pca_conference_room

January 18, 2022

1 Principal Component Analysis

Below are the Principal Component Analysis on the first 13 features:

1. index: Index for each data point
2. sim: Index for each simulation
3. tem: Temperature of air supplied to the zone (°C)
4. mass: Total mass flow rate of air supply to the zone (kg/s)
5. n: North Wall Temperature (°C)
6. w: West Wall Temperature (°C)
7. s: South Wall Temperature (°C)
8. sw: South Window Temperature (°C)
9. e: East Wall Temperature (°C)
10. ew: East Window Temperature (°C)
11. floor: Floor Temperature (°C)
12. ceiling: Ceiling Temperature (°C)
13. n_occ: Number of occupants in zone
14. x: location of occupant of interest on x-axis (m)
15. 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)

[9]:
```
data_loc = '../data/preprocessed/'
```

1.1 Conference Room

1.1.1 1. Standardize the data

[10]:
```
import pandas as pd
from sklearn.preprocessing import StandardScaler

con_room_data = pd.read_csv(data_loc+"conference_room.csv")

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

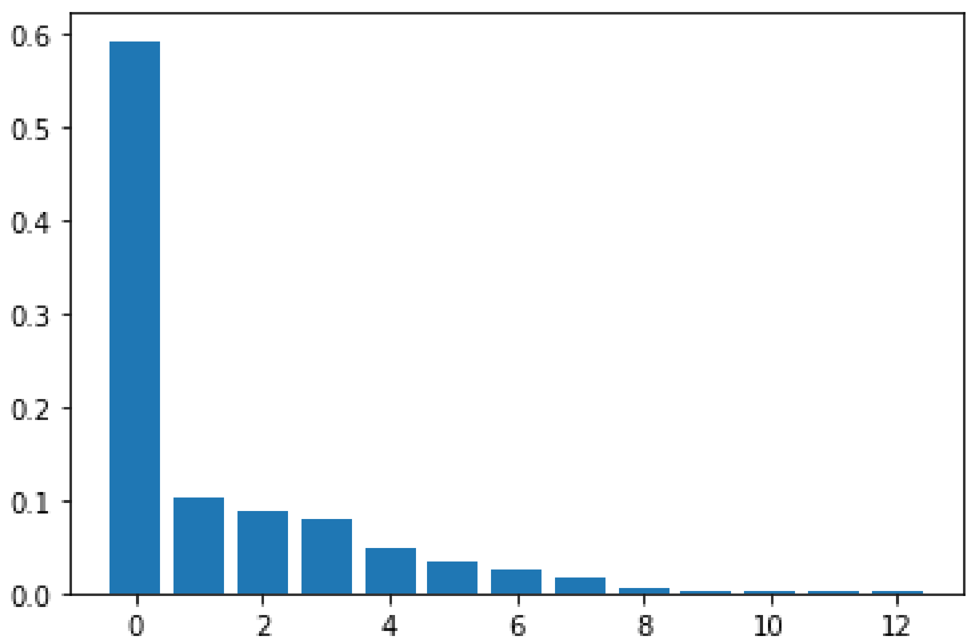
```python
# Seperate the data into features and labels
X = con_room_data.drop(columns=['MRT', 'T', 'V'])
y_MRT = con_room_data['MRT']
y_T = con_room_data['T']
y_V = con_room_data['V']

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

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

[10]:

```
                tem          mass             n             w             s  \
count  2.095800e+04  2.095800e+04  2.095800e+04  2.095800e+04  2.095800e+04
mean  -4.310471e-17 -4.757569e-17  8.324540e-16  2.804879e-16 -3.261234e-16
std    1.000024e+00  1.000024e+00  1.000024e+00  1.000024e+00  1.000024e+00
min   -1.475736e+00 -1.580859e+00 -2.757295e+00 -2.813610e+00 -2.518167e+00
25%   -8.367246e-01 -7.712921e-01 -4.492384e-01 -6.161947e-01 -4.785246e-01
50%   -1.977131e-01 -1.930300e-01  1.277757e-01  4.825129e-01  3.373321e-01
75%    7.608042e-01  7.321895e-01  7.047898e-01  4.825129e-01  7.452605e-01
max    4.275367e+00  1.888714e+00  1.281804e+00  1.581220e+00  1.561117e+00

                 sw             e            ew         floor       ceiling  \
count  2.095800e+04  2.095800e+04  2.095800e+04  2.095800e+04  2.095800e+04
mean   1.493481e-16 -6.394761e-16  8.086702e-17 -3.902229e-16  8.464716e-16
std    1.000024e+00  1.000024e+00  1.000024e+00  1.000024e+00  1.000024e+00
min   -2.552468e+00 -2.492894e+00 -2.478706e+00 -2.867409e+00 -2.893951e+00
25%   -5.250738e-01 -5.087353e-01 -4.909610e-01 -4.279673e-01 -4.354616e-01
50%    8.314466e-02  2.849281e-01  1.053624e-01  5.992101e-02  5.479341e-01
75%    6.913631e-01  6.817599e-01  7.016859e-01  5.478093e-01  5.479341e-01
max    2.516018e+00  1.475423e+00  2.490656e+00  1.523586e+00  1.039632e+00

              n occ             x             y
count  2.095800e+04  2.095800e+04  2.095800e+04
mean  -3.272447e-14  3.813283e-14 -9.820309e-15
std    1.000024e+00  1.000024e+00  1.000024e+00
min   -1.674496e+00 -1.133249e+00 -1.282534e+00
25%   -8.380860e-01 -1.133249e+00 -1.282534e+00
50%    8.347336e-01 -2.697370e-01 -2.252214e-01
75%    8.347336e-01  9.039089e-01  1.160499e+00
max    8.347336e-01  1.773502e+00  1.160499e+00
```

