Prediction of the star temperature

Content

Project Description

Astronomy company would like to define the temperature on the surface of the newly spotted stars. For that purpose it's required to predict the star temperature using maching learning and based on the previos data from the database of the stars.

Main tasks are:

- import and prepare data;
- perform the exploratory analysis;
- rescale the data, and split it on train and test samples;
- build neural networks;
- decalre the function for training and prediction;
- plot the comparison chart of actual and predicted star temperature;
- perfom the network tuning (using dropout, optimisers, qunatity of layers, activation functions);
- compare the models and select the best;

- RMSE score on the best network shall be 4500 or lower.

Data import

In [1]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import torch
import torch.nn as nn
from sklearn.preprocessing import OneHotEncoder,StandardScaler , MinMaxScaler
from sklearn.model_selection import train_test_split
from sklearn.metrics import mean_squared_error
```

In [10]:
```
df_stars = pd.read_csv('data_stars.csv', index_col = [0])
```

Data preparation and analysis

In [11]:
```
# display 5 first rows
df_stars.head()
```

Out[11]:

	Temperature (K)	Luminosity(L/Lo)	Radius(R/Ro)	Absolute magnitude(Mv)	Star type	Star color
0	3068	0.002400	0.1700	16.12	0	red
1	3042	0.000500	0.1542	16.60	0	red
2	2600	0.000300	0.1020	18.70	0	red
3	2800	0.000200	0.1600	16.65	0	red
4	1939	0.000138	0.1030	20.06	0	red

In [13]:
```
# display info
df_stars.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 228 entries, 0 to 239
Data columns (total 6 columns):
 #   Column                  Non-Null Count  Dtype  
---  ------                  --------------  -----  
 0   Temperature (K)         228 non-null    int64  
 1   Luminosity(L/Lo)        228 non-null    float64
 2   Radius(R/Ro)            228 non-null    float64
 3   Absolute magnitude(Mv)  228 non-null    float64
 4   Star type               228 non-null    int64  
 5   Star color              228 non-null    object 
dtypes: float64(3), int64(2), object(1)
memory usage: 12.5+ KB
```

In [14]:
```
# display the data of numeric columns
df_stars.describe()
```

Out[14]:

	Temperature (K)	Luminosity(L/Lo)	Radius(R/Ro)	Absolute magnitude(Mv)	Star type
count	228.000000	228.000000	228.000000	228.000000	228.000000
mean	10680.692982	107654.047662	236.607302	4.345969	2.473684
std	9742.810427	176985.132549	515.015990	10.664949	1.736930
min	1939.000000	0.000110	0.008400	-11.920000	0.000000
25%	3336.000000	0.000878	0.107500	-6.241250	1.000000
50%	5776.000000	0.030500	0.672500	10.260000	2.000000
75%	16417.500000	198650.000000	45.250000	13.830000	4.000000
max	40000.000000	849420.000000	1948.500000	20.060000	5.000000

In [15]:
```
# display the unique values of cuolumn star color
df_stars['Star color'].sort_values().unique()
```

Out[15]:
```
array(['blue', 'blue white', 'red', 'white', 'white-yellow'], dtype=object)
```

In [16]:
```
# format unified
df_stars['Star color'] = df_stars['Star color'].str.lower()
```

In [17]:
```
# update of the similar colors name to one format
def str_replace(color):
    if color == 'blue ':
        return 'blue'
    elif color == 'blue white ' or color == 'blue-white':
        return 'blue white'
    elif color == 'yellow-white':
        return 'white-yellow'
    else:
        return color
```

In [18]:
```
# deletion of implicit colors
correct_color = []
for i in df_stars['Star color']:
    correct_color.append(str_replace(i))
```

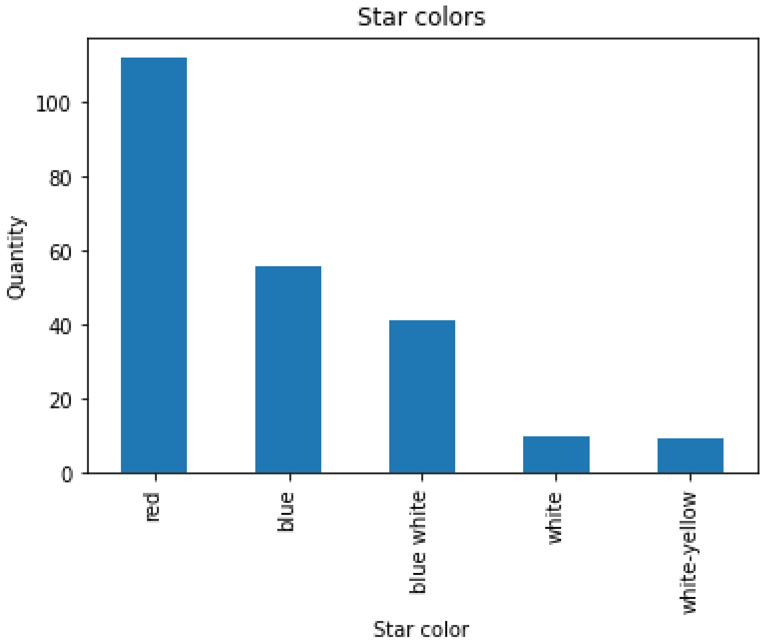
In [19]:
```
df_stars['Star color'] = correct_color
```

In [20]:
```
# plotting the color destribution

print(df_stars.groupby('Star color')['Star type'].count().sort_values(ascending=False))
df_stars.groupby('Star color')['Star type'].count().sort_values(ascending=False).plot(kind = 'bar', title = 'Star colors')
plt.xlabel('Star color')
plt.ylabel('Quantity')
```

```
Star color
red             112
blue             56
blue white       41
white            10
white-yellow      9
Name: Star type, dtype: int64
```

Out[20]:
```
Text(0, 0.5, 'Quantity')
```



In [21]:
```
# selection of stars with quantity of color less than 5
star_colors = df_stars.groupby('Star color')['Star type'].count().sort_values(ascending=False).reset_index()
star_colors = star_colors.rename(columns={"Star type": "quantity"})
star_color_good = star_colors.query('quantity > 5')['Star color']
```

In [22]:
```
# Deletion of colors with quantity of stars less than 5

df_stars = df_stars.rename(columns={"Star color": "Star_color"})
df_stars = df_stars.query('Star_color in @star_color_good')
df_stars = df_stars.rename(columns={"Star_color": "Star color"})
```

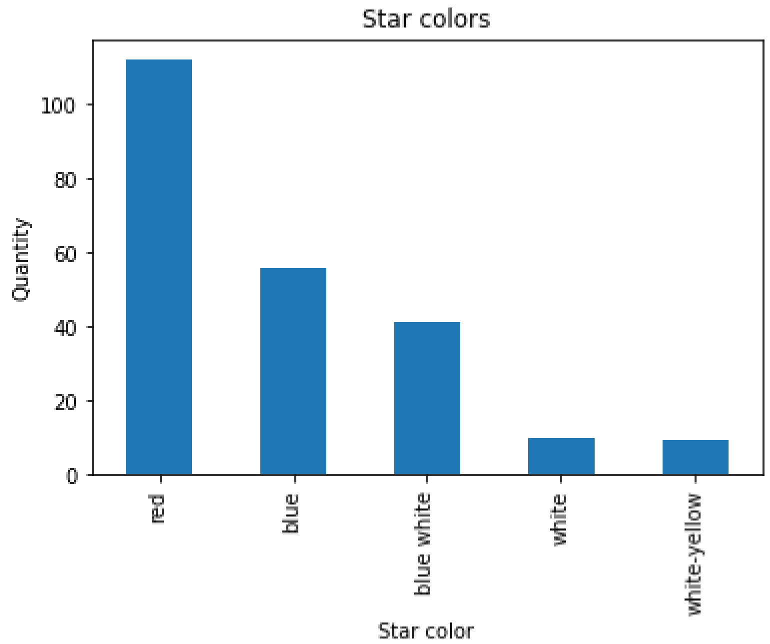
In [23]:
```
# display the color destribution table and plot it

print(df_stars.groupby('Star color')['Star type'].count().sort_values(ascending=False))
df_stars.groupby('Star color')['Star type'].count().sort_values(ascending=False).plot(kind = 'bar', title = 'Star colors')
plt.xlabel('Star color')
plt.ylabel('Quantity')
```

