pca_small_office

January 18, 2022

1 Principal Component Analysis

Below are the Principal Component Analysis on the first 10 features:

1. index: Index for each data point
2. sim: Index for each simulation
3. saf: Total mass flow rate of air supply to the zone (kg/s)
4. sat: Temperature of air supplied to the zone (°C)
5. ewt: Exterior (South) Wall Temperature (°C)
6. ist: Interior (North, East, and West) Walls' Temperature (°C)
7. wit: Window Temperature (°C)
8. n_occ: Number of occupants in zone
9. x: location of occupant of interest on x-axis (m)
10. y: location of occupant of interest on y-axis (m)

The last 3 features are treated as target predictions for evaluation purpose.

1. MRT: Mean radiant temperature of the occupant of interest's head and chest (°C)
2. T: Average temperature of air surrounding the occupant of interest (°C)
3. V: Average speed of air surrounding the occupant of interest occupant (°C)

[1]:
```
data_loc = '../data/preprocessed/'
```

1.1 Small Office

1.1.1 1. Standardize the data

[2]:
```
import pandas as pd
from sklearn.preprocessing import StandardScaler

small_office_data = pd.read_csv(data_loc+"small_office.csv")

# Remove the index column
small_office_data.drop(columns=['index', 'sim'], inplace=True)

# Seperate the data into features and labels
X = small_office_data.drop(columns=['MRT', 'T', 'V'])
y_MRT = small_office_data['MRT']
y_T = small_office_data['T']
y_V = small_office_data['V']
```

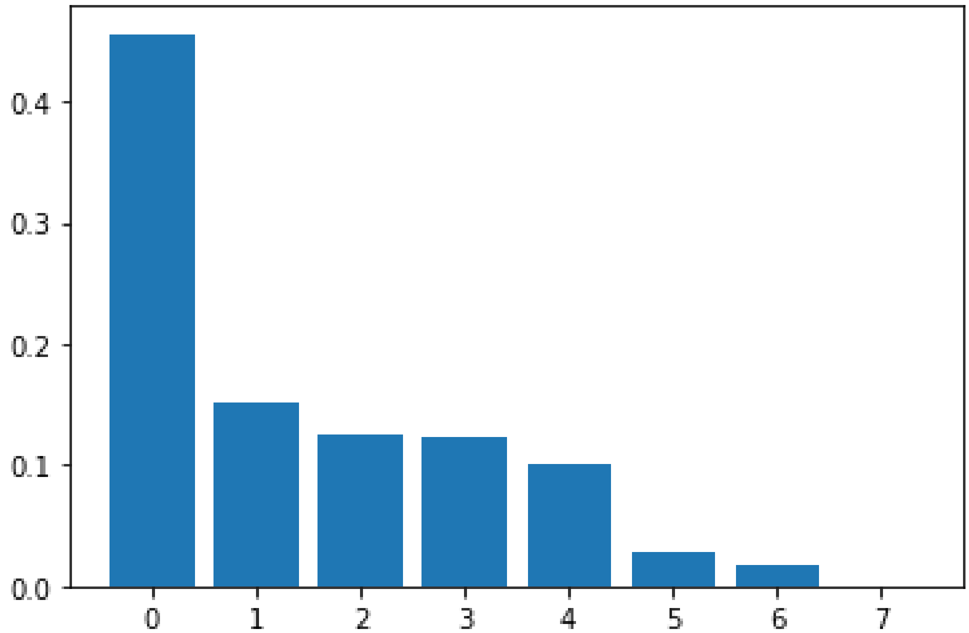
```python
# Standardize the data
scaler = StandardScaler()
scaler.fit(X)

X_std = pd.DataFrame(scaler.transform(X), columns=X.columns)
X_std.describe()
```

```
[2]:                  saf           sat           ewt           ist           wit  \
count  6.804000e+03  6.804000e+03  6.804000e+03  6.804000e+03  6.804000e+03
mean   1.179865e-15  4.536511e-15 -4.042222e-15  8.012322e-16 -3.642263e-15
std    1.000073e+00  1.000073e+00  1.000073e+00  1.000073e+00  1.000073e+00
min   -1.153200e+00 -1.691151e+00 -1.034078e+00 -1.110044e+00 -1.109349e+00
25%   -7.274033e-01 -9.101396e-01 -7.559377e-01 -8.141045e-01 -8.031388e-01
50%   -1.774154e-01  1.302726e-01 -2.016575e-01 -2.243554e-01 -4.969283e-01
75%    5.499878e-01  6.500105e-01  9.109050e-01  8.706192e-01  1.147352e+00
max    1.508031e+00  1.170685e+00  1.745327e+00  1.758436e+00  1.837049e+00

              n_occ             x             y
count  6.804000e+03  6.804000e+03  6.804000e+03
mean   1.557703e-14 -4.951947e-16  3.662104e-15
std    1.000073e+00  1.000073e+00  1.000073e+00
min   -1.912203e+00 -1.569743e+00 -8.660254e-01
25%   -5.275044e-01 -9.962782e-01 -8.660254e-01
50%    8.571946e-01 -2.744114e-02 -8.660254e-01
75%    8.571946e-01  9.413959e-01  1.154701e+00
max    8.571946e-01  1.516260e+00  1.154701e+00
```

