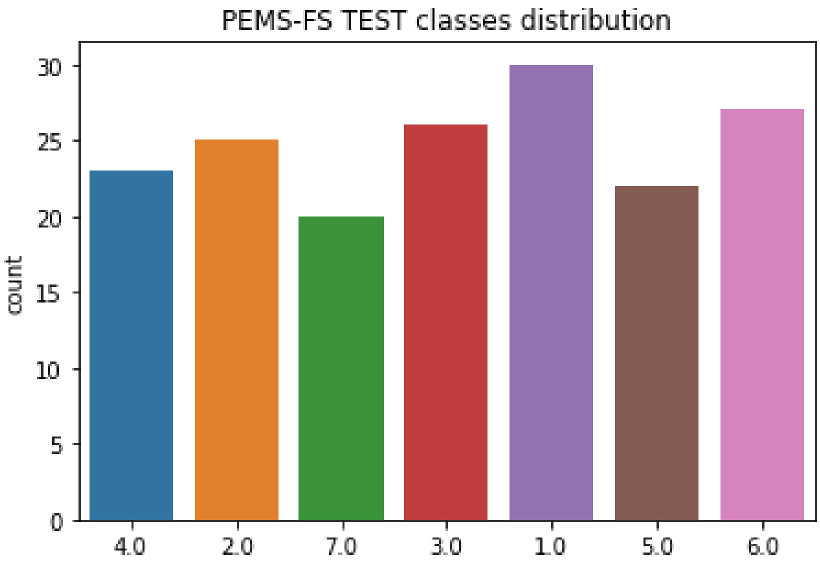




Se poate observa ca majoritatea datelor se afla intr-un interval relativ restrans, ceea ce ar putea reprezenta o dificultate in antrenare, atunci cand se doreste optimizarea modelului si obtinerea unei acuratete foarte buna.

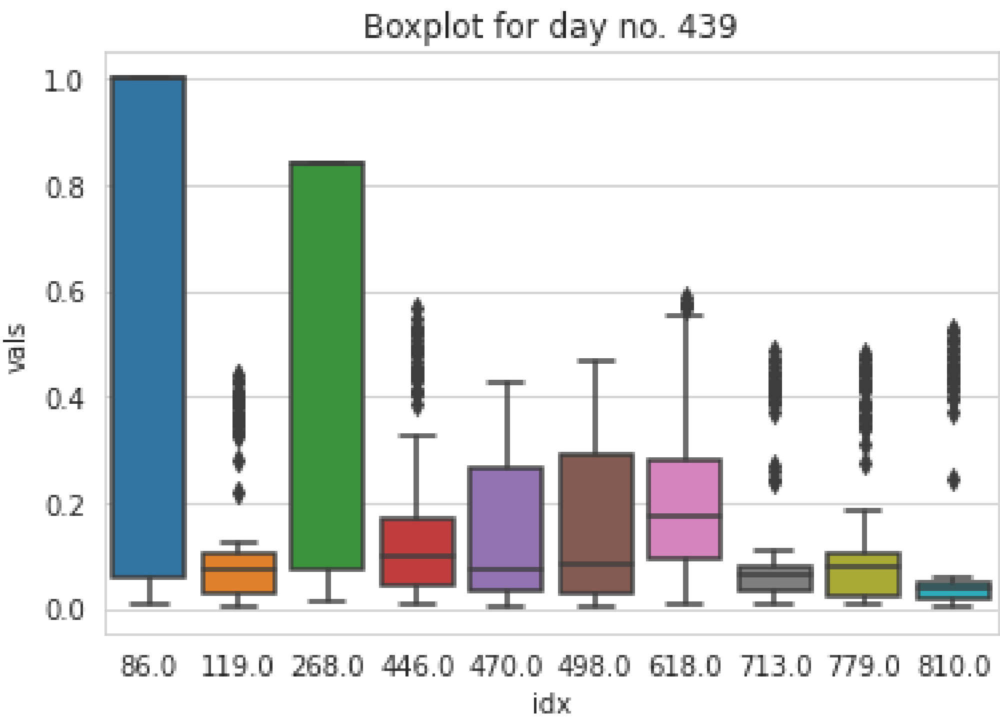
Frecventa de aparitie a claselor in setul de date pentru UWaveGesture dataset