```
Star color
red             112
blue             56
blue white       41
white            10
white-yellow      9
Name: Star type, dtype: int64
```

Out[23]:

```
Text(0, 0.5, 'Quantity')
```



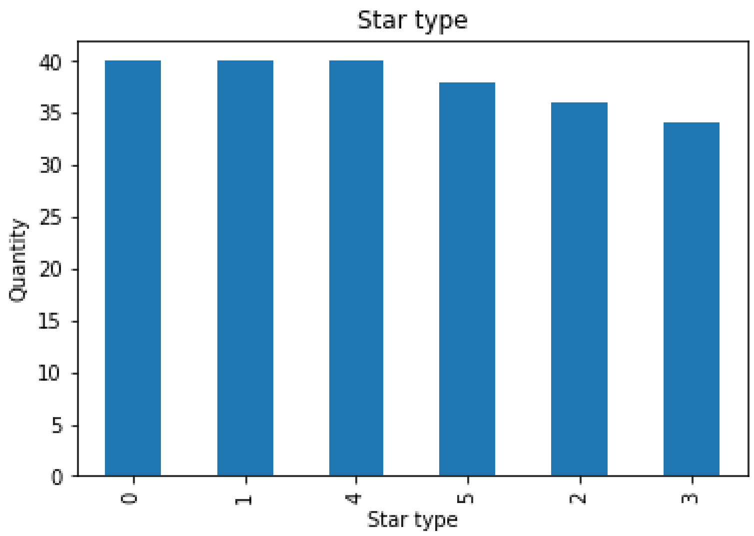
In [15]:

```
# plottinf the star type destribution

df_stars.groupby('Star type')['Unnamed: 0'].count().sort_values(ascending=False).plot(kind = 'bar', title = 'Star type')
plt.xlabel('Star type')
plt.ylabel('Quantity')
```

Out[15]:

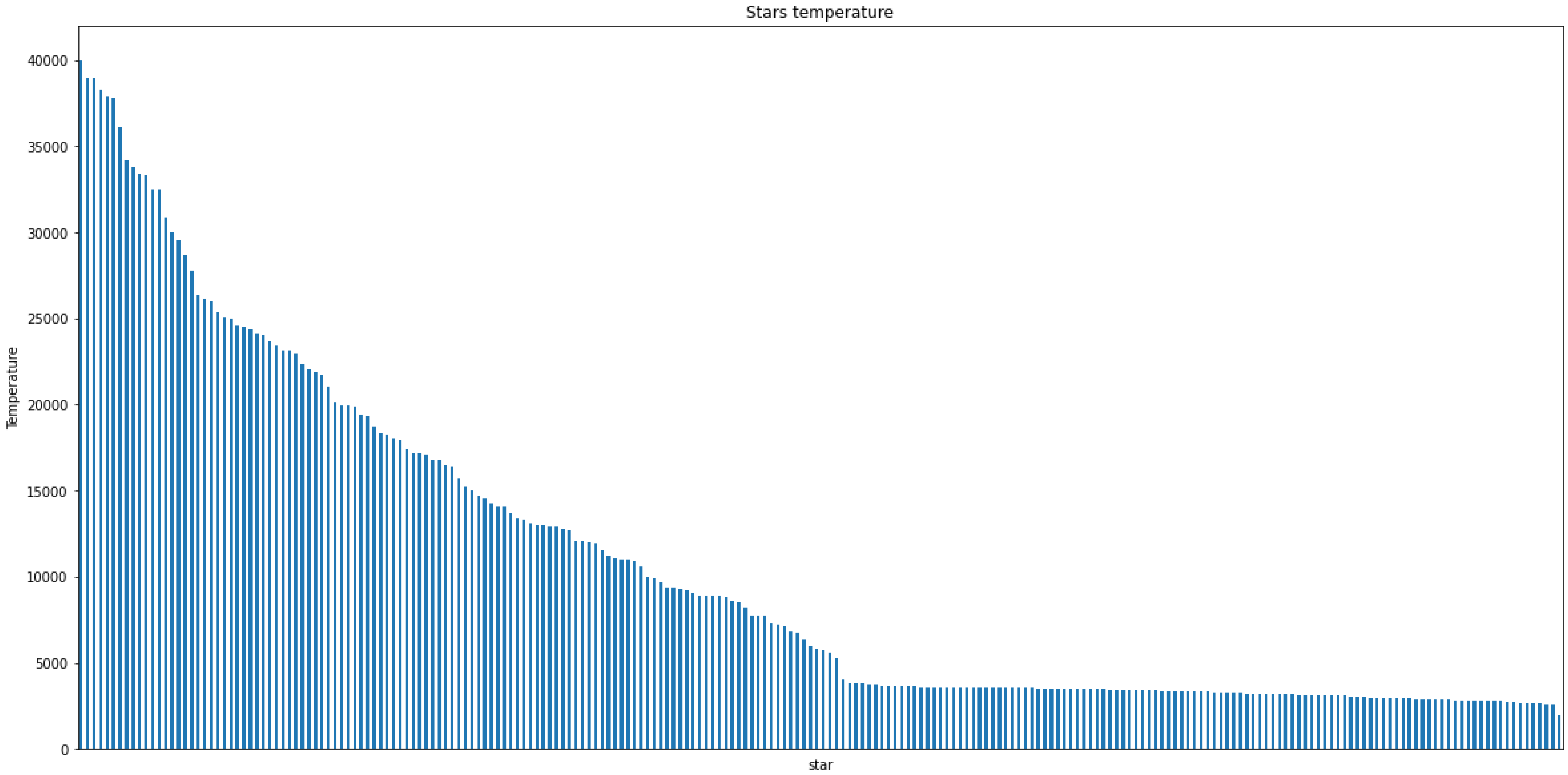
```
Text(0, 0.5, 'Quantity')
```



In [24]:
```
# plotting the stars temperature destribution