1.1.2 2. Perform PCA

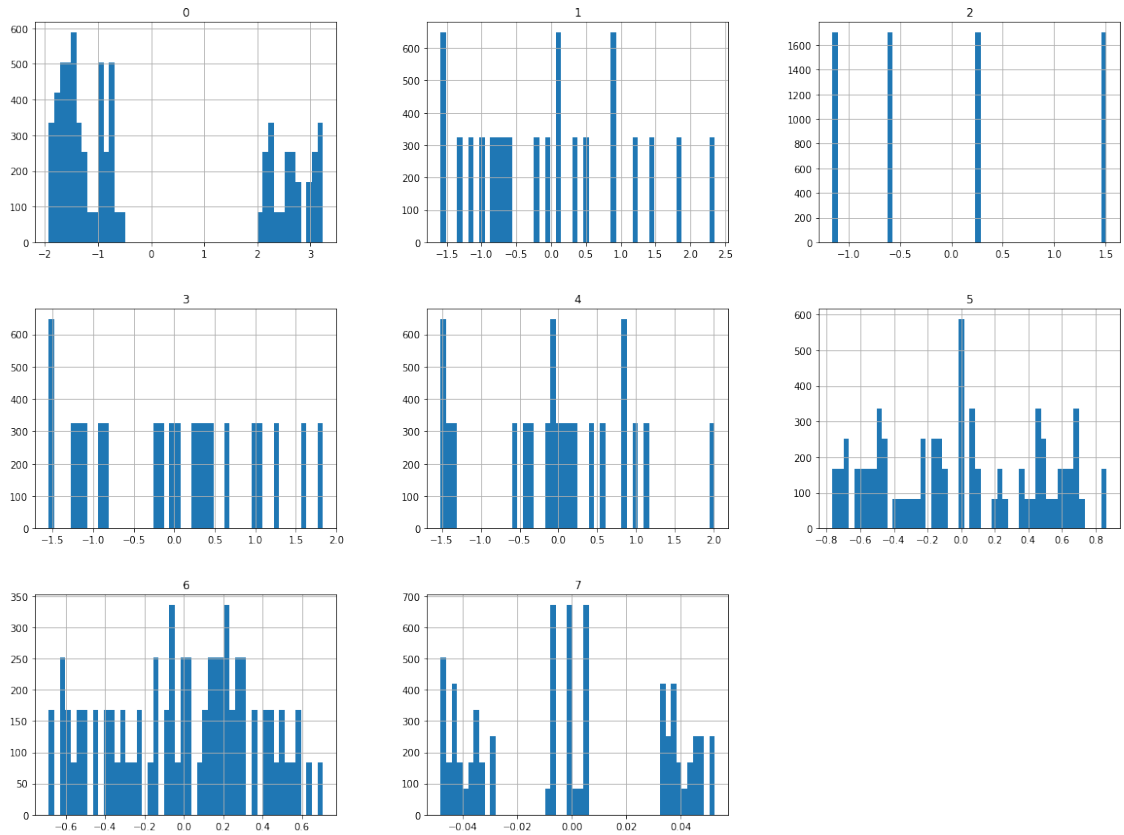
```python
[3]: # Perform PCA
from sklearn.decomposition import PCA
import matplotlib.pyplot as plt
import numpy as np
from numpy import savetxt

pca = PCA()
pca.fit(X_std)

e_vectors = pca.components_ # The eigenvectors
evr = pca.explained_variance_ratio_ # The variance explained by each eigenvector

# Save the eigenvectors to a text file
savetxt("../reports/data/pca_small_office_eigenvectors.csv", e_vectors,␣
 ↪delimiter=',')

plt.bar(range(len(evr)), evr)
```

```
plt.savefig('../figures/evr_pca_small_office.png')
```



[4]:
```
# Tramsform the data
X_pca = pd.DataFrame(pca.transform(X_std))
fig, ax = plt.subplots(figsize=(20,15))
X_pca.hist(bins=50, ax=ax)
fig.savefig('../figures/hist_pca_small_office.png')
```

```
/tmp/ipykernel_89149/2505846687.py:4: UserWarning: To output multiple subplots,
the figure containing the passed axes is being cleared
  X_pca.hist(bins=50, ax=ax)
```



After performing PCA on the features, the distribution graph shows more normal distribution features (8 features).

1.1.3 3. Compare models' results with and without PCA on predicting MRT

3.1 Split the data into training and testing

[5]:
```python
# Split the data into training and testing
from sklearn.model_selection import train_test_split

# Without PCA
X_train, X_test, y_train, y_test = train_test_split(X_std, y_MRT, test_size=0.
↪2, random_state=42)

# With PCA
X_train_pca, X_test_pca, y_train_pca, y_test_pca = train_test_split(X_pca,␣
↪y_MRT, test_size=0.2, random_state=42)
```

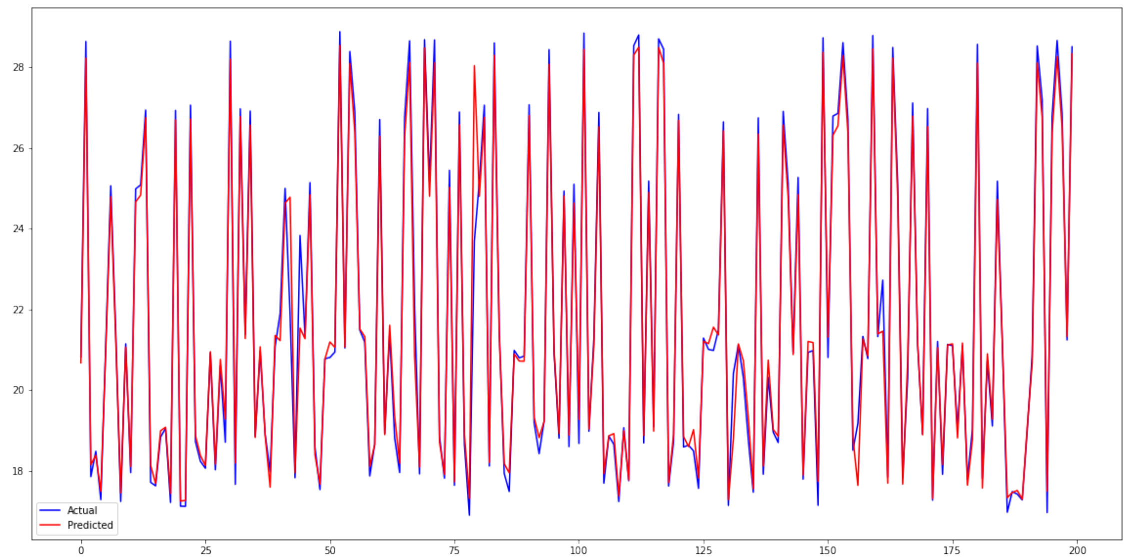
3.2 Train and evaluate the Linear Regression model