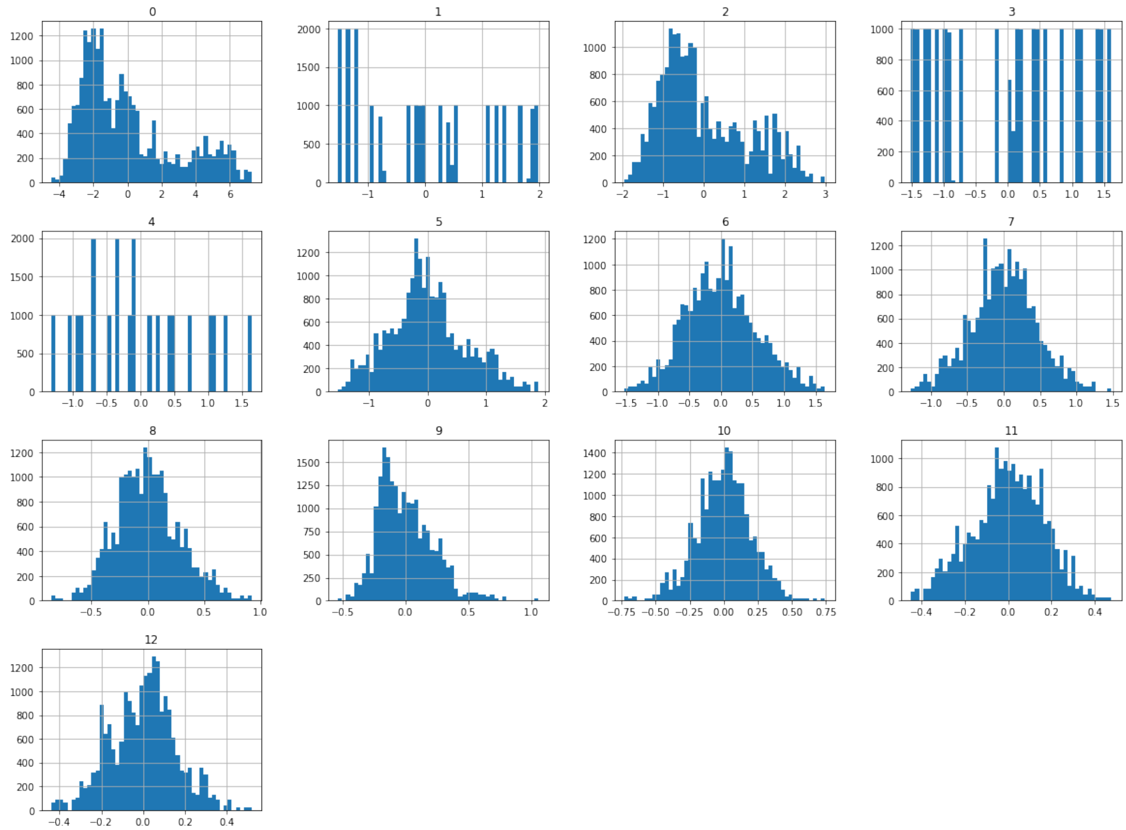
1.1.2 2. Perform PCA

[11]:
```
# 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_conference_room_eigenvectors.csv", e_vectors,␣
↪delimiter=',')

plt.bar(range(len(evr)), evr)
plt.savefig('../figures/evr_pca_conference_room.png')
```