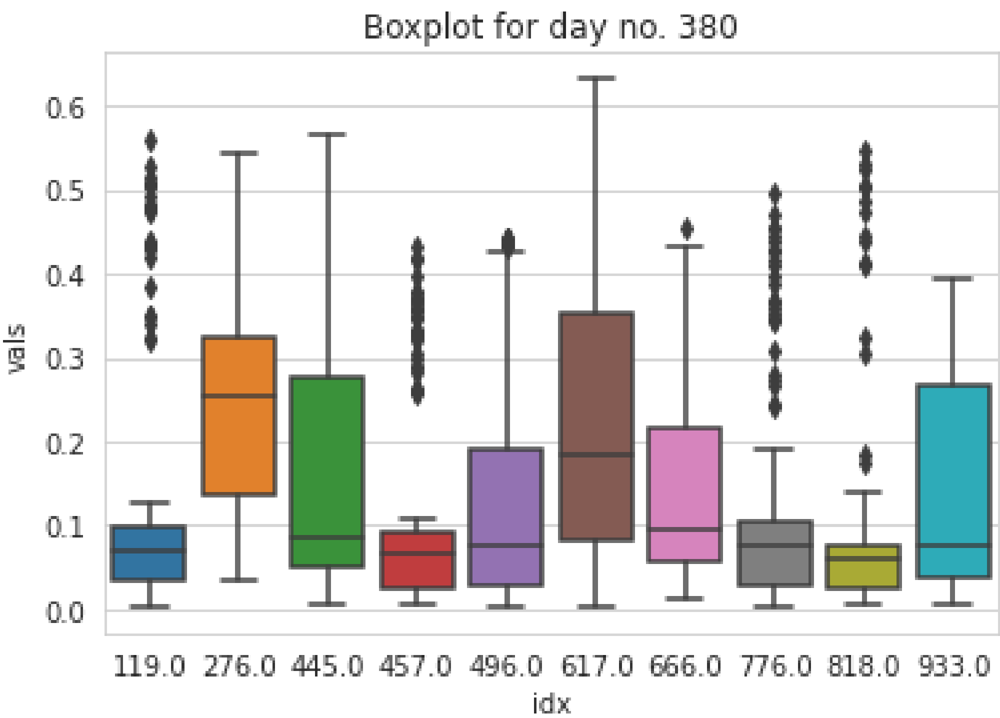


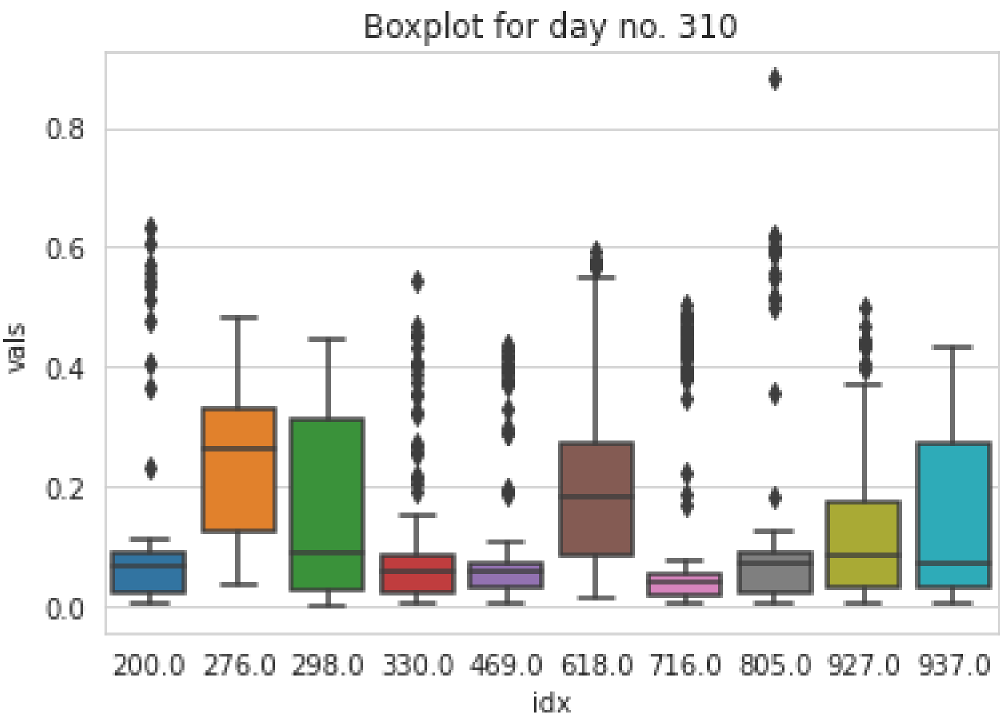


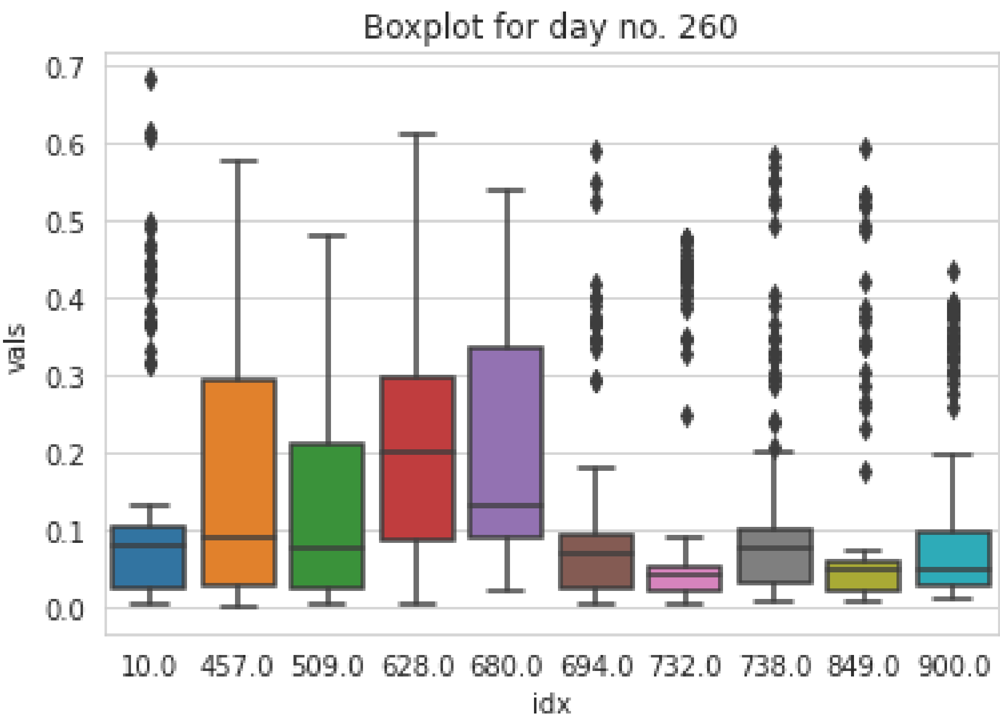
Observam ca setul de date PEMS-FS contine un numar inegal de clase atat in setul de antrenare, cat si in cel de testare. Cu toate acestea, nu se poate considera nicio clasa redundanta, toate avand un numar apropiat de exemple.

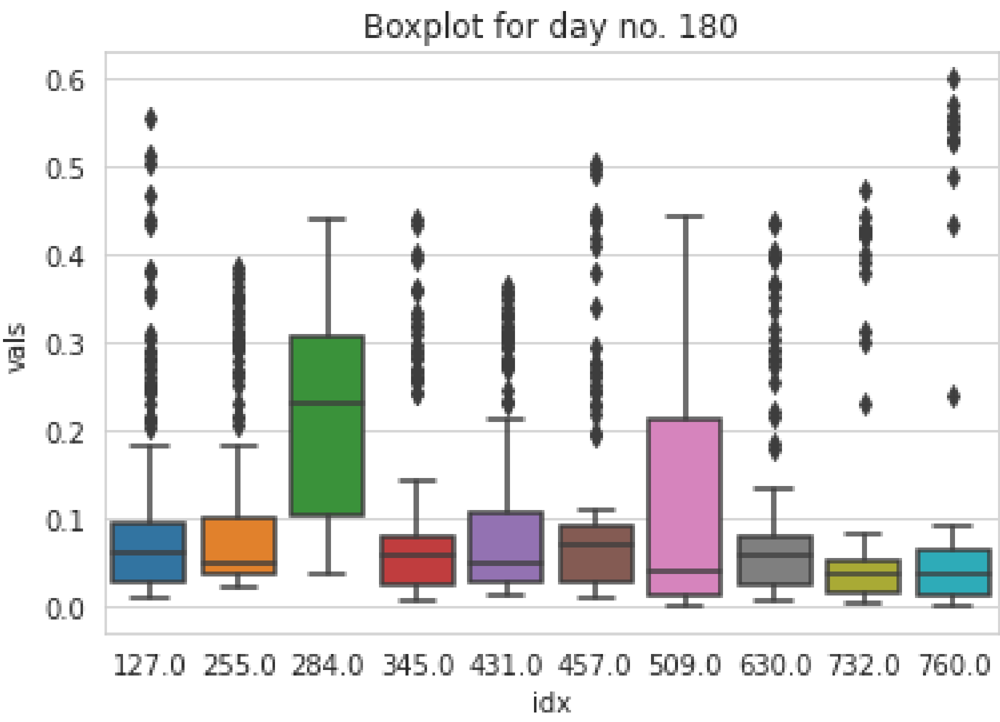
Varierea ratei de ocupare pentru top 10 senzori cu deviatia cea mai mare pentru 8 zile selectate arbitrar uniform din totalul zilelor