3.2.1 Without PCA

[6]:

```python
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error
import pickle
import time

# Train linear regression model on training data
model = LinearRegression()
start = time.time()
model.fit(X_train, y_train)
stop = time.time()
lr_train_time = stop - start
print(f"Training time: {lr_train_time}s")

# Save the model to a pickle file
filename = '../reports/models/lr_MRT_small_office_model.pkl'
pickle.dump(model, open(filename, 'wb'))

# Predict on test data
y_pred = model.predict(X_test)

# Evaluate the model
mse = mean_squared_error(y_test, y_pred)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

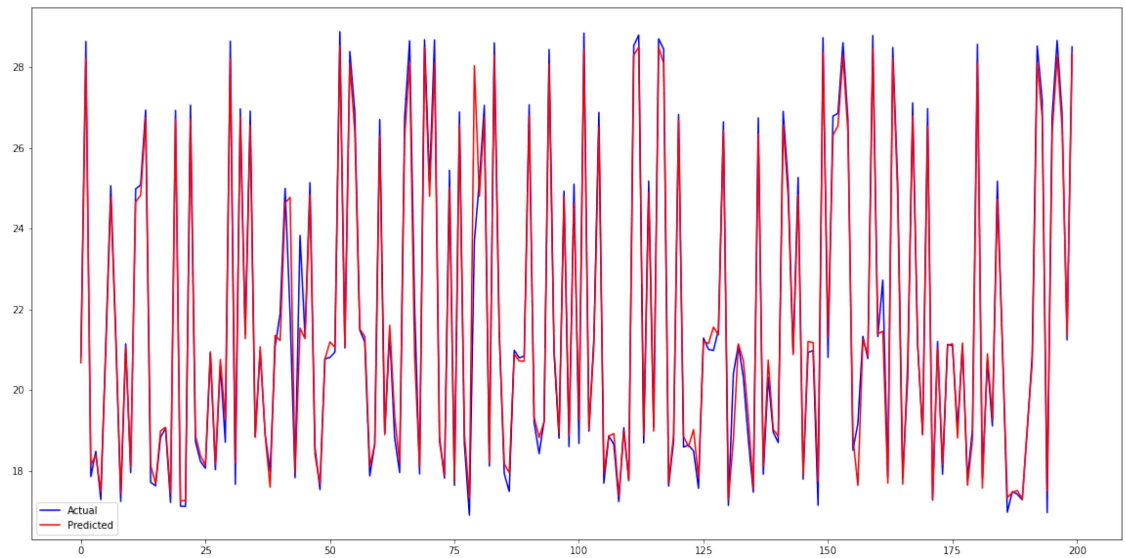
```
Training time: 0.009639263153076172s
Mean squared error: 0.4468471967271326
```



3.2.2 With PCA

[7]:
```
# Train linear regression model on training data
start = time.time()
model.fit(X_train_pca, y_train_pca)
stop = time.time()
lr_pca_train_time = stop - start
print(f"Training time: {lr_pca_train_time}s")

# Predict on test data
y_pred_pca = model.predict(X_test_pca)

# Save the model to a pickle file
filename = '../reports/models/lr_MRT_pca_small_office_model.pkl'
pickle.dump(model, open(filename, 'wb'))

# Evaluate the model
mse = mean_squared_error(y_test_pca, y_pred_pca)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test_pca[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_pca[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 0.007021188735961914s
Mean squared error: 0.44684719672713213
```



3.3 Train and evaluate the Feedforward Neural Network model

3.2.1 Without PCA

[8]:
```
# Create neural network model
from keras.models import Sequential
from keras.layers import Dense

N_NEURONS = 1024
N_LAYERS = 4

model = Sequential()
model.add(Dense(units=N_NEURONS, input_dim=X.shape[1], activation='relu'))
for i in range(N_LAYERS-1):
    model.add(Dense(units=N_NEURONS, activation='relu'))
model.add(Dense(units=1, activation='linear')) # Output layer
model.compile(loss='mean_squared_error', optimizer='adam')

# Train the model
start = time.time()
model.fit(X_train, y_train, epochs=100, verbose=0)
stop = time.time()
nn_train_time = stop - start
print(f"Training time: {nn_train_time}s")

# Predict on test data
y_pred_nn = model.predict(X_test)
model.save('../reports/models/nn_MRT_small_office_model.pkl')
```

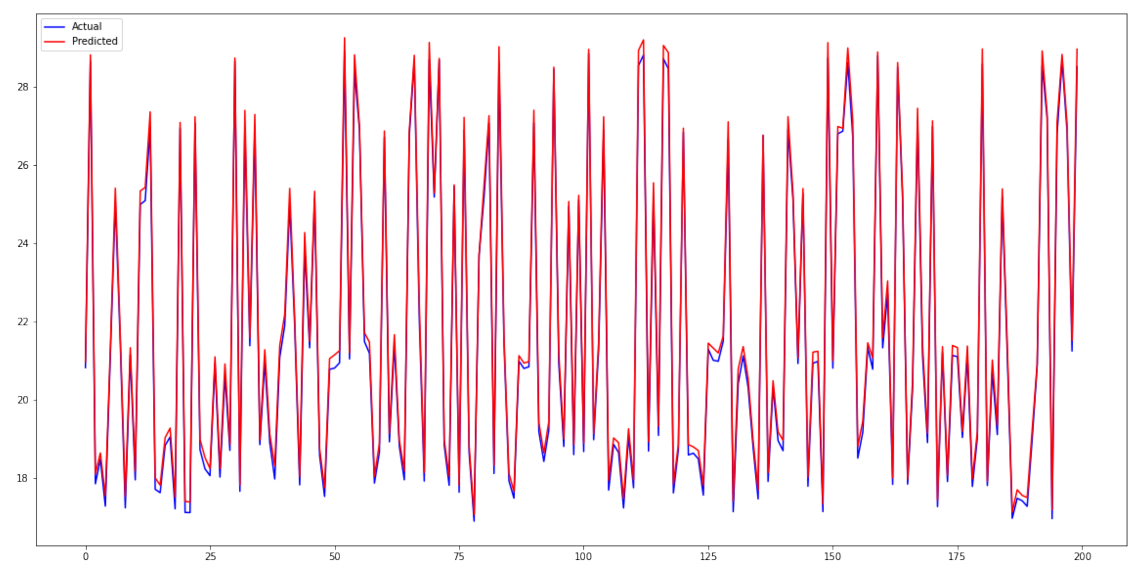
```python
# Evaluate the model
mse = mean_squared_error(y_test, y_pred_nn)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_nn[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
2022-01-18 22:26:42.903428: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcudart.so.10.1
2022-01-18 22:26:46.144988: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcuda.so.1
2022-01-18 22:26:46.217934: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:46.218518: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1716] Found device 0 with
properties:
pciBusID: 0000:04:00.0 name: GeForce GTX 1060 6GB computeCapability: 6.1
coreClock: 1.7845GHz coreCount: 10 deviceMemorySize: 5.93GiB
deviceMemoryBandwidth: 178.99GiB/s
2022-01-18 22:26:46.218566: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcudart.so.10.1
2022-01-18 22:26:46.308605: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcublas.so.10
2022-01-18 22:26:46.330107: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcufft.so.10
2022-01-18 22:26:46.338832: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcurand.so.10
2022-01-18 22:26:46.373684: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcusolver.so.10
2022-01-18 22:26:46.386646: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcusparse.so.10
2022-01-18 22:26:46.531948: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
```