df_stars['Temperature (K)'].sort_values(ascending=False).plot(kind='bar',figsize = (20,10))
plt.xlabel('star')
plt.ylabel('Temperature')
plt.title('Stars temperature')
plt.xticks([])
```

Out[24]:
```
([], [])
```

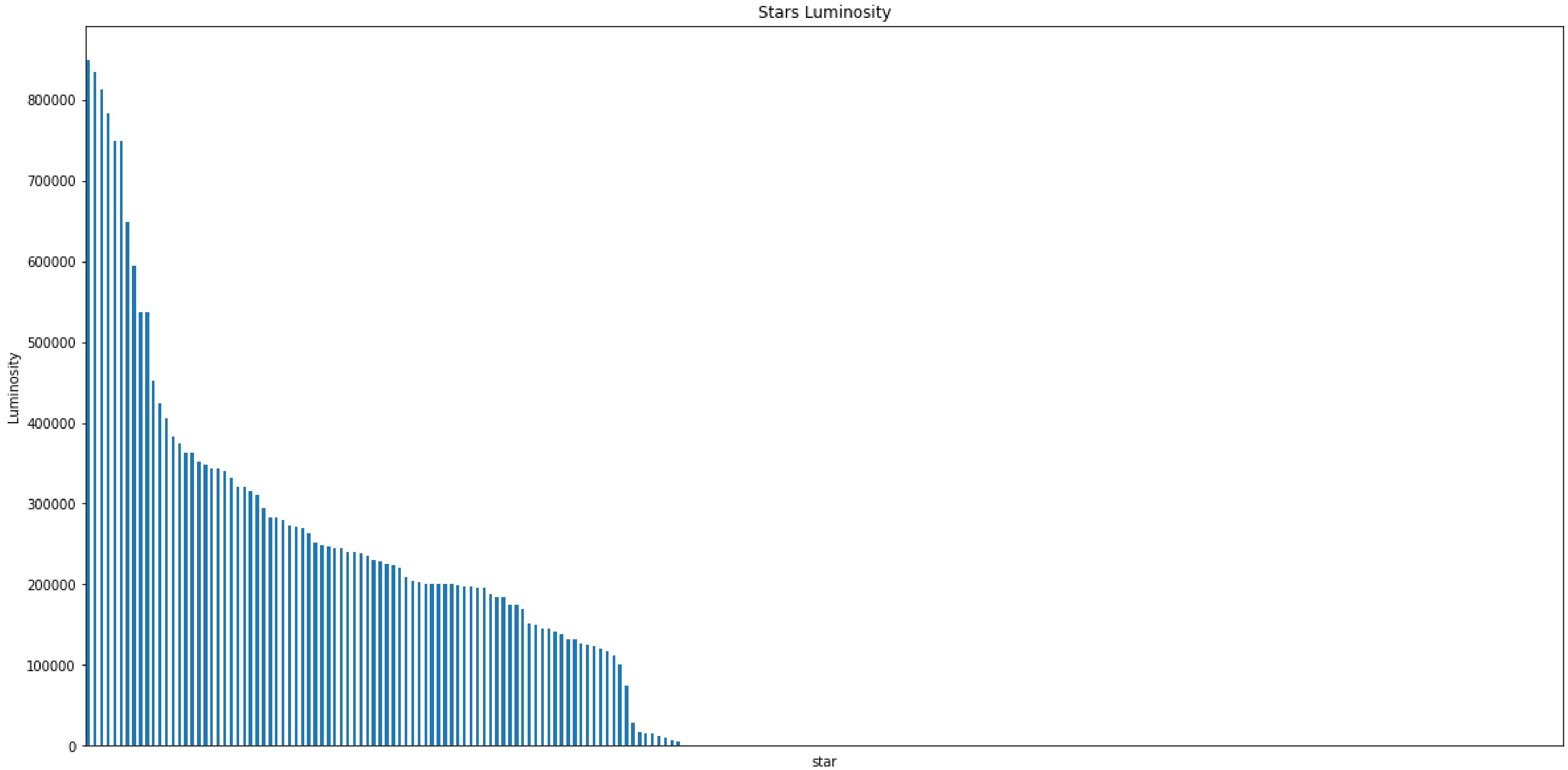


In [25]:
```
# plotting the stars Luminosity destribution

df_stars['Luminosity(L/Lo)'].sort_values(ascending=False).plot(kind='bar',figsize = (20,10))
plt.xlabel('star')
plt.ylabel('Luminosity')
plt.title('Stars Luminosity')

plt.xticks([])
```

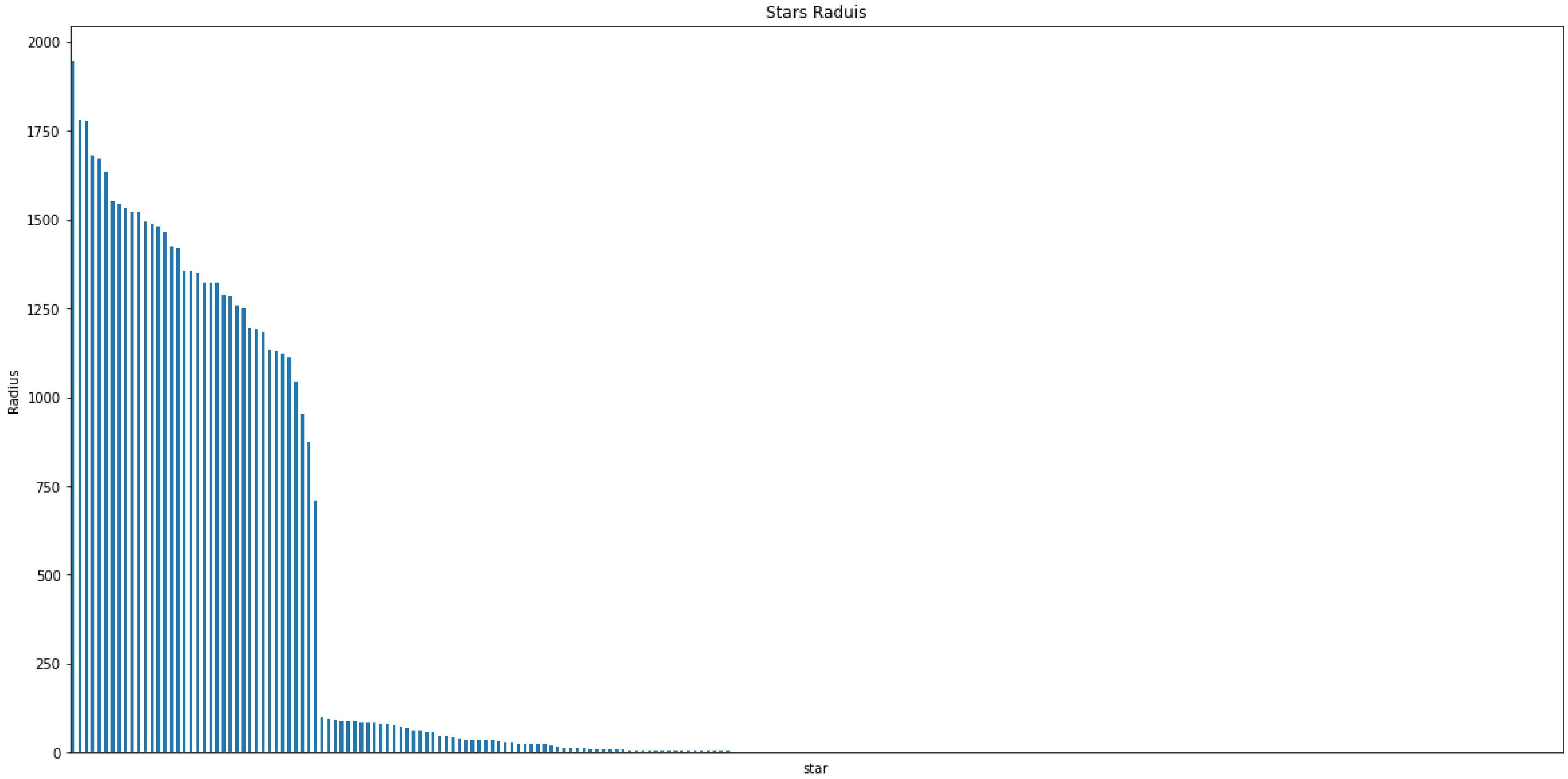
Out[25]:
```
([], [])
```



In [26]:
```
# plotting the stars radius destribution

df_stars['Radius(R/Ro)'].sort_values(ascending=False).plot(kind='bar',figsize = (20,10))
plt.xlabel('star')
plt.ylabel('Radius')
plt.title('Stars Raduis')
plt.xticks([])
```

Out[26]: ([], [])



Conclusions

1) During the analysis the incorrect color names were revealed and chaned to correct.

2) Based on the information shown on histogram, the can cocnlude following:

- most part of stars color is red, blue and white-blue;
- more than a half of stars has temperature of 5000 K;
- 70 % of stars have radius below 250;
- 55% o stars has luminosity less then 40 000 units.

Data encoding

In [20]:
```
# separation of categorical an dnumeric features

numeric_cols = df_stars.drop(columns = ['Star color','Star type']).columns
categorical_cols = ['Star color','Star type']

print('Numeric:',numeric_cols,'\n','\n', 'Categorical:',categorical_cols)
```

```
Numeric: Index(['Temperature (K)', 'Luminosity(L/Lo)', 'Radius(R/Ro)',
       'Absolute magnitude(Mv)'],
      dtype='object')