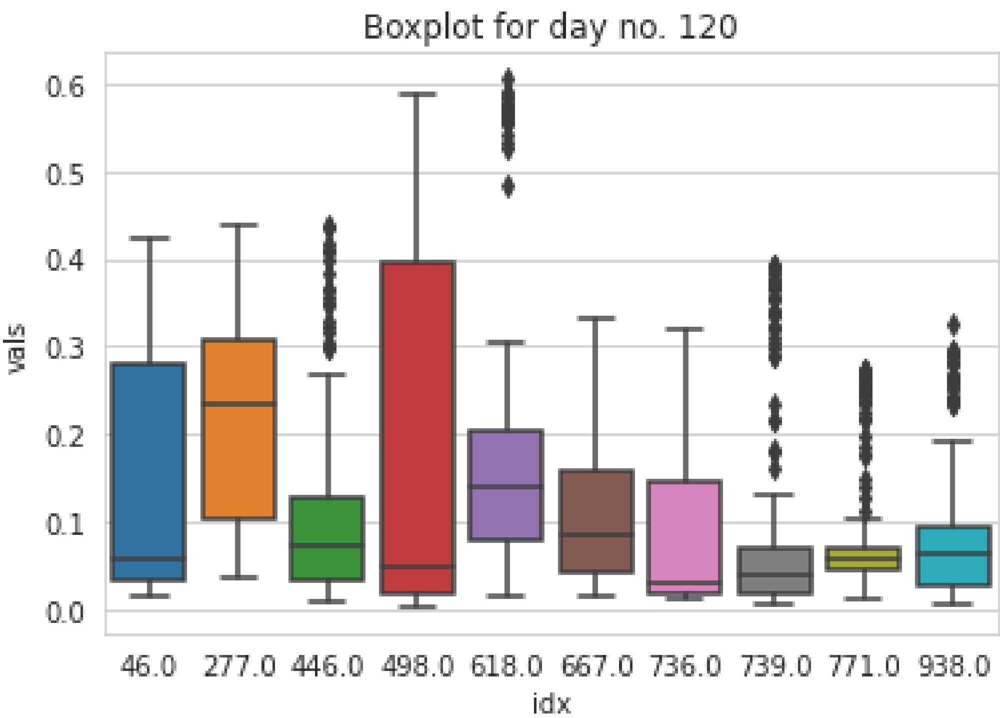


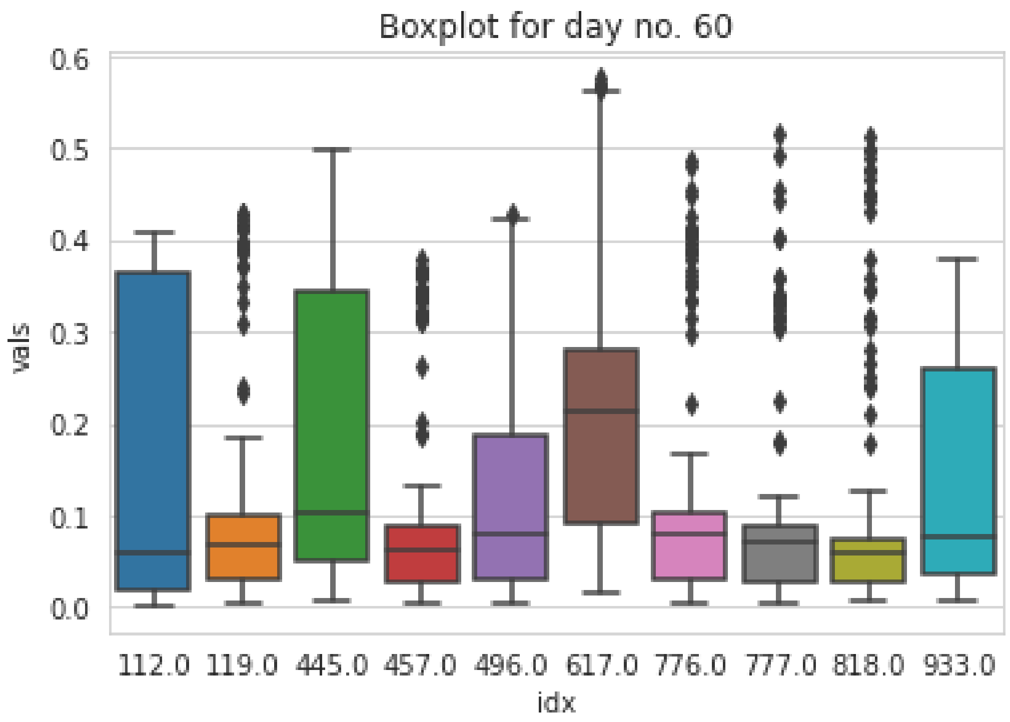


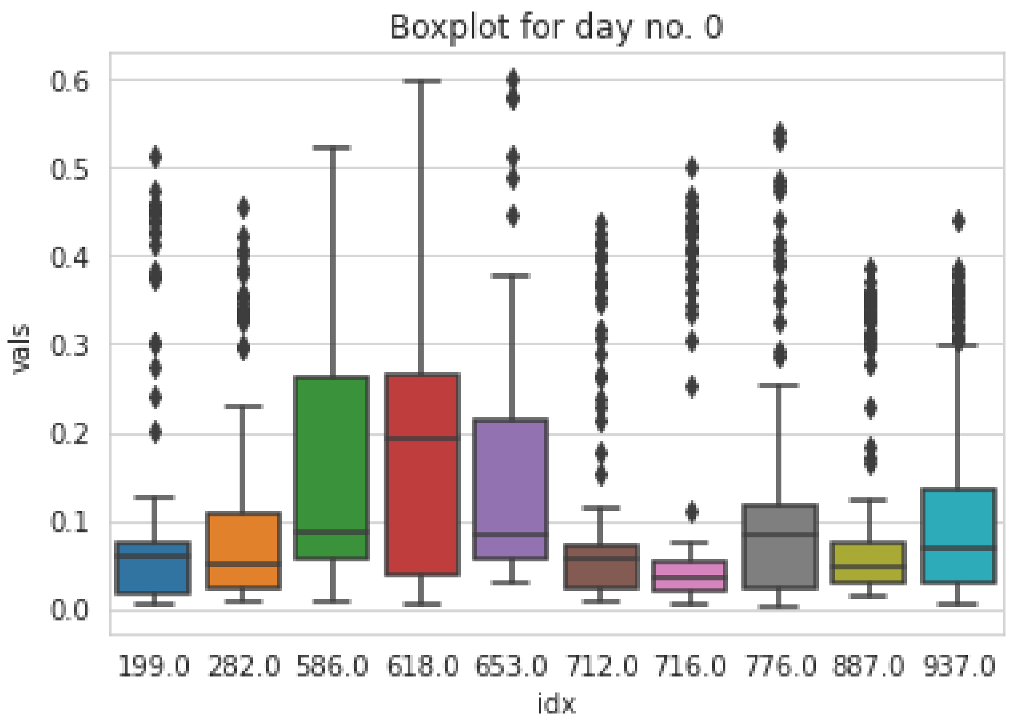

Boxplot for day no. 310
vals
0.0
0.2
0.4
0.6
0.8
200.0
276.0
298.0
330.0
469.0
618.0
716.0
805.0
927.0
937.0
idx


Boxplot for day no. 260
vals
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
10.0
457.0
509.0
628.0
680.0
694.0
732.0
738.0
849.0
900.0
idx


Boxplot for day no. 180
0.6
0.5
0.4
0.3
0.2
0.1
0.0
vals
127.0
255.0
284.0
345.0
431.0
457.0
509.0
630.0
732.0
760.0
idx


Boxplot for day no. 120
0.6
0.5
0.4
0.3
0.2
0.1
0.0
vals
46.0
277.0
446.0
498.0
618.0
667.0
736.0
739.0
771.0
938.0
idx