```
opened dynamic library libcudnn.so.7
2022-01-18 22:26:46.532339: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:46.533501: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:46.534392: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1858] Adding visible gpu
devices: 0
2022-01-18 22:26:46.567549: I
tensorflow/core/platform/profile_utils/cpu_utils.cc:104] CPU Frequency:
2194705000 Hz
2022-01-18 22:26:46.570703: I tensorflow/compiler/xla/service/service.cc:168]
XLA service 0x5580306dd990 initialized for platform Host (this does not
guarantee that XLA will be used). Devices:
2022-01-18 22:26:46.570751: I tensorflow/compiler/xla/service/service.cc:176]
StreamExecutor device (0): Host, Default Version
2022-01-18 22:26:46.823022: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:46.823726: I tensorflow/compiler/xla/service/service.cc:168]
XLA service 0x558030749430 initialized for platform CUDA (this does not
guarantee that XLA will be used). Devices:
2022-01-18 22:26:46.823763: I tensorflow/compiler/xla/service/service.cc:176]
StreamExecutor device (0): GeForce GTX 1060 6GB, Compute Capability 6.1
2022-01-18 22:26:46.825790: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:46.826517: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1716] Found device 0 with
properties:
pciBusID: 0000:04:00.0 name: GeForce GTX 1060 6GB computeCapability: 6.1
coreClock: 1.7845GHz coreCount: 10 deviceMemorySize: 5.93GiB
deviceMemoryBandwidth: 178.99GiB/s
2022-01-18 22:26:46.826602: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcudart.so.10.1
2022-01-18 22:26:46.826657: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcublas.so.10
2022-01-18 22:26:46.826759: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcufft.so.10
```

```
2022-01-18 22:26:46.826825: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcurand.so.10
2022-01-18 22:26:46.826889: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcusolver.so.10
2022-01-18 22:26:46.826944: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcusparse.so.10
2022-01-18 22:26:46.826996: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcudnn.so.7
2022-01-18 22:26:46.827182: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:46.827983: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:46.828670: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1858] Adding visible gpu
devices: 0
2022-01-18 22:26:46.829767: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
opened dynamic library libcudart.so.10.1
2022-01-18 22:26:48.479171: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1257] Device interconnect
StreamExecutor with strength 1 edge matrix:
2022-01-18 22:26:48.479218: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1263]      0
2022-01-18 22:26:48.479231: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1276] 0:   N
2022-01-18 22:26:48.481506: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:48.482152: I
tensorflow/stream_executor/cuda/cuda_gpu_executor.cc:982] successful NUMA node
read from SysFS had negative value (-1), but there must be at least one NUMA
node, so returning NUMA node zero
2022-01-18 22:26:48.482693: I
tensorflow/core/common_runtime/gpu/gpu_device.cc:1402] Created TensorFlow device
(/job:localhost/replica:0/task:0/device:GPU:0 with 4420 MB memory) -> physical
GPU (device: 0, name: GeForce GTX 1060 6GB, pci bus id: 0000:04:00.0, compute
capability: 6.1)
2022-01-18 22:26:49.514718: I
tensorflow/stream_executor/platform/default/dso_loader.cc:48] Successfully
```

```
opened dynamic library libcublas.so.10

Training time: 66.49229383468628s
WARNING:tensorflow:From /home/khiem/anaconda3/lib/python3.8/site-
packages/tensorflow/python/training/tracking/tracking.py:111:
Model.state_updates (from tensorflow.python.keras.engine.training) is deprecated
and will be removed in a future version.
Instructions for updating:
This property should not be used in TensorFlow 2.0, as updates are applied
automatically.
WARNING:tensorflow:From /home/khiem/anaconda3/lib/python3.8/site-
packages/tensorflow/python/training/tracking/tracking.py:111: Layer.updates
(from tensorflow.python.keras.engine.base_layer) is deprecated and will be
removed in a future version.
Instructions for updating:
This property should not be used in TensorFlow 2.0, as updates are applied
automatically.

2022-01-18 22:27:55.915142: W tensorflow/python/util/util.cc:348] Sets are not
currently considered sequences, but this may change in the future, so consider
avoiding using them.

INFO:tensorflow:Assets written to:
../reports/models/nn_MRT_small_office_model.pkl/assets
Mean squared error: 0.06137310958422803
```

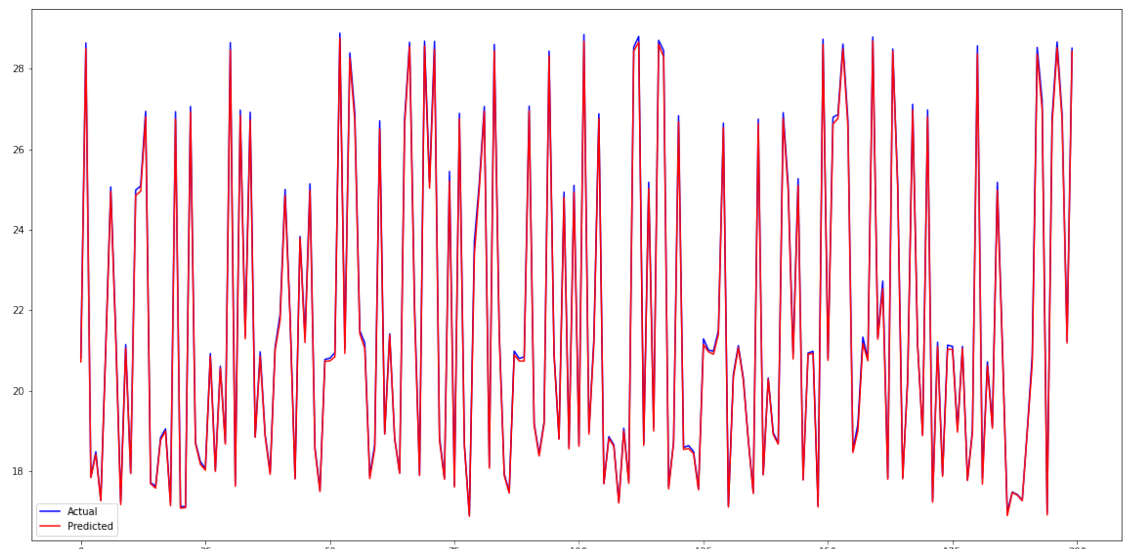


3.3.2 With PCA

[9]:
```
# Train the model
start = time.time()
model.fit(X_train_pca, y_train_pca, epochs=100, verbose=0)
```

```python
stop = time.time()
nn_pca_train_time = stop - start
print(f"Training time: {nn_pca_train_time}s")

# Predict on test data
y_pred_nn_pca = model.predict(X_test_pca)
model.save('../reports/models/nn_MRT_pca_small_office_model.pkl')