 Categorical: ['Star color', 'Star type']
```

In [21]:
```
# create a copy of df
df_stars_for_coding = df_stars.copy()
```

In [22]:
```
scaler = MinMaxScaler()
```

In [23]:
```
# numeric features encoding

scaler.fit(df_stars_for_coding[numeric_cols])
numeric_transformed = pd.DataFrame(scaler.transform(df_stars_for_coding[numeric_cols]),columns = [numeric_cols])
```

In [24]:
```
# display the result
numeric_transformed
```

Out[24]:

	Temperature (K)	Luminosity(L/Lo)	Radius(R/Ro)	Absolute magnitude(Mv)
0	0.029663	2.695957e-09	0.000083	0.876798
1	0.028980	4.591368e-10	0.000075	0.891807
2	0.017367	2.236820e-10	0.000048	0.957473
3	0.022622	1.059547e-10	0.000078	0.893371
4	0.000000	3.296367e-11	0.000049	1.000000
...	...	...	...	...
223	0.972150	4.412776e-01	0.695919	0.062226
224	0.759307	9.818959e-01	0.612777	0.040338
225	0.181025	6.327765e-01	0.730304	0.037211
226	0.191692	4.767253e-01	0.570694	0.021576
227	0.944352	3.471816e-01	0.915063	0.128831

228 rows × 4 columns

In [25]:
```
numeric_transformed.columns = df_stars.drop(columns = ['Star color','Star type']).columns
```

In [26]:
```
# categorical features encoding
ohe = OneHotEncoder()
categorical_transformed = ohe.fit_transform(df_stars_for_coding[categorical_cols]).toarray()
```

In [27]:
```
# encoded data to dataset
categorical_transformed = pd.DataFrame(categorical_transformed)
```

In [28]:
```
# display the results
categorical_transformed
```

Out[28]:

	0	1	2	3	4	5	6	7	8	9	10
0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
...	...	...	...	...	...	...	...	...	...	...	...
223	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
224	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
225	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
226	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
227	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

228 rows × 11 columns

In [29]:

```
# join the encoded data
df_stars_prepared = numeric_transformed.join(categorical_transformed)
```

In [30]:

```
# display the results
df_stars_prepared
```

Out[30]:

	Temperature (K)	Luminosity(L/Lo)	Radius(R/Ro)	Absolute magnitude(Mv)	0	1	2	3	4	5	6	7	8	9	10
0	0.029663	2.695957e-09	0.000083	0.876798	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
1	0.028980	4.591368e-10	0.000075	0.891807	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
2	0.017367	2.236820e-10	0.000048	0.957473	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
3	0.022622	1.059547e-10	0.000078	0.893371	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
4	0.000000	3.296367e-11	0.000049	1.000000	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
223	0.972150	4.412776e-01	0.695919	0.062226	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
224	0.759307	9.818959e-01	0.612777	0.040338	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
225	0.181025	6.327765e-01	0.730304	0.037211	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
226	0.191692	4.767253e-01	0.570694	0.021576	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
227	0.944352	3.471816e-01	0.915063	0.128831	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0

228 rows × 15 columns

In [31]:

```
# selection of target
df_stars_Y = df_stars_prepared['Temperature (K)']
```

In [32]:

```
# Selection of features
df_stars_X = df_stars_prepared.drop(columns = ['Temperature (K)'])
```

In [33]:

```
# split the data to train and test samples
X_train, X_test, y_train, y_test = train_test_split(df_stars_X, df_stars_Y, test_size=0.3, random_state=42)
```

In [34]:

```
# data transform to tensor
X_train = torch.FloatTensor(X_train.values)
X_test = torch.FloatTensor(X_test.values)
y_train = torch.FloatTensor(y_train.values)
y_test = torch.FloatTensor(y_test.values)
```

Building Neural networks

Building base Neural network

In [35]:
```
# function for calculation of RMSE plotting the hist of comparison actual and predicted temperature of stars

def plot_result (preds, y_test_):
    preds = preds.detach().numpy()
    y_test_ = y_test_.detach().numpy()
    df = pd.DataFrame(preds, columns = ['prediction'])
    df['actual'] = y_test_
    for i in df.columns:
        df[i] = df[i] * df_stars['Temperature (K)'].max()
    df.plot(kind = 'bar',figsize=(20,10))
    plt.title('star temperature')
    plt.ylabel('temprature')
    plt.xticks([])
    print(df.head())
    print('\n','RMSE:',mean_squared_error(df['actual'],df['prediction'],squared = False))
```

In [36]:
```
# Net 1 building

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)

    def forward(self, x):
        x = self.fc1(x)
        x = self.fc2(x)
        x = self.fc3(x)
        return x
```

```
net_1 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [37]:
```
# net 1 training and making a prediction

optimizer = torch.optim.Adam(net_1.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_1.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_1.eval(),
            test_preds_1 = net_1.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_1) == y_test).float().mean().data
            print(accuracy)
```

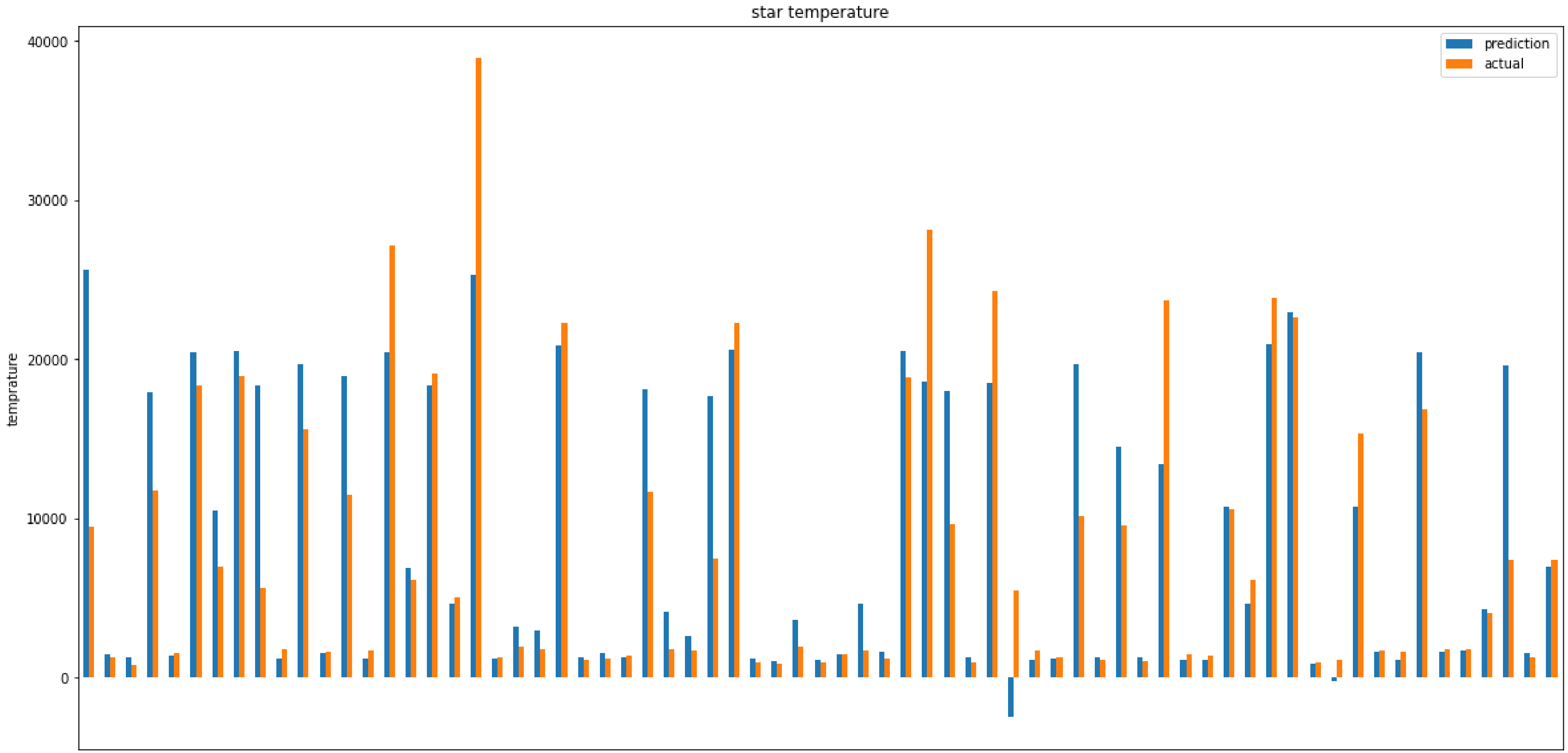
```
tensor(0.1294, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0775, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0485, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0294, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0226, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0195, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0176, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0166, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0163, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0162, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [38]:

```
# net results
plot_result(test_preds_1,y_test)
```

```
     prediction        actual
0  25638.511719   9449.041992
1   1454.730591   1272.693848
2   1245.530518    799.768799
3  17902.568359  11718.031250
4   1319.206055   1472.373291
```

```
 RMSE: 4868.386
```



Вывод по сети_1

RMSE для сети_1 приемлемое можно использовать данную сеть для ее дальнейшего улучшения. Хотя сеть иногда дает отрицательные значения...

Building neural network with LeakyReLU activaton

In [39]:
```
# bulding net_2

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.act1 = nn.LeakyReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.act2 = nn.LeakyReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.act2(x)
        x = self.fc3(x)
        x = self.act3(x)
        return x

net_2 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [40]:
```
# net_2 training and making a prediction

optimizer = torch.optim.Adam(net_2.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
```

```
    preds = net_2.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_2.eval(),
            test_preds_2 = net_2.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_2) == y_test).float().mean().data
            print(accuracy)
```

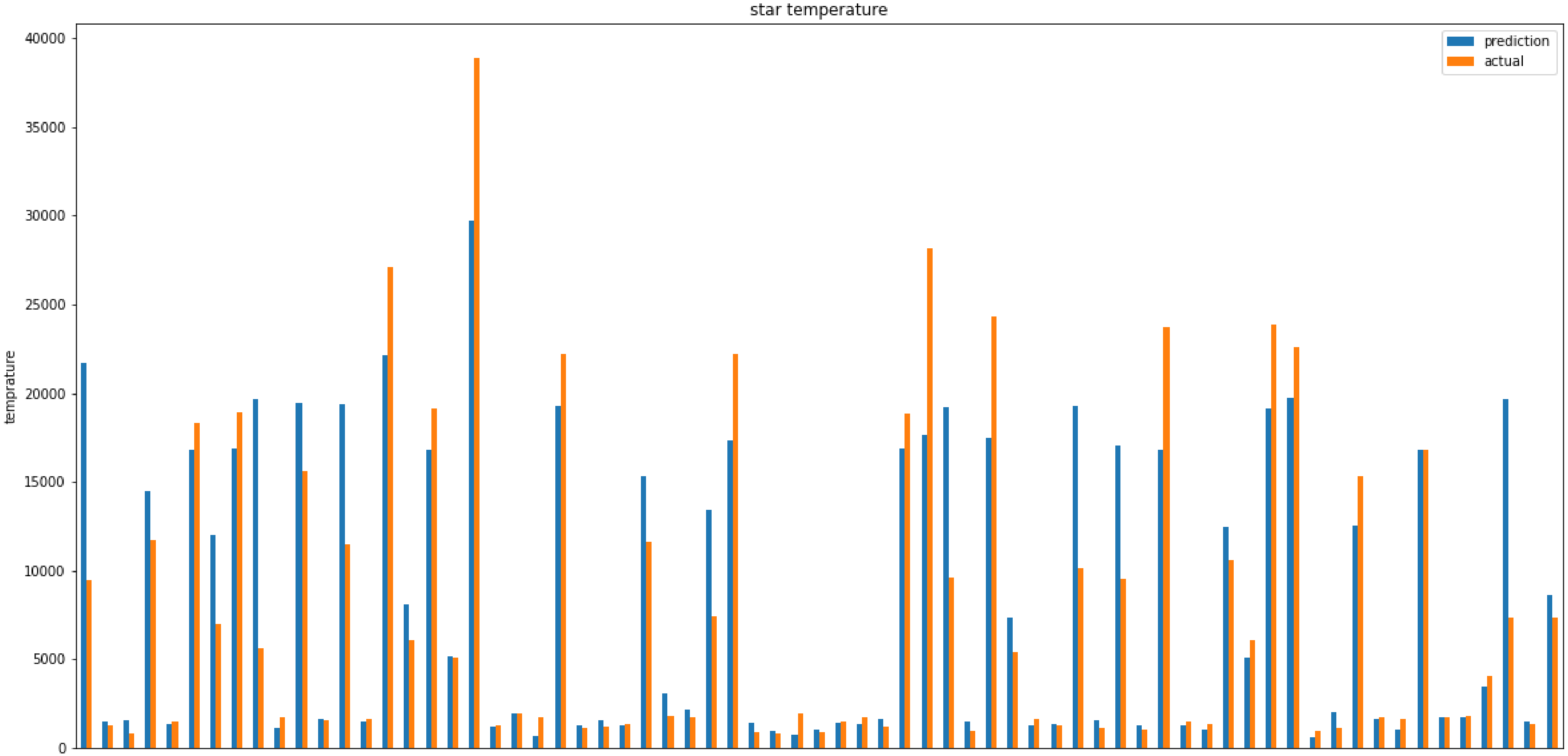
```
tensor(0.1117, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0811, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0615, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0446, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0314, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0250, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0218, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0194, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0172, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0154, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0142, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0135, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0131, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0128, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0126, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0124, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0122, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0120, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0118, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0116, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [41]:

```
plot_result(test_preds_2,y_test)
```

```
     prediction        actual
0  21669.697266   9449.041992
1   1492.615234   1272.693848
2   1537.019897    799.768799
3  14472.894531  11718.031250
4   1318.640869   1472.373291
```

```
RMSE: 4356.7583
```



Вывод по сети_2

RMSE для сети_2 уже достигло необходимых показателей, но зачем останавливаться если ее можно использовать для дальнейшего улучшения.

Building neural network with Sigmoid activaton function

In [42]:
```
# building net_3

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.act1 = nn.Sigmoid()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.act2 = nn.Sigmoid()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.act3 = nn.Sigmoid()


    def forward(self, x):
        x = self.fc1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.act2(x)
        x = self.fc3(x)
        x = self.act3(x)
        return x

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 18
hidden_size_2 = 45
output_size = 1

net_3 = NeuralNet(input_size, hidden_size_1, hidden_size_2,output_size)
```

In [43]:
```
# net_3 training and making a prediction

optimizer = torch.optim.Adam(net_3.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 600

for epoch in range(num_epochs):
```

```
    optimizer.zero_grad()
    preds = net_2.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 100 == 0) or (epoch == 600) :
            net_3.eval(),
            test_preds_3 = net_3.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_3) == y_test).float().mean().data
            print(accuracy)
```