[12]:
```
# 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_conference_room.png')
```

```
/tmp/ipykernel_54312/4093233920.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

[13]:
```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)
```

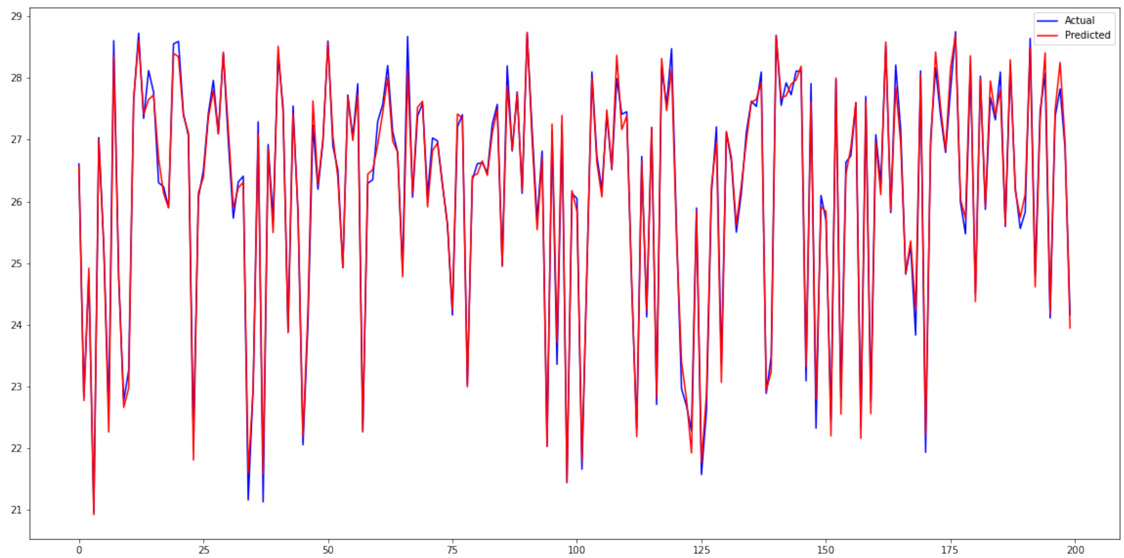
3.2 Train and evaluate the Linear Regression model

3.2.1 Without PCA

[14]:

```
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_conference_room_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()
```

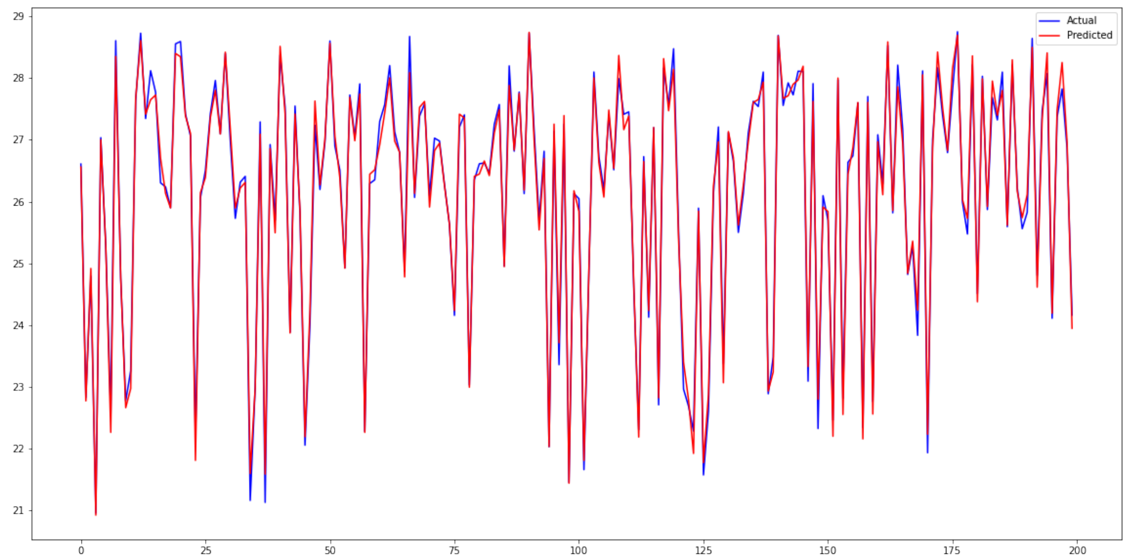
```
Training time: 0.012637376785278320s
Mean squared error: 0.036303047735584584
```



3.2.2 With PCA

[15]:
```
# 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_conference_room_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: 0.014313220977783203s
Mean squared error: 0.03630304773558465
```



3.3 Train and evaluate the Feedforward Neural Network model

3.2.1 Without PCA

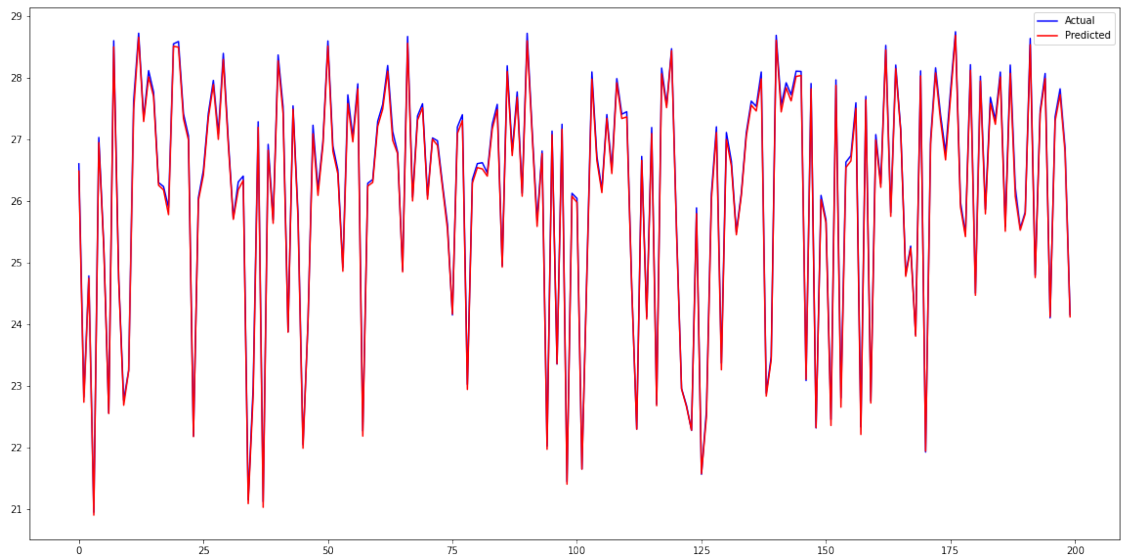
[16]:
```
# Create neural network model
from keras.models import Sequential
from keras.layers import Dense