# Evaluate the model
mse = mean_squared_error(y_test_pca, y_pred_nn_pca)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test_pca[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_nn_pca[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 64.83526039123535s
INFO:tensorflow:Assets written to:
../reports/models/nn_MRT_pca_small_office_model.pkl/assets
Mean squared error: 0.012783482480221155
```



[10]:
```python
# Save training times to a csv file
import csv
```

```
with open('../reports/data/training_times_small_office_MRT.csv', 'w') as␣
↪csvfile:
    writer = csv.writer(csvfile)
    writer.writerow(['Model', 'Training time (s)'])
    writer.writerow(['Linear regression', lr_train_time])
    writer.writerow(['Linear regression with PCA', lr_pca_train_time])
    writer.writerow(['Neural network', nn_train_time])
    writer.writerow(['Neural network with PCA', nn_pca_train_time])
```

1.1.4 4. Compare models' results with and without PCA on predicting T

4.1 Split the data into training and testing

[11]:
```
# Split the data into training and testing
from sklearn.model_selection import train_test_split

# Without PCA
X_train, X_test, y_train, y_test = train_test_split(X_std, y_T, test_size=0.2,␣
↪random_state=42)

# With PCA
X_train_pca, X_test_pca, y_train_pca, y_test_pca = train_test_split(X_pca, y_T,␣
↪test_size=0.2, random_state=42)
```

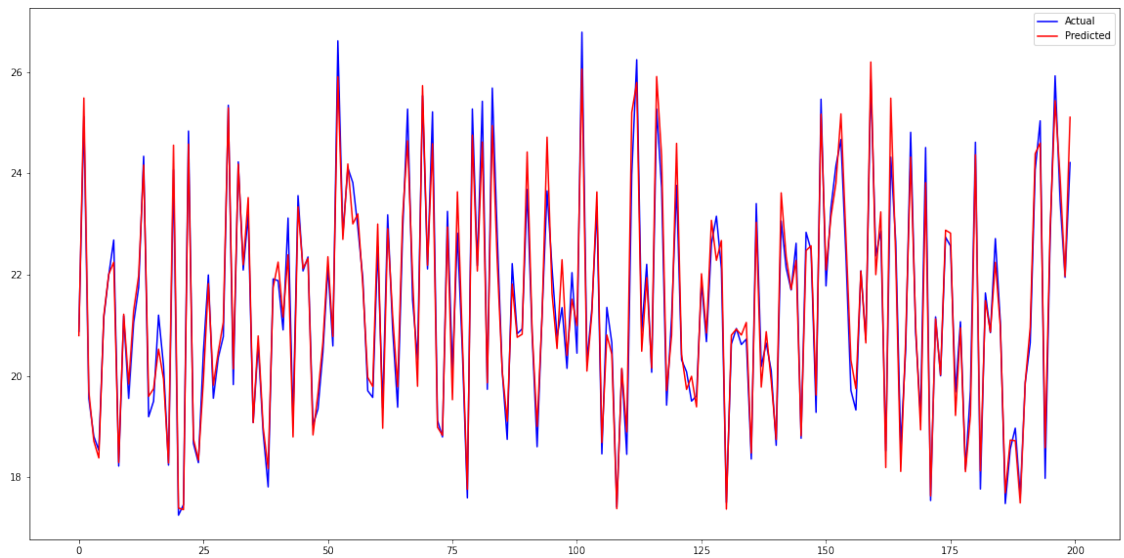
4.2 Train and evaluate the Linear Regression model

4.2.1 Without PCA

[12]:
```
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error
import pickle
import time

# Train linear regression model on training data
model = LinearRegression()
start = time.time()
model.fit(X_train, y_train)
stop = time.time()
lr_train_time = stop - start
print(f"Training time: {lr_train_time}s")

# Save the model to a pickle file
filename = '../reports/models/lr_T_small_office_model.pkl'
pickle.dump(model, open(filename, 'wb'))

# Predict on test data
y_pred = model.predict(X_test)
```

```
# Evaluate the model
mse = mean_squared_error(y_test, y_pred)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 0.004322052001953125s
Mean squared error: 0.16577728412217882
```

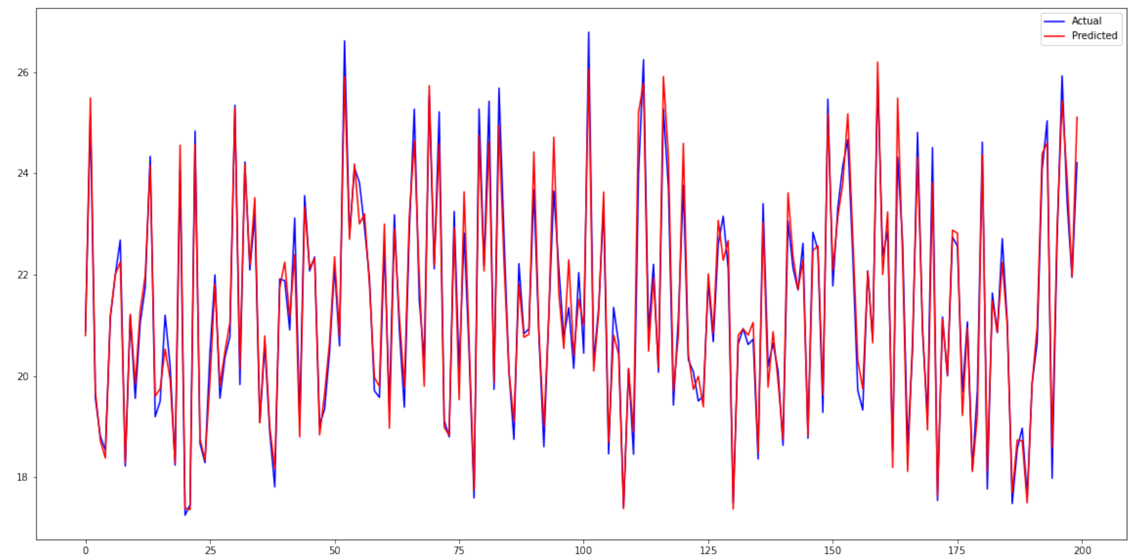


4.2.2 With PCA

[13]:
```
# Train linear regression model on training data
start = time.time()
model.fit(X_train_pca, y_train_pca)
stop = time.time()
lr_pca_train_time = stop - start
print(f"Training time: {lr_pca_train_time}s")

# Predict on test data
y_pred_pca = model.predict(X_test_pca)

# Save the model to a pickle file
filename = '../reports/models/lr_T_pca_small_office_model.pkl'
pickle.dump(model, open(filename, 'wb'))
```