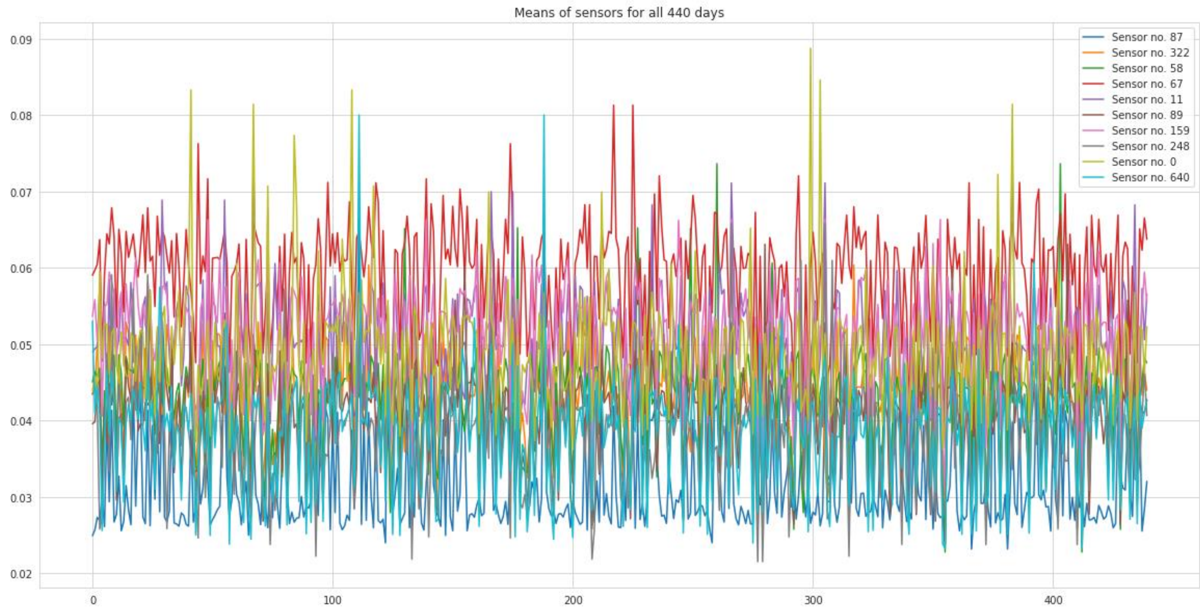


In urma analizei acestor grafice, cu mici exceptii, se observa cum majoritatea valorilor inregistrate de senzorii selectati se afla inspre limita inferioara a spectrului de valori. Asta poate reprezenta 2 lucruri:

1. Senzorii care au valori inregistrare mai mici (poate prin amplasarea lor in locatia respectiva) au si o sensibilitate la variatie, rezultand date mai imprastiate comparativ cu ceilalti senzori.

2. Posibil ca toti senzorii sa aiba valori mai apropiate de limita inferioara si atunci e nevoie de un pas in plus la preprocesarea datelor, dupa confirmarea acestei supozitii.

Evolutia mediilor celor mai relevanti 10 senzori pe durata tuturor celor 440 de zile



Putem remarca ca valorile in general sunt restranse intr-un interval mic de valori, apropiat destul de mult de origine.

Cerinta 2. *Pentru cerinta a doua am folosit datasetul UWaveGesture*

Feature Selection: Pentru a reduce datele de input la o dimensiune care poate fi gestionata si mai usor de analizat, am aplicat urmatoarele operatii:

- Am impartit fiecare axa (x, y si z) in ferestre de lungime 105 -> rezulta 3 ferestre per fiecare axa = 9 ferestre in total
- Pentru fiecare astfel de fereastra am facut media valorilor din seria de timp
- O intrare X din setul de date reprezinta aceste 9 valori obtinute in urma operatiilor de mai sus

In continuare, analiza atributelor si antrenarea modelelor este realizata pe aceasta noua reprezentare a datelor.

Extragerea atributelor

```
Applying mean on x_axis: -1.1325396825710079e-07
Applying mean on y_axis: -1.191991341994739e-07
Applying mean on z_axis: -2.6096681093963078e-08
Applying std on x_axis: 0.6537793630419304
Applying std on y_axis: 0.7495870421412952
Applying std on z_axis: 0.7088489128654653
Applying avg absolute diff on x_axis: 0.5317972085502645
Applying avg absolute diff on y_axis: 0.6496156217923061
Applying avg absolute diff on z_axis: 0.6049543094942061
Applying min on x_axis: -1.363360857142857
Applying min on y_axis: -1.3331605714285715
Applying min on z_axis: -1.3638615238095237
Applying max on x_axis: 1.360968380952381
Applying max on y_axis: 1.3764914000000001
Applying max on z_axis: 1.33198819047619
Applying max-min diff on x_axis: 2.7243292380952377
Applying max-min diff on y_axis: 2.7096519714285714
Applying max-min diff on z_axis: 2.695849714285714
Applying median on x_axis: -0.02353086190476192
Applying median on y_axis: 0.03759409047619046
Applying median on z_axis: 0.09206555714285715
Applying median abs dev on x_axis: 0.4542284999999999
Applying median abs dev on y_axis: 0.6274349095238094
Applying median abs dev on z_axis: 0.548894542857143
Applying IQR on x_axis: 0.912718819047619
Applying IQR on y_axis: 1.2576291285714287
Applying IQR on z_axis: 1.158704673809524
Applying negative count on x_axis: 632
Applying negative count on y_axis: 673
Applying negative count on z_axis: 716
Applying positive count on x_axis: 688
Applying positive count on y_axis: 647
Applying positive count on z_axis: 604
Applying values above mean on x_axis: 632
Applying values above mean on y_axis: 673
Applying values above mean on z_axis: 716
Applying values below mean on x_axis: 688
Applying values below mean on y_axis: 647
Applying values below mean on z_axis: 604
Applying number of peaks on x_axis: 451
Applying number of peaks on y_axis: 442
Applying number of peaks on z_axis: 441
Applying skewness on x_axis: 0.09000602953872863
Applying skewness on y_axis: -0.07910393643284531
Applying skewness on z_axis: -0.18151097976780978
Applying kurtosis on x_axis: -0.7231033556102662
Applying kurtosis on y_axis: -1.181820388478901
Applying kurtosis on z_axis: -1.0416019685057663
Applying energy on x_axis: 5.642042413121732
Applying energy on y_axis: 7.416825685449181
Applying energy on z_axis: 6.632561512771293
Average resultant acc is 44.3750263226313
Signal magnitude area is 1.786367140079365
```

De pe urma acestor metrici, valorile obtinute nu indica vreo anomalie evidenta.

Antrenare de modele ML

Folosind percentile=10 (valoarea default din sklearn) am fi folosit doar un atribut din cele 9, ceea ce este destul de riscant intrucat se pierde foarte multa informatie pentru fiecare exemplu.

Rezultate pentru folosirea Select Percentile cu percentile=50, adica folosirea a 4 din 9 atribute per fiecare intrare din dataset

```
--- Performance Analysis for Random Forest classifier ---
Best accuracy was 0.7833333333333333
        with params {'bootstrap': False, 'max_depth': 5, 'n_estimators': 100}


--- Performance Analysis for SVM classifier ---
Best accuracy was 0.8333333333333334
        with params {'C': 0.15, 'kernel': 'rbf'}


--- Performance Analysis for XGBoost classifier ---
Best accuracy was 0.725
        with params {'learning_rate': 0.15, 'max_depth': 2, 'n_estimators': 100}
```