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_conference_room_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()
```

```
Training time: 190.46492838859558s
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 14:04:03.738644: 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.
```

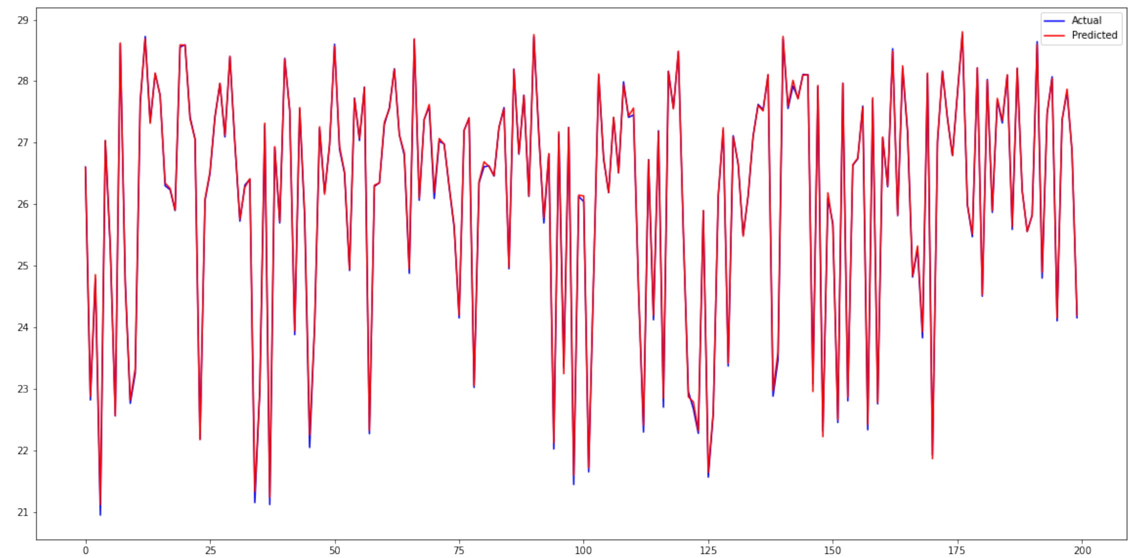
```
INFO:tensorflow:Assets written to:
../reports/models/nn_MRT_conference_room_model.pkl/assets
Mean squared error: 0.005940737672679868
```



3.3.2 With PCA

[17]:
```
# 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_MRT_pca_conference_room_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: 200.48521423339844s
INFO:tensorflow:Assets written to:
../reports/models/nn_MRT_pca_conference_room_model.pkl/assets
Mean squared error: 0.0023151260541025287
```




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

with open('../reports/data/training_times_conference_room_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

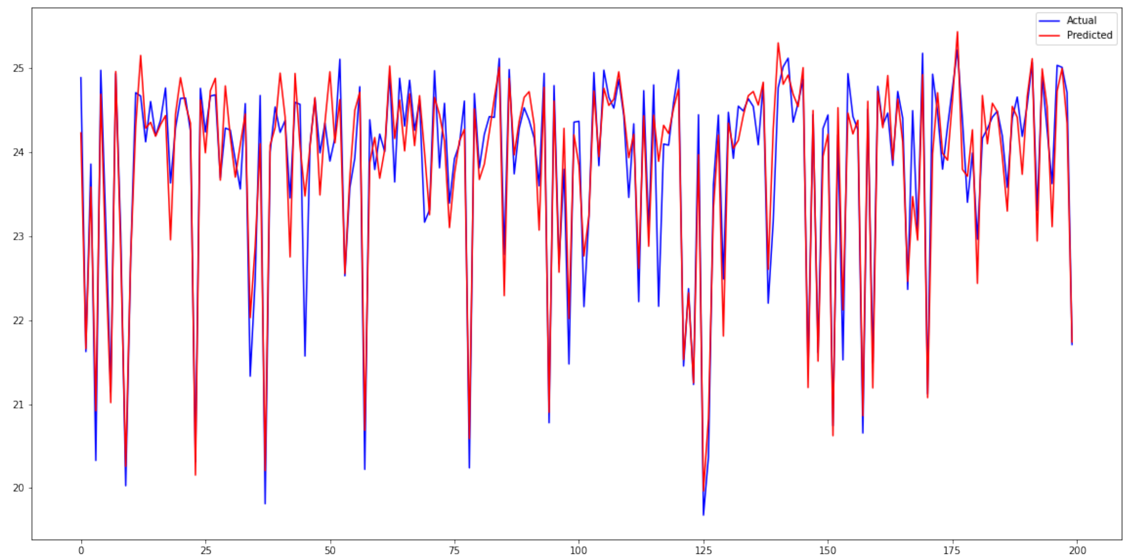
```
[19]: # Split the data into training and testing
from sklearn.model_selection import train_test_split