```
tensor(0.)
tensor(0.)
tensor(0.)
tensor(0.)
tensor(0.)
tensor(0.)
```

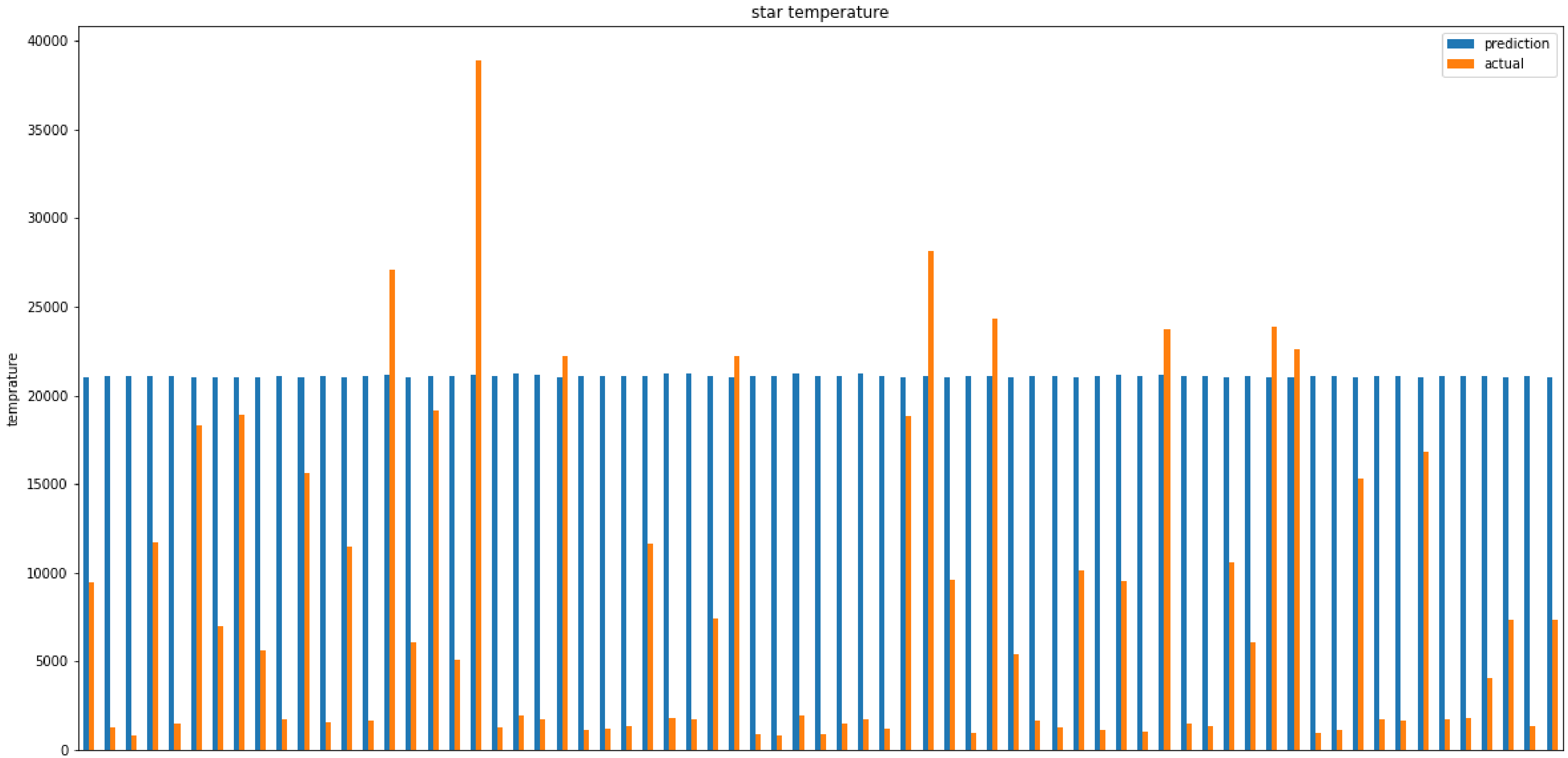
In [44]:

```
# display the results of net_3

plot_result(test_preds_3,y_test)
```

	prediction	actual
0	21032.304688	9449.041992
1	21063.041016	1272.693848
2	21090.667969	799.768799
3	21094.648438	11718.031250
4	21062.929688	1472.373291

```
 RMSE: 15818.15
```



Вывод по сети_3

Функция сигмоид дает среднее значение - такую нейронную сеть предлагаю не использовать для улучшения параметров

Neural Networks tuning

learning rate tuning

In [45]:
```
# based on net 1 building net_4
```

```
torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)

    def forward(self, x):
        x = self.fc1(x)
        x = self.fc2(x)
        x = self.fc3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [46]:

```
# net 4 training and making a prediction (changes are - lr +=0.01)

optimizer = torch.optim.Adam(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

```
tensor(0.1294, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0166, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0162, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
```

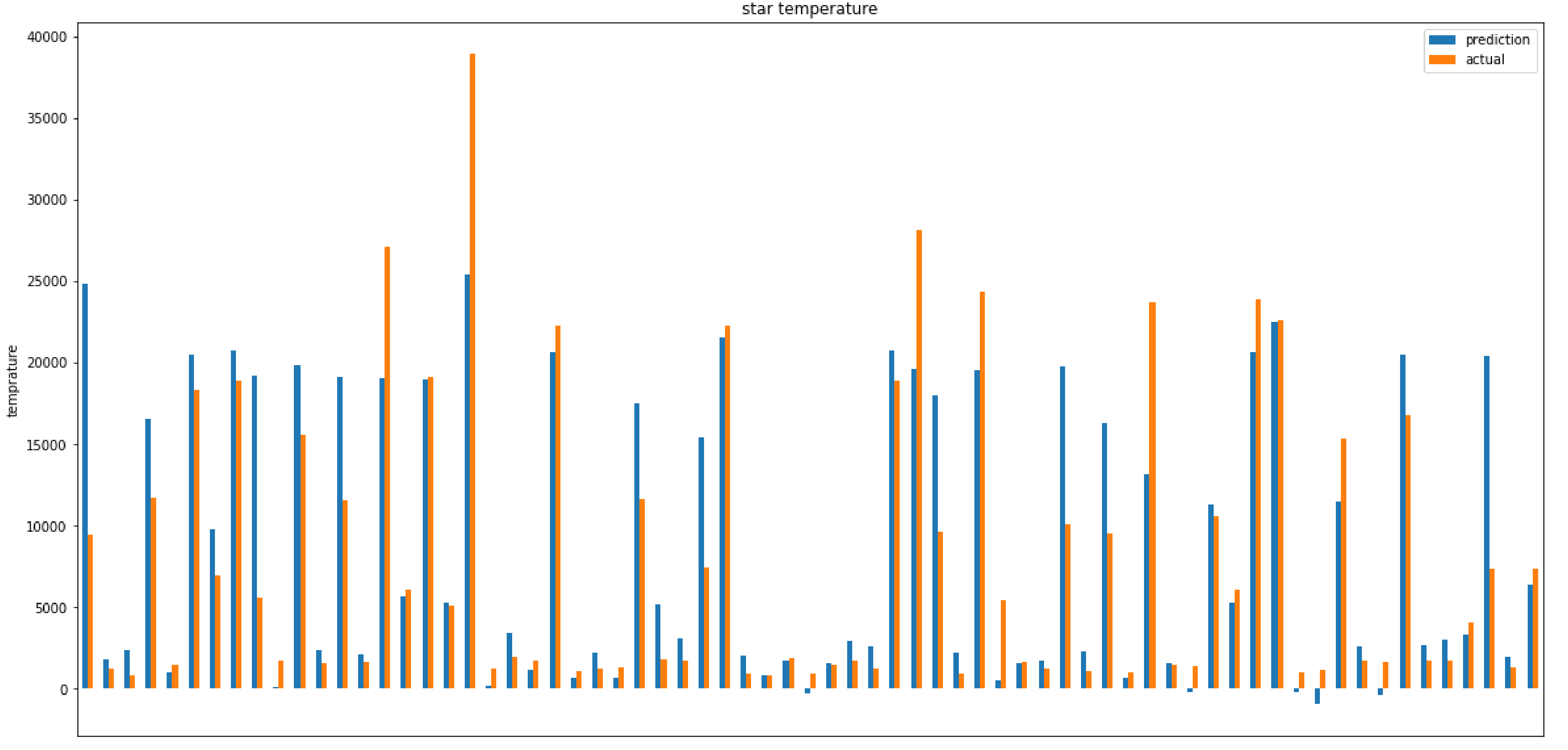
In [47]:

```
# display the results

plot_result(test_preds_4,y_test)
```

	prediction	actual
0	24865.097656	9449.041992
1	1804.313721	1272.693848
2	2341.796387	799.768799
3	16544.482422	11718.031250
4	977.397095	1472.373291

RMSE: 4803.809



In [48]:

```
# based on net 2 building the net_5

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
```

```
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.act1 = nn.LeakyReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.act2 = nn.LeakyReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.act2(x)
        x = self.fc3(x)
        x = self.act3(x)
        return x

net_5 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [49]:

```
# net_5 training and making a prediction (changes are - lr +=0.001)

optimizer = torch.optim.Adam(net_5.parameters(),lr=0.002)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_5.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_5.eval(),
            test_preds_5 = net_5.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_5) == y_test).float().mean().data
            print(accuracy)
```

```
tensor(0.1117, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0628, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0349, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0232, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0193, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0167, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0150, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0142, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0136, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0132, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0128, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0123, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0118, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0111, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0107, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0103, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0100, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0098, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0097, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0096, grad_fn=<MseLossBackward0>)
tensor(0.)
```

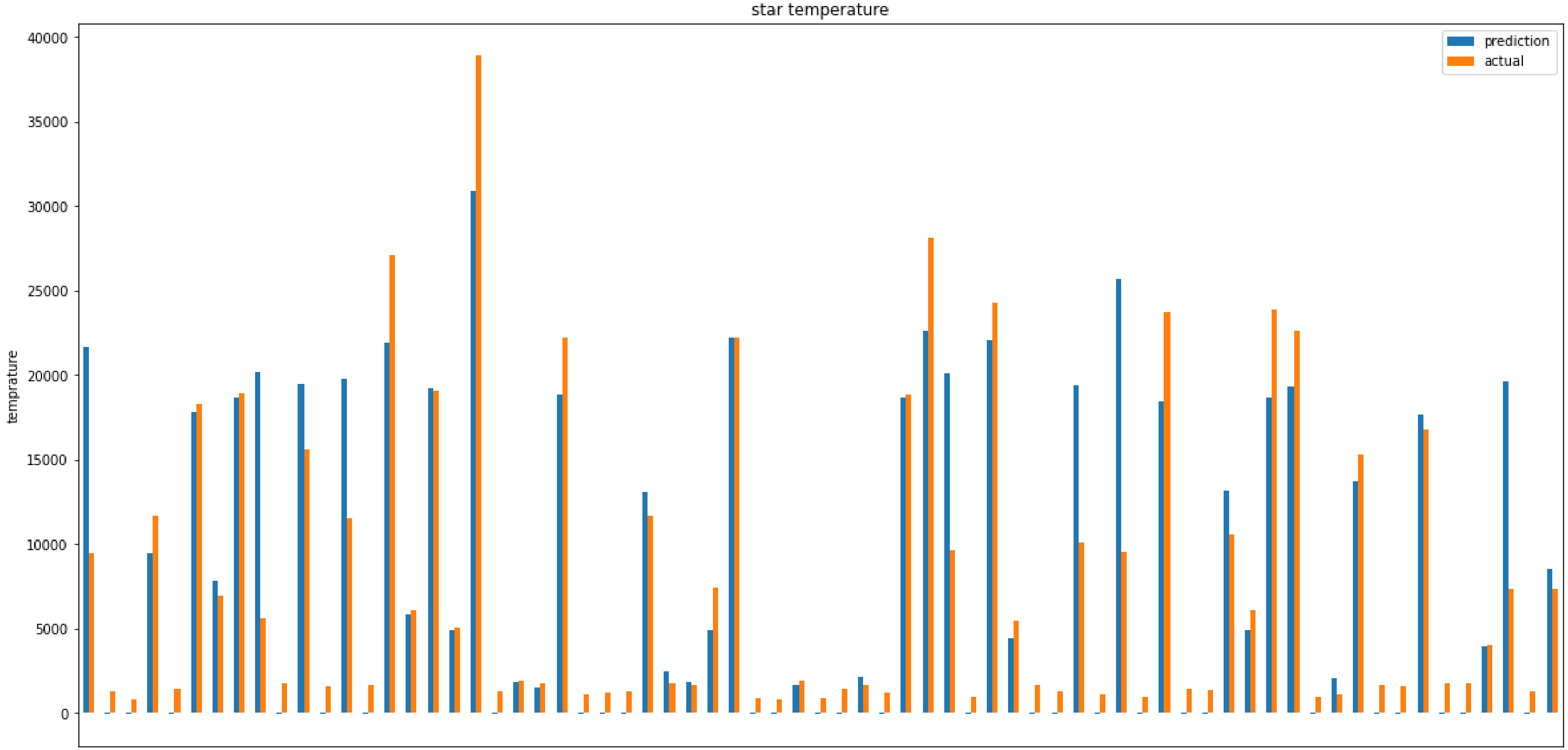
In [50]:

```
# displaay the results

plot_result(test_preds_5,y_test)
```

```
     prediction        actual
0  21693.945312   9449.041992
1     -8.832759   1272.693848
2    -15.238729    799.768799
3   9485.941406  11718.031250
4     -8.603992   1472.373291
```

RMSE: 4400.8994



Learning rate changes

- Changes of learning rate has slightly increase the RMSE score of net 1 - changes are accepted and to be used for the further model optimisation.
- Changes of learning rate has reduce the RMSE score of net 2 - changes rejected.

Optimizer tuning

In [52]:
```
# based on  optimised net 1 building the net_1

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)

    def forward(self, x):
        x = self.fc1(x)
        x = self.fc2(x)
        x = self.fc3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [53]:
```
# traininf od net_4 (chnages - optimizer - SGD)

optimizer = torch.optim.SGD(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
```