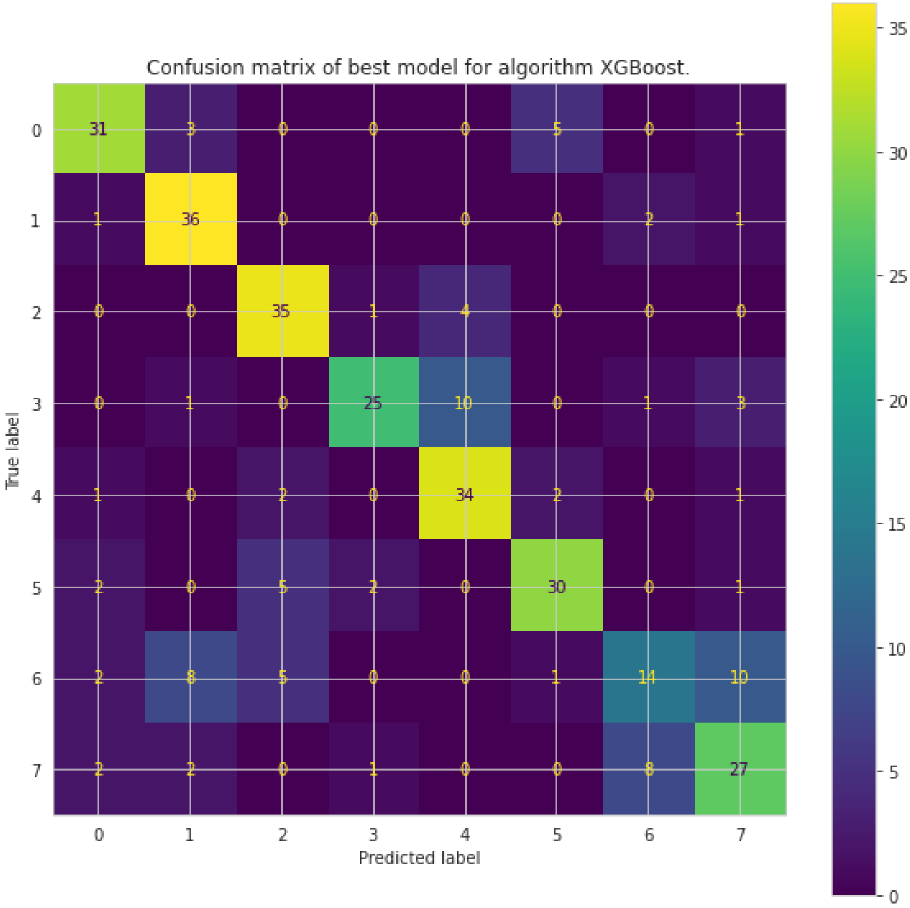
Rezultate pentru folosirea Select Percentile cu percentile=100, adica folosirea tuturor celor 9 din 9 atribute per fiecare intrare din dataset

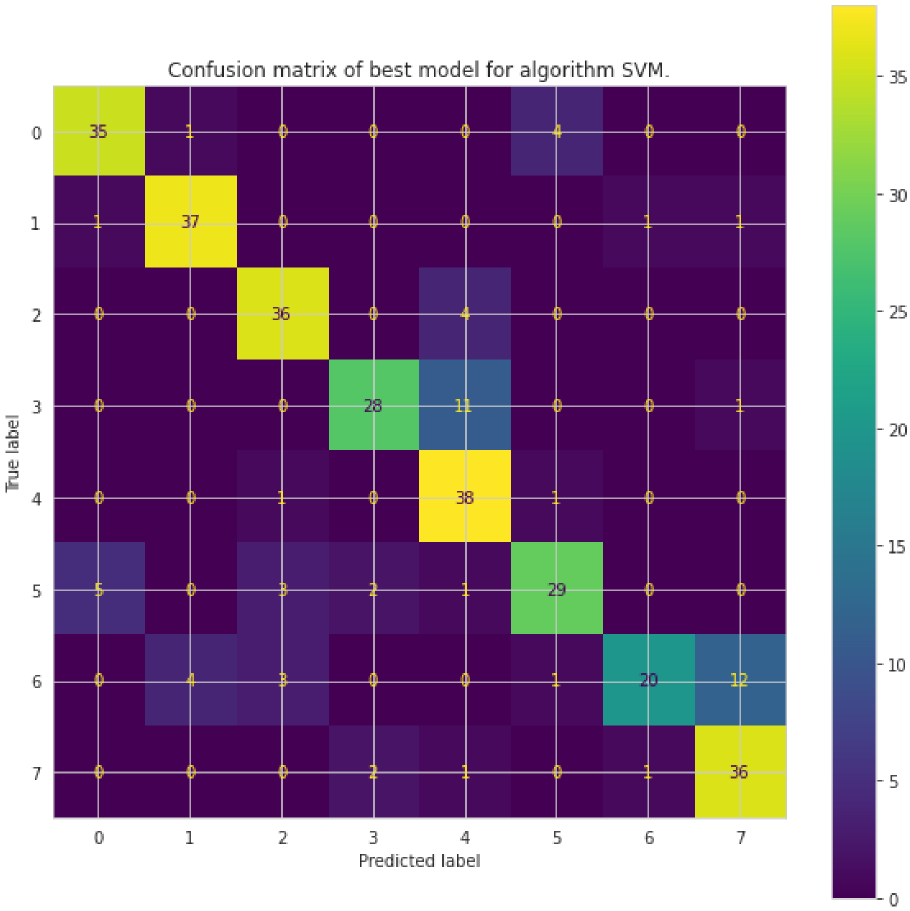
```
--- Performance Analysis for Random Forest classifier ---
Best accuracy was 0.8
        with params {'bootstrap': False, 'max_depth': 50, 'n_estimators': 50}


--- Performance Analysis for SVM classifier ---
Best accuracy was 0.8333333333333334
        with params {'C': 0.15, 'kernel': 'rbf'}


--- Performance Analysis for XGBoost classifier ---
Best accuracy was 0.7333333333333333
        with params {'learning_rate': 0.2, 'max_depth': 2, 'n_estimators': 150}
```

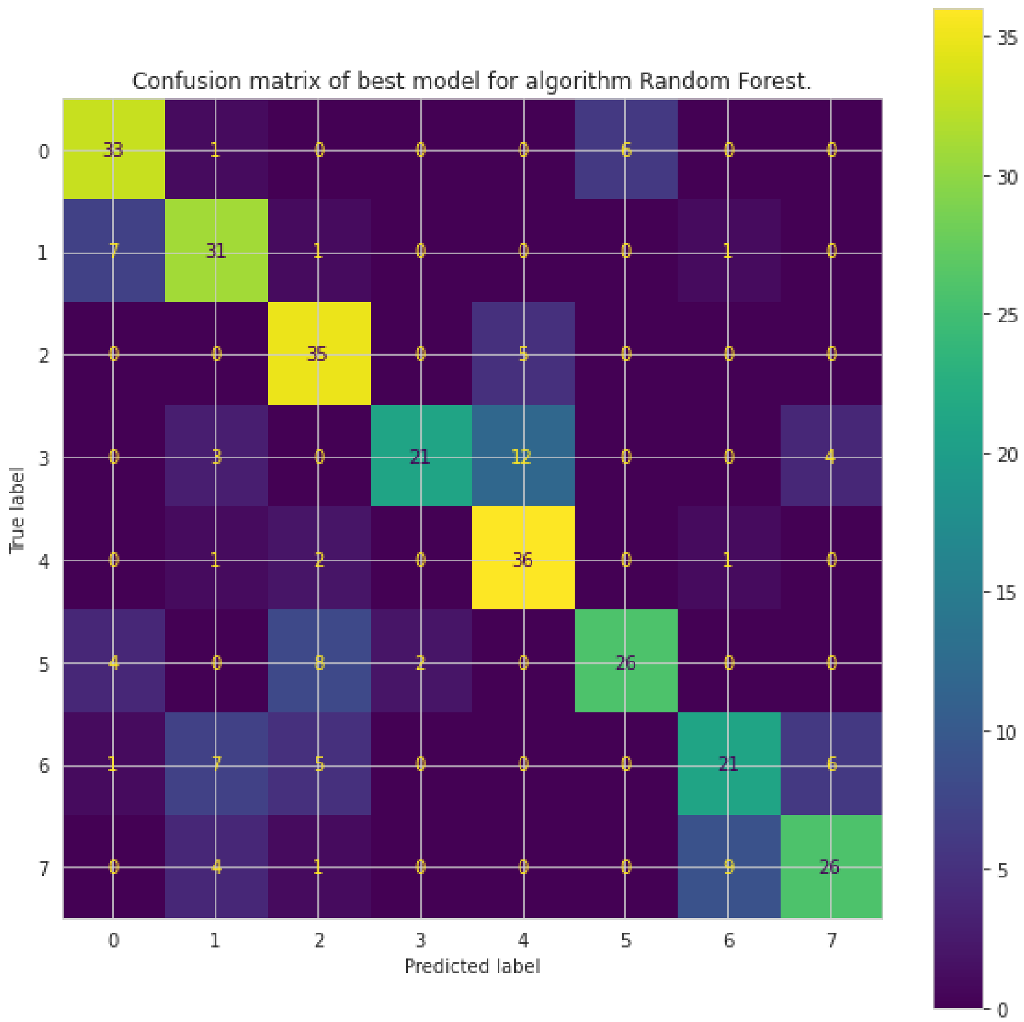
Pentru XGBoost learning_rate joaca un rol foarte important. Pentru SVC, kernelul “rbf” pare a fi cel mai constant dpdv al performantei obtinute. De asemenea, pare ca valoarea de 0.15 pentru “C” este ideala intrucat ofera cele mai bune performante. Random Forest pare ca prefera un numar finit de estimatori si o adancime maxima care nu este infinita. Dar aici intervine si dimensiunea relativ scazuta a setului de date.