# 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

[20]:
```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_T_conference_room_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()
```

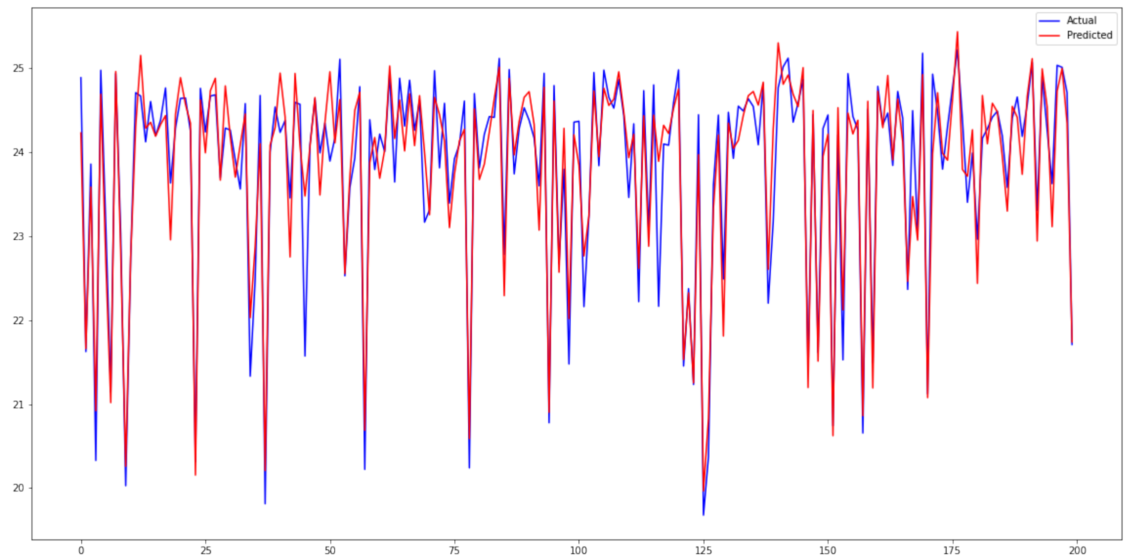
```
Training time: 0.009361028671264648s
Mean squared error: 0.13248888237360454
```



4.2.2 With PCA

[21]:
```
# 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_conference_room_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: 0.011274337768554688s
Mean squared error: 0.13248888237360457
```