```python
# Evaluate the model
mse = mean_squared_error(y_test_pca, y_pred_pca)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test_pca[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_pca[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 0.008044004440307617s
Mean squared error: 0.1657772841221792
```



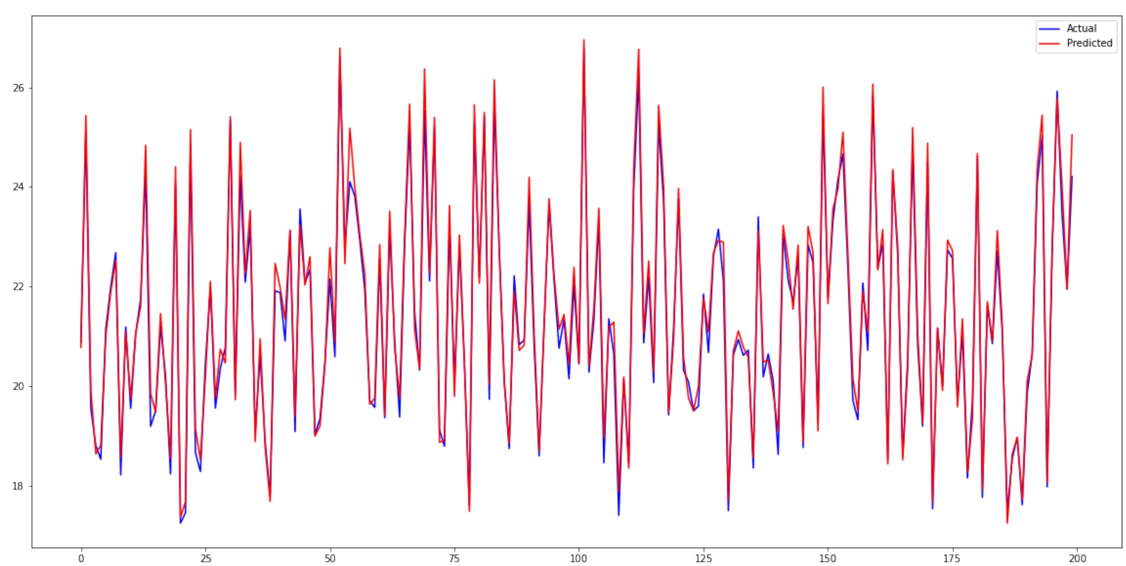
4.3 Train and evaluate the Feedforward Neural Network model

4.2.1 Without PCA

[14]:
```python
# Create neural network model
from keras.models import Sequential
from keras.layers import Dense

N_NEURONS = 1024
N_LAYERS = 4

model = Sequential()
model.add(Dense(units=N_NEURONS, input_dim=X.shape[1], activation='relu'))
for i in range(N_LAYERS-1):
```

```python
    model.add(Dense(units=N_NEURONS, activation='relu'))
model.add(Dense(units=1, activation='linear')) # Output layer
model.compile(loss='mean_squared_error', optimizer='adam')

# Train the model
start = time.time()
model.fit(X_train, y_train, epochs=100, verbose=0)
stop = time.time()
nn_train_time = stop - start
print(f"Training time: {nn_train_time}s")

# Predict on test data
y_pred_nn = model.predict(X_test)
model.save('../reports/models/nn_T_small_office_model.pkl')

# Evaluate the model
mse = mean_squared_error(y_test, y_pred_nn)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_nn[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

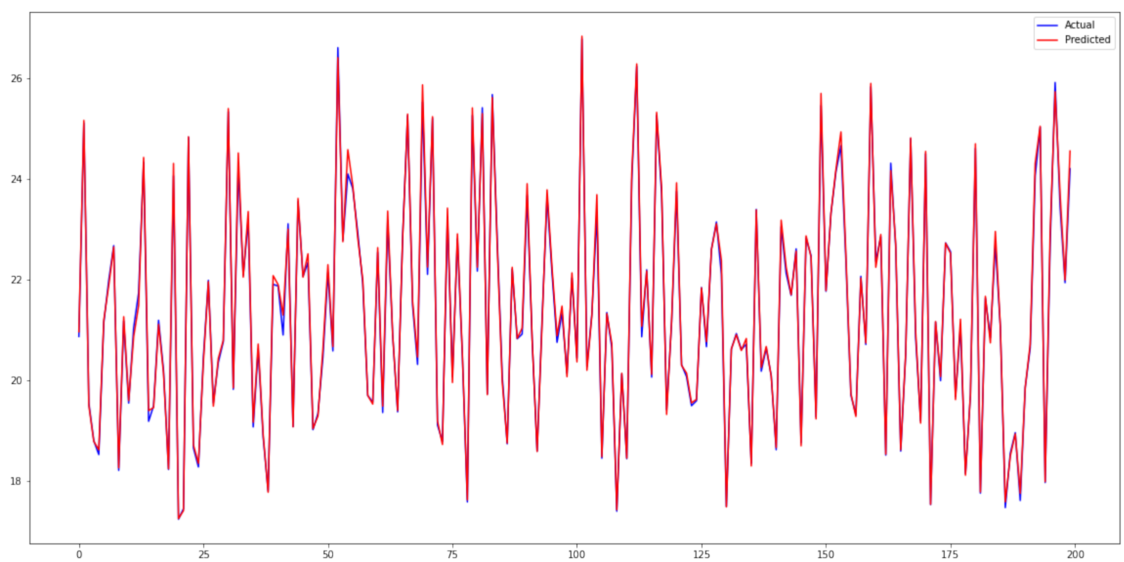
```
Training time: 67.4417929649353s
INFO:tensorflow:Assets written to:
../reports/models/nn_T_small_office_model.pkl/assets
Mean squared error: 0.08417043735503117
```



4.3.2 With PCA

[15]:
```
# Train the model
start = time.time()
model.fit(X_train_pca, y_train_pca, epochs=100, verbose=0)
stop = time.time()
nn_pca_train_time = stop - start
print(f"Training time: {nn_pca_train_time}s")

# Predict on test data
y_pred_nn_pca = model.predict(X_test_pca)
model.save('../reports/models/nn_T_pca_small_office_model.pkl')

# Evaluate the model
mse = mean_squared_error(y_test_pca, y_pred_nn_pca)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test_pca[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_nn_pca[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 66.73648047447205s
INFO:tensorflow:Assets written to:
../reports/models/nn_T_pca_small_office_model.pkl/assets
Mean squared error: 0.015143678320327581
```