Observam ca in mod constant Support Vector Machine Classifier obtine cea mai buna acuratete pe setul de antrenare. Am considerat in continuare modelul antrenat folosind percentile=50, intrucat acuratetea la antrenare este aceeasi, dar volumul de date este considerabil mai mic, imbunatatind astfel performanta.

	General Accuracy	**Classes**	1	2	3	4	5	6	7	8
Classifiers and Parameters *(best performing)*										
Random Forest *Bootstrap: False* *Max_depth: 50,* *N_estimators: 50*	Train: 0.8 Test: 0.72	Precision Recall F1	0.73 0.82 0.77	0.66 0.77 0.76	0.67 0.87 0.76	**0.91** 0.52 0.66	0.68 0.9 0.77	0.81 0.65 0.72	0.65 0.52 0.58	0.72 0.65 0.68
Support Vector Machine *C: 0.15* *Kernel: rbf*	Train**: 0.83** Test: **0.81**	Precision Recall F1	0.85 0.87 0.86	0.88 **0.92** **0.9**	0.84 0.9 0.87	0.87 0.7 0.77	0.69 0.95 0.8	0.83 0.72 0.77	0.9 0.5 0.65	0.72 0.9 0.8
XGBoost *Learning_rate: 0.2* *Max_depth: 2* *N_estimators: 150*	Train: 0.73 Test: 0.72	Precision Recall F1	0.79 0.77 0.78	0.72 0.9 0.8	0.74 0.87 0.8	0.86 0.62 0.72	0.7 0.85 0.77	0.79 0.75 0.77	0.56 0.35 0.43	0.61 0.67 0.64


Confusion matrix of best model for algorithm XGBoost.
True label
Predicted label


Confusion matrix of best model for algorithm SVM.
True label
Predicted label



Mai sus sunt prezentate rezultatele pentru cea mai buna combinatie de parametrii pentru fiecare algoritm, urmarind: acuratetea generala, recall, precision si F1 (ultimele trei la nivel de clasa).

De asemenea, sunt afisate matricile de confuzie pentru acesti algoritmi.

Toate aceste date sunt obtinute de pe urma predictiilor pe setul de testare.

Etapa 2

Analiza datelor pentru PEMS-SF
Am realizat analiza asupra secventelor de timp pentru 10 cei mai "sensibili" senzori (adica cu variatia standard cea mai mare). Am obtinut urmatoarele rezultate:

Analyzing day number 0.
    mean: 0.06314583333333333
    std: 0.054040430948349524
    min: 0.0
    max: 0.329
    median: 0.0521
    max-min diff: 0.329
    IQR: 0.05985
    number of peaks: 42
    skewness: 1.926261696888133
    kurtosis: 5.106245282031292

Analyzing day number 60.
    mean: 0.07126944444444444
    std: 0.04268916932278181
    min: 0.0083
    max: 0.156
    median: 0.07645
    max-min diff: 0.1477
    IQR: 0.06155000000000001
    number of peaks: 30
    skewness: 0.10068100566356297
    kurtosis: -1.050568312492597

Analyzing day number 120.
    mean: 0.07384791666666667
    std: 0.04277140134993825
    min: 0.0139
    max: 0.2958
    median: 0.06820000000000001
    max-min diff: 0.2819

IQR: 0.055900000000000005
number of peaks: 36
skewness: 1.3309766490412855
kurtosis: 3.9871911679885024

Analyzing day number 180.
mean: 0.04743819444444444
std: 0.024580166452875786
min: 0.0077
max: 0.092
median: 0.048350000000000004
max-min diff: 0.0843
IQR: 0.04625
number of peaks: 44
skewness: -0.03183009884987836
kurtosis: -1.3613317480516258

Analyzing day number 260.
mean: 0.07223055555555555
std: 0.0573946005950833
min: 0.0099
max: 0.2707
median: 0.0644
max-min diff: 0.2608
IQR: 0.04915
number of peaks: 44
skewness: 1.7583734562826396
kurtosis: 3.062884266543046

Analyzing day number 310.
mean: 0.06564722222222223
std: 0.03377642164218432
min: 0.0203
max: 0.1588
median: 0.0613
max-min diff: 0.1385
IQR: 0.042300000000000004

number of peaks: 47
skewness: 0.7573157586425023
kurtosis: -0.38260250425278297

Analyzing day number 380.
mean: 0.07126944444444444
std: 0.04268916932278181
min: 0.0083
max: 0.156
median: 0.07645
max-min diff: 0.1477
IQR: 0.06155000000000001
number of peaks: 30
skewness: 0.10068100566356297
kurtosis: -1.050568312492597

Analyzing day number 439.
mean: 0.07158958333333335
std: 0.023530951008872217
min: 0.0286
max: 0.119
median: 0.07769999999999999
max-min diff: 0.0904
IQR: 0.041025000000000006
number of peaks: 41
skewness: -0.2603369201727651
kurtosis: -1.270940391218219

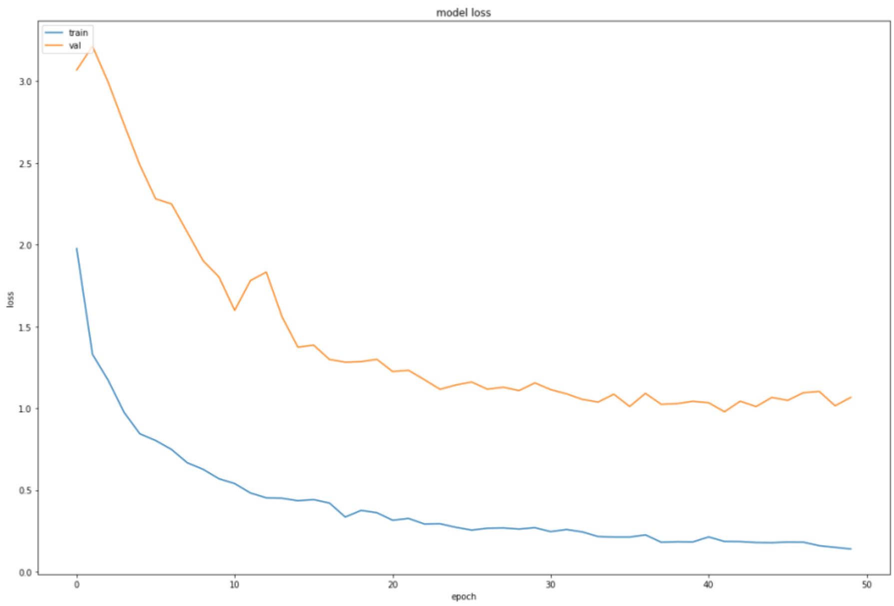
Multi-Layered Perceptron
Arhitectura folosita este descrisa prin:
- optimizator: Adam
- loss: categorical_crossentropy
- batch_size: 16