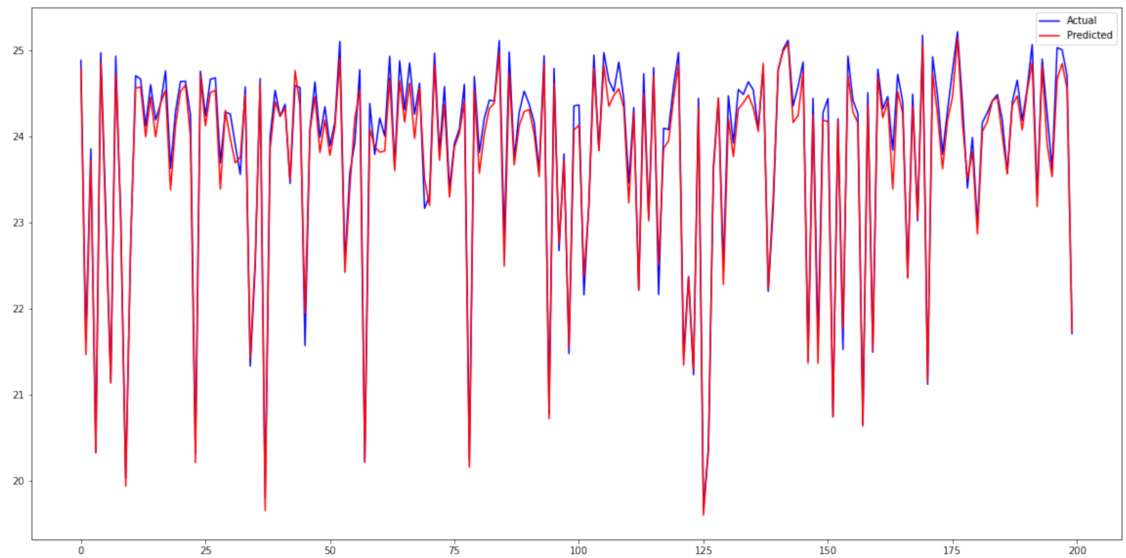
4.3 Train and evaluate the Feedforward Neural Network model

4.2.1 Without PCA

[22]:
```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):
    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_conference_room_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: 198.21673274040222s
INFO:tensorflow:Assets written to:
../reports/models/nn_T_conference_room_model.pkl/assets
Mean squared error: 0.028228071596030416
```

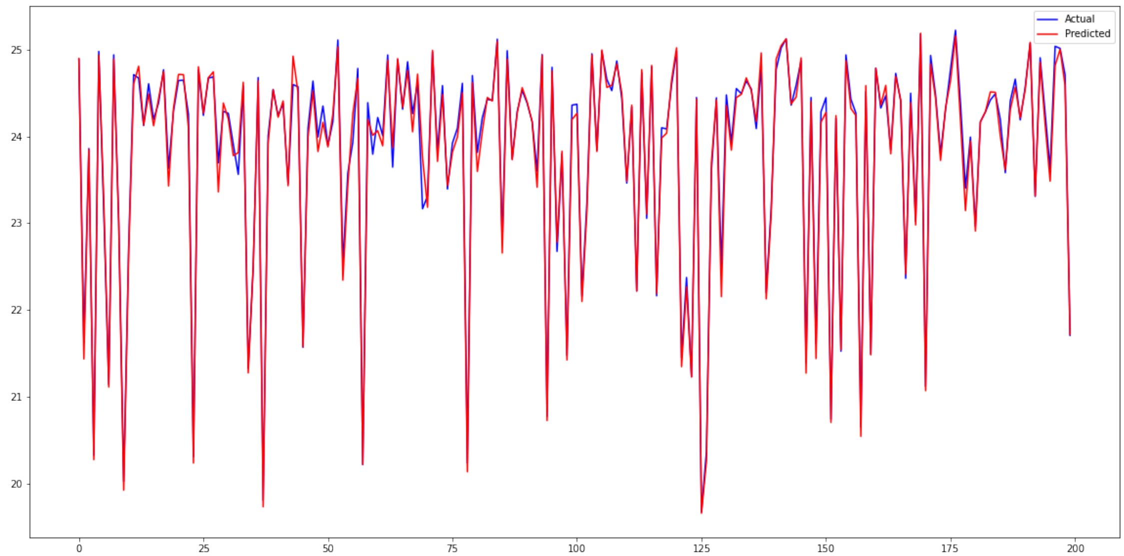


4.3.2 With PCA

[23]:
```
# 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_conference_room_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: 199.61321687698364s
INFO:tensorflow:Assets written to:
../reports/models/nn_T_pca_conference_room_model.pkl/assets
Mean squared error: 0.01676264223699558
```