[16]:
```python
# Save training times to a csv file
import csv

with open('../reports/data/training_times_small_office_T.csv', 'w') as csvfile:
    writer = csv.writer(csvfile)
    writer.writerow(['Model', 'Training time (s)'])
    writer.writerow(['Linear regression', lr_train_time])
    writer.writerow(['Linear regression with PCA', lr_pca_train_time])
    writer.writerow(['Neural network', nn_train_time])
    writer.writerow(['Neural network with PCA', nn_pca_train_time])
```

1.1.5 5. Compare models' results with and without PCA on predicting V

5.1 Split the data into training and testing

[17]:
```python
# Split the data into training and testing
from sklearn.model_selection import train_test_split

# Without PCA
X_train, X_test, y_train, y_test = train_test_split(X_std, y_V, test_size=0.2,␣
↪random_state=42)

# With PCA
X_train_pca, X_test_pca, y_train_pca, y_test_pca = train_test_split(X_pca, y_V,␣
↪test_size=0.2, random_state=42)
```

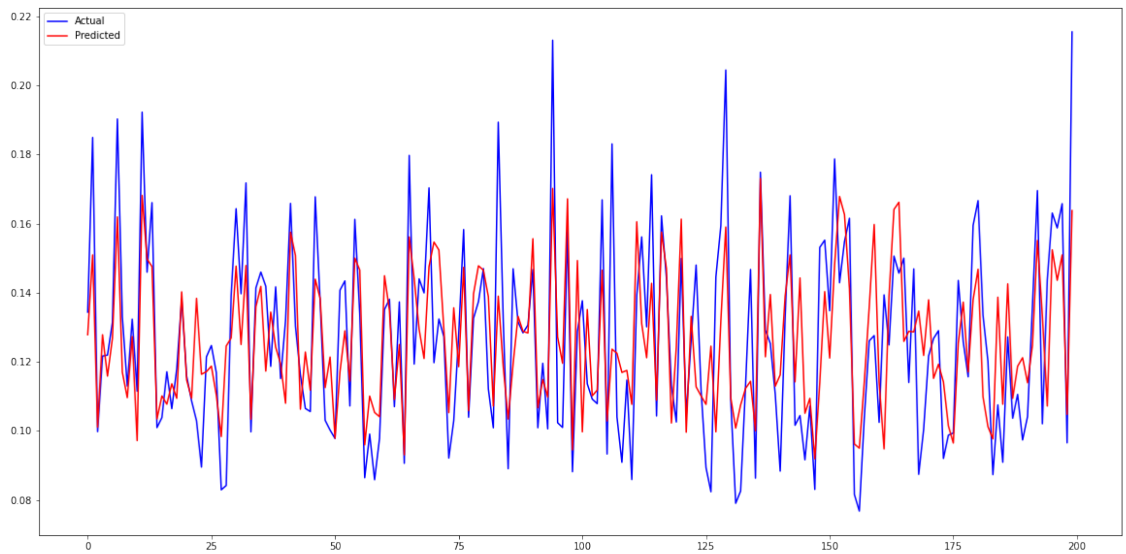
5.2 Train and evaluate the Linear Regression model

5.2.1 Without PCA

[18]:
```python
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error
import pickle
import time

# Train linear regression model on training data
model = LinearRegression()
start = time.time()
model.fit(X_train, y_train)
stop = time.time()
lr_train_time = stop - start
print(f"Training time: {lr_train_time}s")

# Save the model to a pickle file
filename = '../reports/models/lr_V_small_office_model.pkl'
pickle.dump(model, open(filename, 'wb'))
```

```
# Predict on test data
y_pred = model.predict(X_test)

# Evaluate the model
mse = mean_squared_error(y_test, y_pred)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 0.006689786911010742s
Mean squared error: 0.00040041562423062617
```

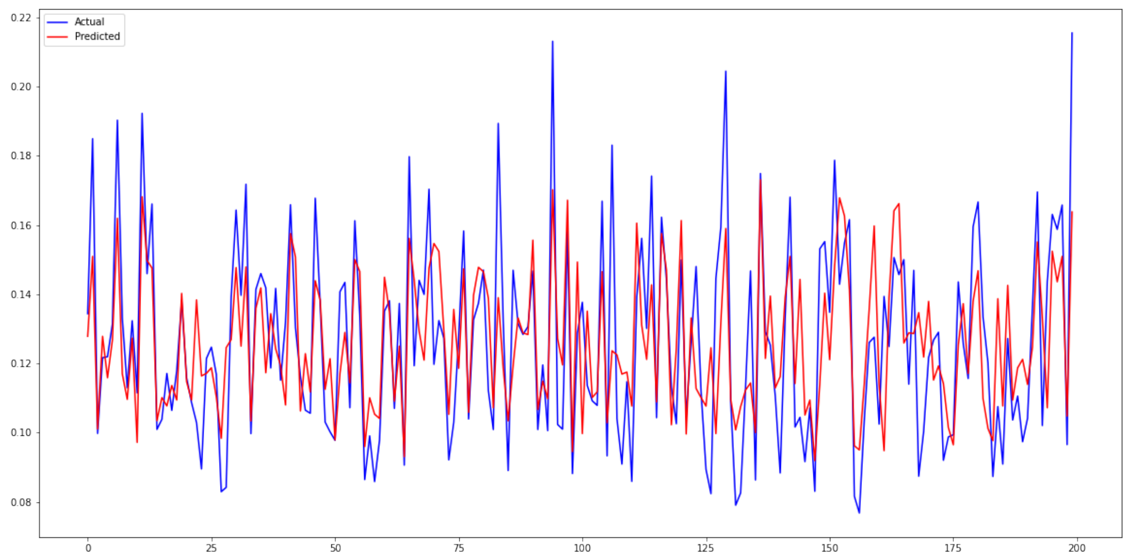


5.2.2 With PCA

[19]:
```
# Train linear regression model on training data
start = time.time()
model.fit(X_train_pca, y_train_pca)
stop = time.time()
lr_pca_train_time = stop - start
print(f"Training time: {lr_pca_train_time}s")

# Predict on test data
y_pred_pca = model.predict(X_test_pca)
```

```
# Save the model to a pickle file
filename = '../reports/models/lr_V_pca_small_office_model.pkl'
pickle.dump(model, open(filename, 'wb'))

# Evaluate the model
mse = mean_squared_error(y_test_pca, y_pred_pca)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test_pca[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_pca[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 0.007543802261352539s
Mean squared error: 0.00040041562423062617
```