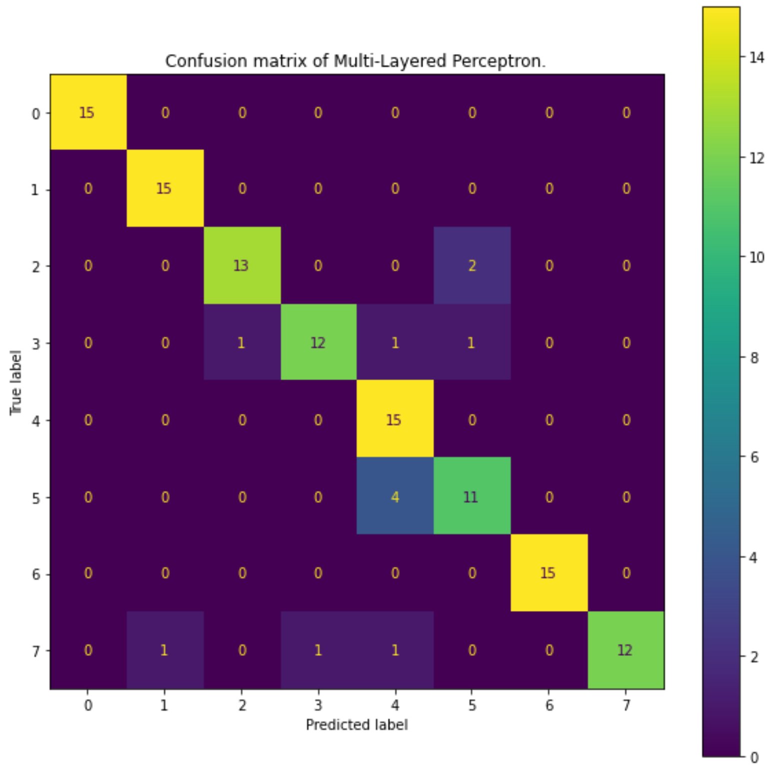
Straturile folosite sunt:

```
classifier = Sequential([
    Flatten(),
    Dropout(0.5),
```

```
    Dense(256, activation='sigmoid'),
    Dropout(0.5),
    Dense(128, activation='sigmoid'),
    Dropout(0.5),
    Dense(8, activation='softmax'),
])
```

Pe setul de antrenare am obtinut o acuratete de 97%, iar pe cel de test o acuratete de 90%.



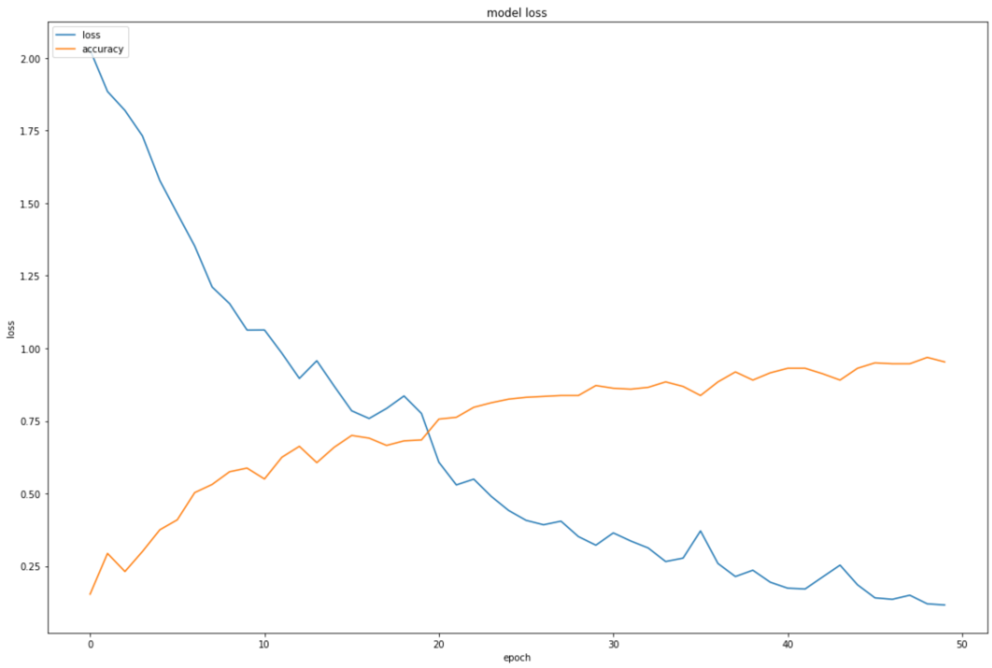


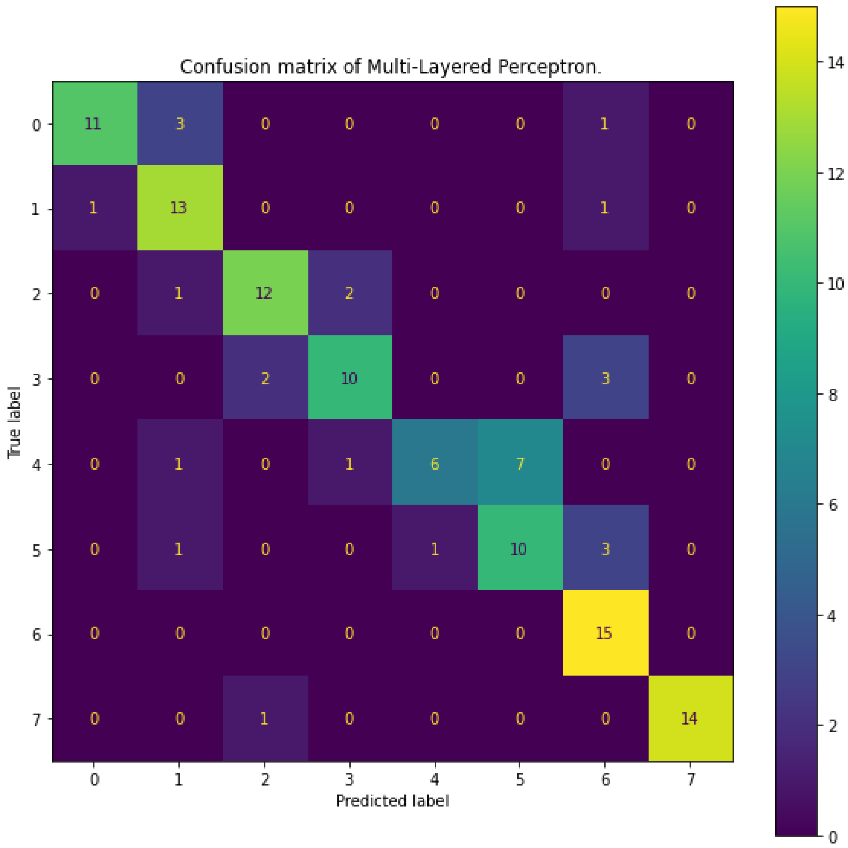
Retea Neurala Convolutionala
Arhitectura pe care am implementat-o se foloseste de cele 2 tutoriale indicate in cerinta temei. Foloseste:
- optimizator: Adam
- loss: categorical crossentropy
- batch_size: 16

Straturile retelei sunt:

```
classifier = Sequential([
    tf.keras.layers.Reshape((315, 3), input_shape=(315,
3)),
    Conv1D(filters=256, kernel_size=5,
activation='relu', padding='same', input_shape=(315,
3)),
    Conv1D(filters=512, kernel_size=5,
activation='relu'),
    tf.keras.layers.GlobalAvgPool1D(),
    Dense(1024, activation='relu'),
    Dense(256, activation='relu'),
    Dense(8, activation='softmax')
])
```

Pe datele de antrenare am obtinut o acuratete de 95%, iar pe datele de test am obtinut o acuratete de 76%.