[24]:
```
# Save training times to a csv file
import csv

with open('../reports/data/training_times_conference_room_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

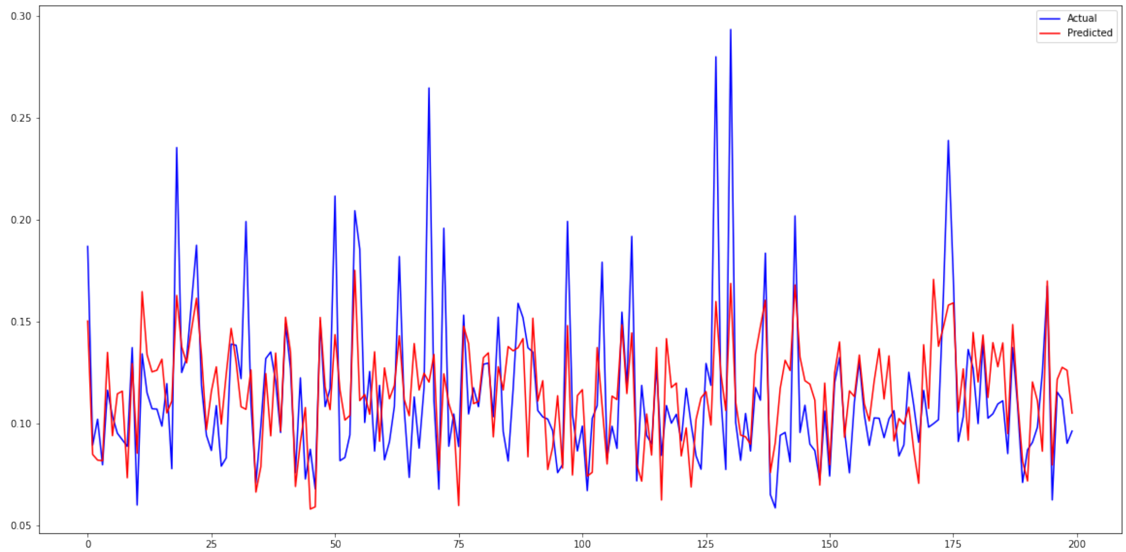
[25]:
```
# Split the data into training and testing
from sklearn.model_selection import train_test_split

# 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

[26]:
```
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_conference_room_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()
```

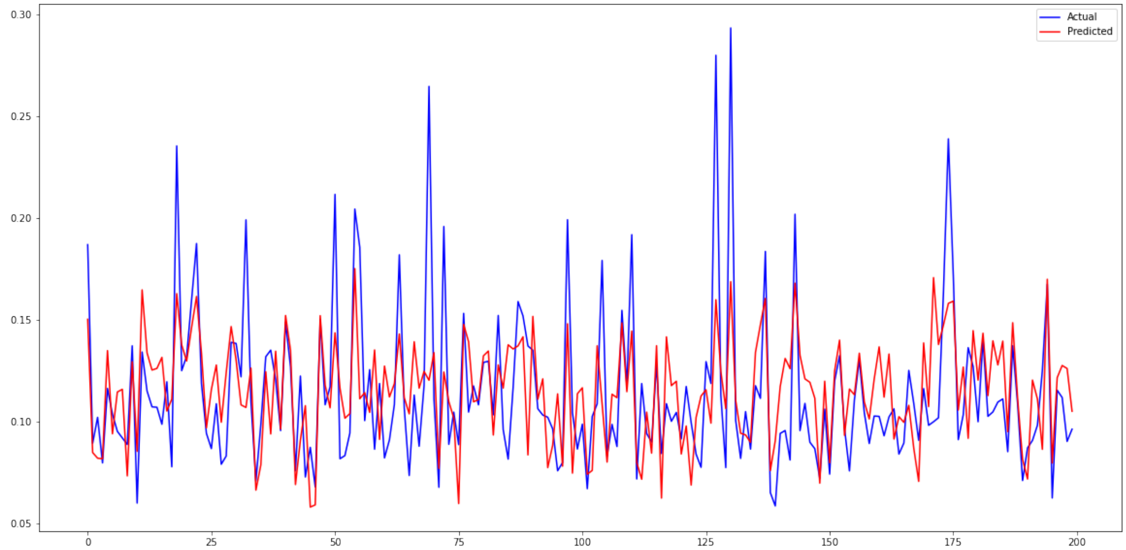
```
Training time: 0.014678001403808594s
Mean squared error: 0.001118630731868217
```



5.2.2 With PCA

[27]:
```python
# 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_conference_room_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: 0.012313365936279297s
Mean squared error: 0.001118630731868217
```