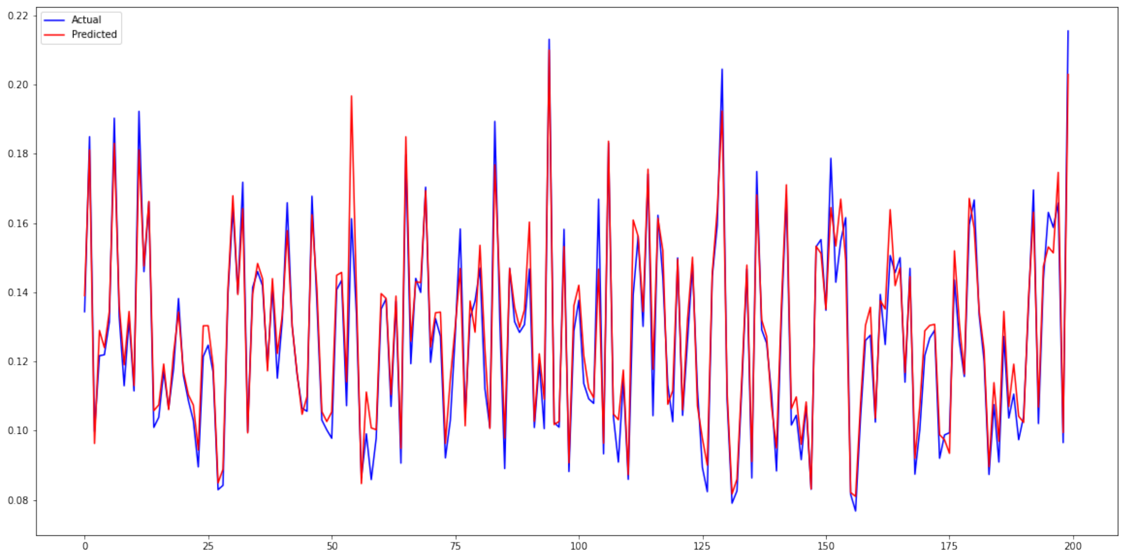
5.3 Train and evaluate the Feedforward Neural Network model

5.2.1 Without PCA

[20]:
```
# Create neural network model
from keras.models import Sequential
from keras.layers import Dense

N_NEURONS = 1024
N_LAYERS = 4
```

```python
model = Sequential()
model.add(Dense(units=N_NEURONS, input_dim=X.shape[1], activation='relu'))
for i in range(N_LAYERS-1):
    model.add(Dense(units=N_NEURONS, activation='relu'))
model.add(Dense(units=1, activation='linear')) # Output layer
model.compile(loss='mean_squared_error', optimizer='adam')

# Train the model
start = time.time()
model.fit(X_train, y_train, epochs=100, verbose=0)
stop = time.time()
nn_train_time = stop - start
print(f"Training time: {nn_train_time}s")

# Predict on test data
y_pred_nn = model.predict(X_test)
model.save('../reports/models/nn_V_small_office_model.pkl')

# Evaluate the model
mse = mean_squared_error(y_test, y_pred_nn)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_nn[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

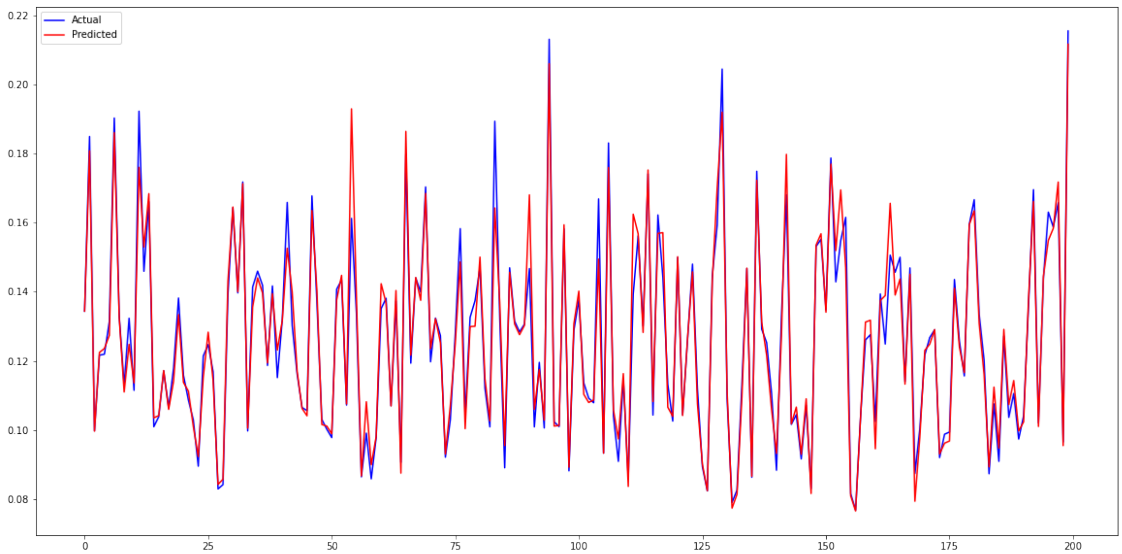
```
Training time: 64.67390871047974s
INFO:tensorflow:Assets written to:
../reports/models/nn_V_small_office_model.pkl/assets
Mean squared error: 5.5294132801361714e-05
```



5.3.2 With PCA

[21]:
```
# Train the model
start = time.time()
model.fit(X_train_pca, y_train_pca, epochs=100, verbose=0)
stop = time.time()
nn_pca_train_time = stop - start
print(f"Training time: {nn_pca_train_time}s")

# Predict on test data
y_pred_nn_pca = model.predict(X_test_pca)
model.save('../reports/models/nn_V_pca_small_office_model.pkl')

# Evaluate the model
mse = mean_squared_error(y_test_pca, y_pred_nn_pca)
print(f'Mean squared error: {mse}')

# Plot the predictions and actual values
plt.figure(figsize=(20,10))
plt.plot(range(200), y_test_pca[:200], color='blue', label='Actual')
plt.plot(range(200), y_pred_nn_pca[:200], color='red', label='Predicted')
plt.legend()
plt.show()
```

```
Training time: 63.3362193107605s
INFO:tensorflow:Assets written to:
../reports/models/nn_V_pca_small_office_model.pkl/assets
Mean squared error: 5.3816516939632154e-05
```



[22]:

```python
# Save training times to a csv file
import csv

with open('../reports/data/training_times_small_office_V.csv', 'w') as csvfile:
    writer = csv.writer(csvfile)
    writer.writerow(['Model', 'Training time (s)'])
    writer.writerow(['Linear regression', lr_train_time])
    writer.writerow(['Linear regression with PCA', lr_pca_train_time])
    writer.writerow(['Neural network', nn_train_time])
    writer.writerow(['Neural network with PCA', nn_pca_train_time])
```