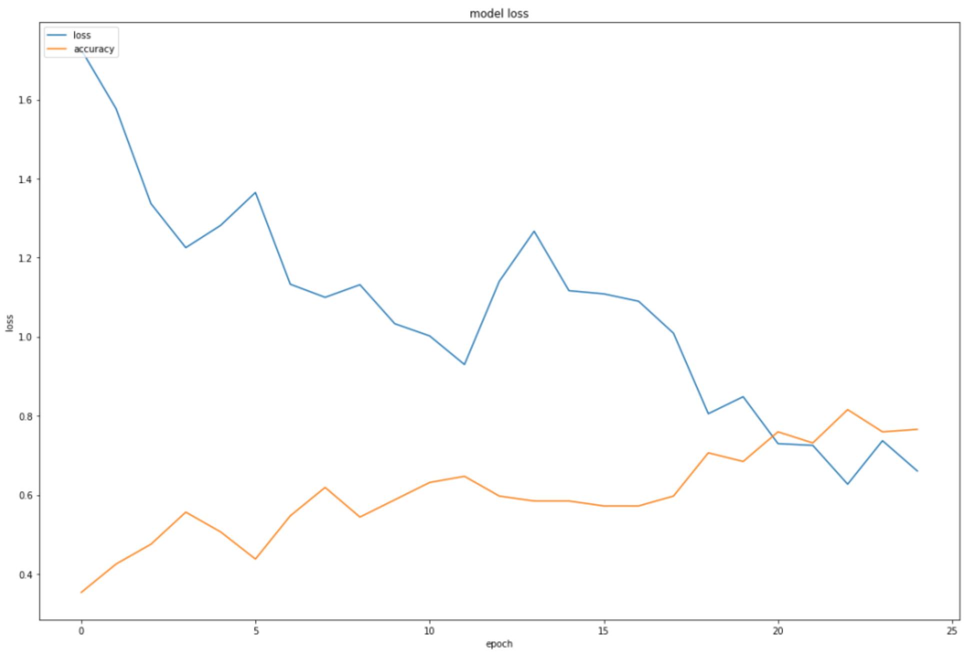


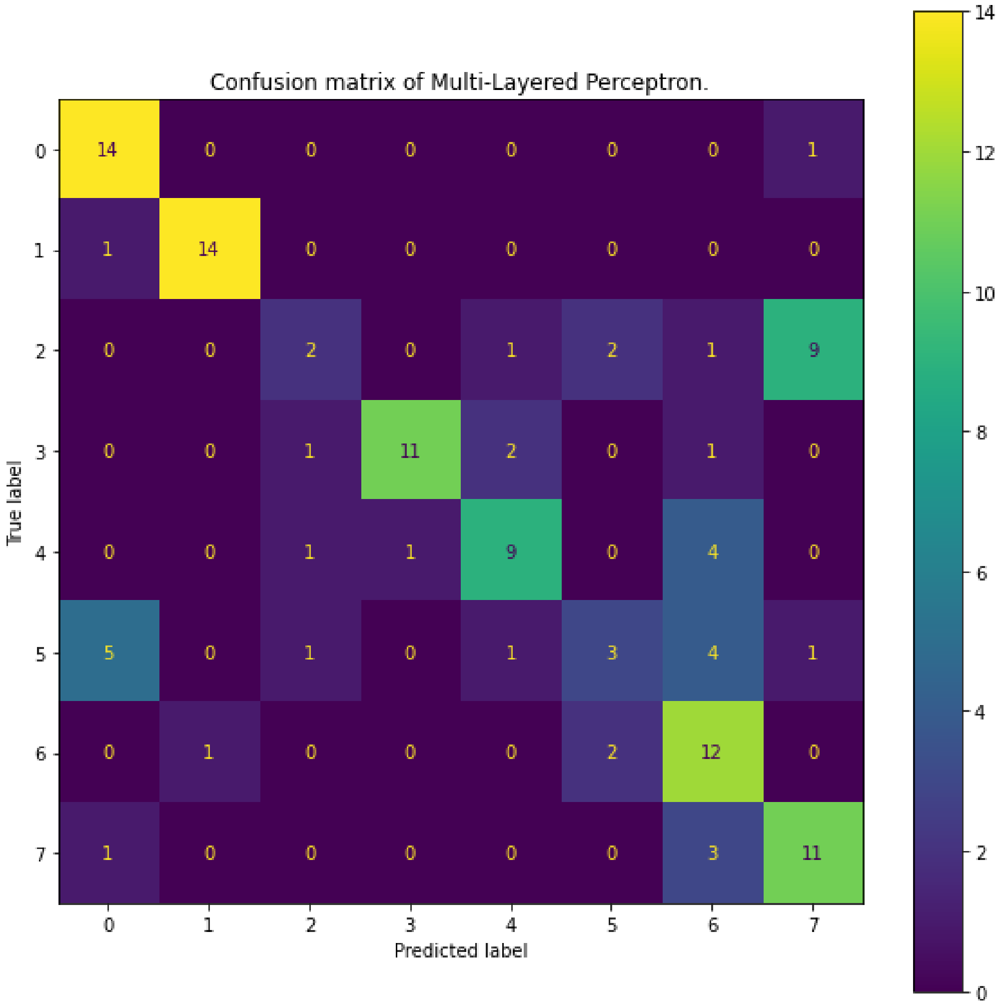
Retea Neurala Recurenta

Pentru reteaua neurala recurente am experimentat cu mai multi hiperparametrii, dar combinatia care a parut cea mai constanta in rezultate, fara alte tehnici de imbunatatire, a fost urmatoarea:

```
5classifier = Sequential()
classifier.add(LSTM(256, input_shape=(315, 3)))
classifier.add(Dense(64, activation='relu'))
classifier.add(Dense(8, activation='softmax'))
classifier.compile(loss='categorical_crossentropy',
optimizer='adam', metrics=['accuracy'])
```

Pe setul de antrenare am obtinut o acuratete de 76%, iar pe cel de testare o acuratete de 63%.





Multi-Layered Perceptron

Train acc: 0.97
Test acc: 0.9
Precision: [**1.**, 0.9375, 0.92857143, 0.86666667, 0.7, 0.84615385, 1., 1.]
Recall: [**1.**, 1., 0.86666667, 0.86666667, 0.93333333, 0.73333333, 1., 0.8]
F1: [**1.**, 0.96774194, 0.89655172, 0.86666667, 0.8, 0.78571429, 1., 0.88888889]

CNN

Train acc: 0.95
Test acc: 0.76
Precision: [0.73333333, 0.82352941, 0.75, 0.76923077, 0.71428571, 0.64285714, 0.8125, 0.93333333]
Recall: [0.73333333, 0.93333333, 0.8, 0.66666667, 0.66666667, 0.6, 0.86666667, 0.93333333]
F1: [0.73333333, 0.875, 0.77419355, 0.71428571, 0.68965517, 0.62068966, 0.83870968, 0.93333333]

RNN

Train acc: 0.76
Test acc: 0.63
Precision: [0.52631579, 0.66666667, 0.59090909, 0.85714286, 0.78947368, 0.33333333, 0.66666667, 0.5625]
Recall: [0.66666667, 0.8, 0.86666667, 0.8, 1., 0.06666667, 0.4, 0.6]
F1: [0.58823529, 0.72727273, 0.7027027, 0.82758621, 0.88235294, 0.11111111, 0.5, 0.58064516]