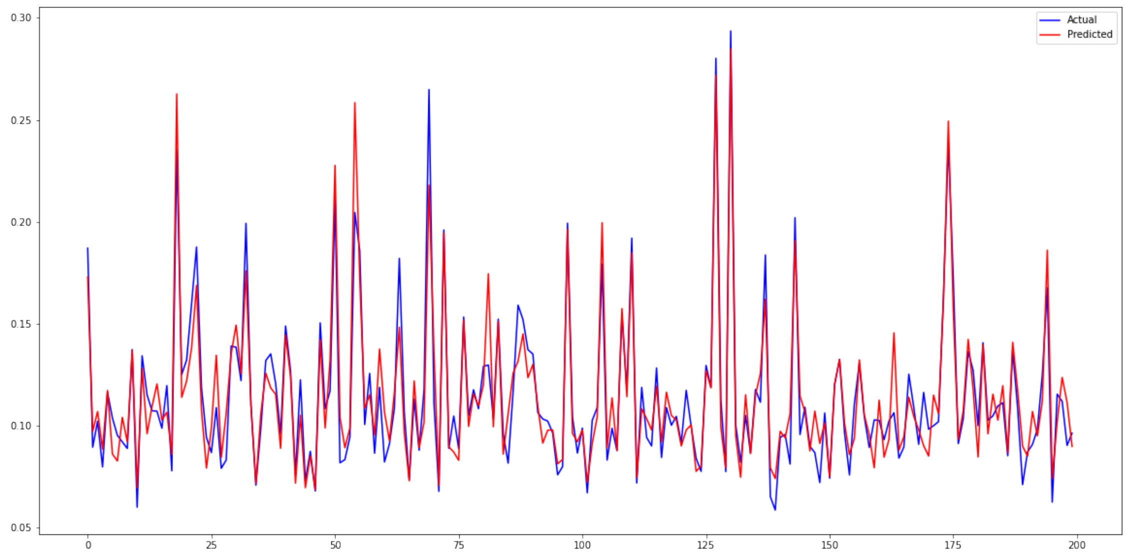
5.3 Train and evaluate the Feedforward Neural Network model

5.2.1 Without PCA

[28]:
```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):
    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
```

```python
y_pred_nn = model.predict(X_test)
model.save('../reports/models/nn_V_conference_room_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: 203.27048873901367s
INFO:tensorflow:Assets written to:
../reports/models/nn_V_conference_room_model.pkl/assets
Mean squared error: 0.0003013890718162625
```

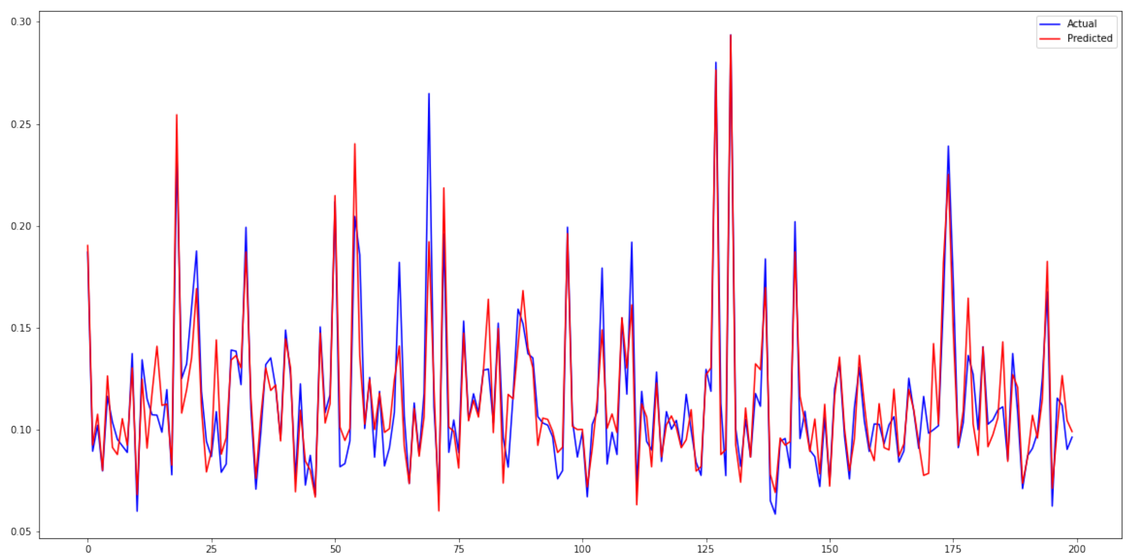


5.3.2 With PCA

[29]:
```python
# 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_conference_room_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: 193.58191180229187s
INFO:tensorflow:Assets written to:
../reports/models/nn_V_pca_conference_room_model.pkl/assets
Mean squared error: 0.00030001247540154495
```



[30]:

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

with open('../reports/data/training_times_conference_room_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])
```