```
    net_4.eval(),
    test_preds_4 = net_4.forward(X_test).flatten()
    accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
    print(accuracy)
```

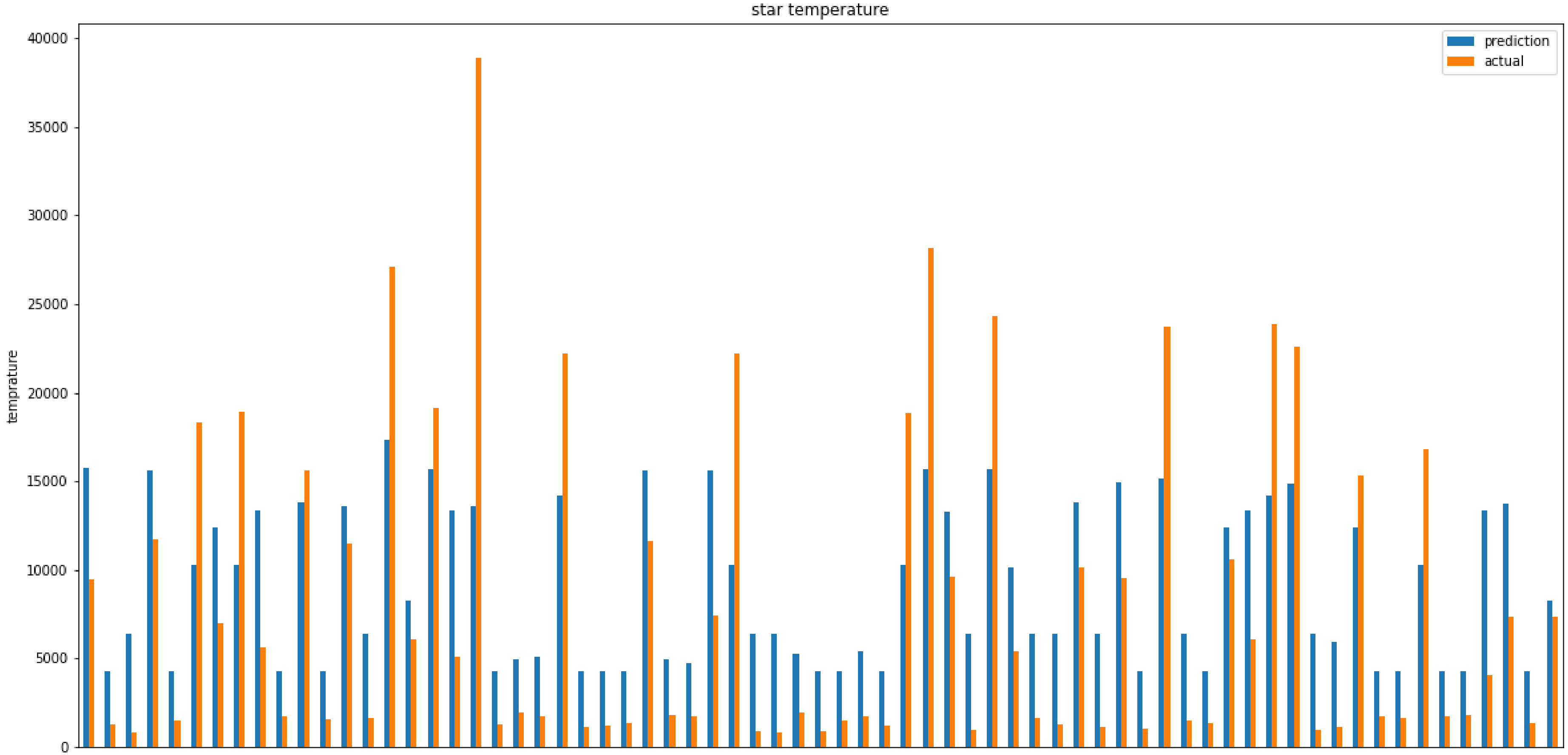
```
tensor(0.1294, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0986, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0893, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0840, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0798, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0763, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0731, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0702, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0674, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0648, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0622, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0596, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0570, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0545, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0519, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0494, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0469, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0444, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0420, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0397, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [54]:

```
plot_result(test_preds_4,y_test)
```

```
     prediction        actual
0  15725.837891   9449.041992
1   4302.927246   1272.693848
2   6401.625977    799.768799
3  15632.453125  11718.031250
4   4302.507324   1472.373291

 RMSE: 6321.381
```



In [55]:
```python
# based on optimised net 1 building the net_4

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
```

```python
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)

    def forward(self, x):
        x = self.fc1(x)
        x = self.fc2(x)
        x = self.fc3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [56]:

```python
# traininf of net_4 (changes - optimizer - RMSprop)

optimizer = torch.optim.RMSprop(net_4.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

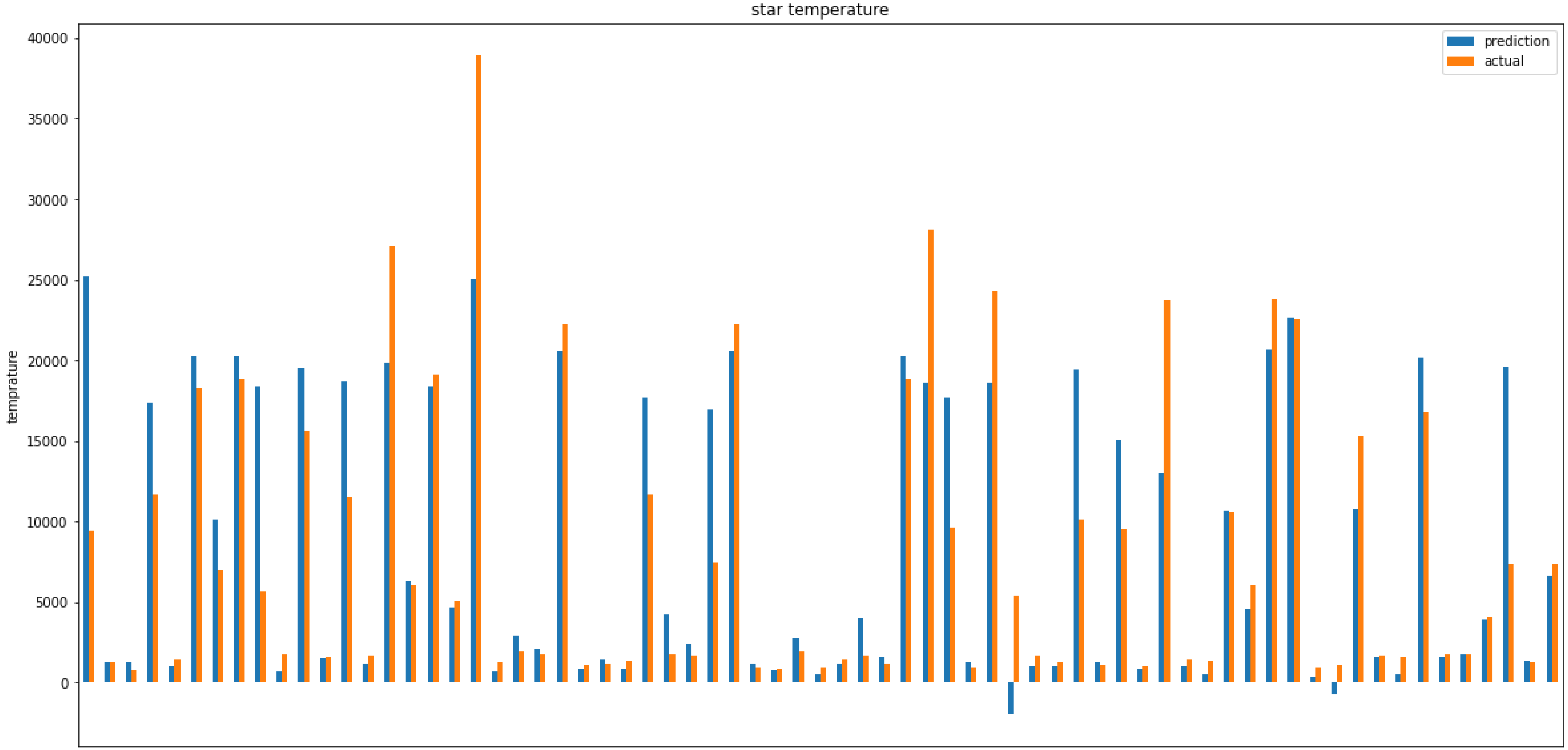
```
tensor(0.1294, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0239, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0180, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0165, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0162, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [57]:

```
plot_result(test_preds_4,y_test)
```

```
     prediction        actual
0  25195.689453   9449.041992
1   1302.915405   1272.693848
2   1295.320801    799.768799
3  17401.923828  11718.031250
4    998.719788   1472.373291
```

```
RMSE: 4810.8184
```



In [58]:

```
# based on net 2 building the net_5

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1
```

```python
class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.act1 = nn.LeakyReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.act2 = nn.LeakyReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.act2(x)
        x = self.fc3(x)
        x = self.act3(x)
        return x

net_5 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [59]:
```python
# training net_5 (changes - optimizer - SGD)

optimizer = torch.optim.SGD(net_5.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_5.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_5.eval(),
            test_preds_5 = net_5.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_5) == y_test).float().mean().data
            print(accuracy)
```

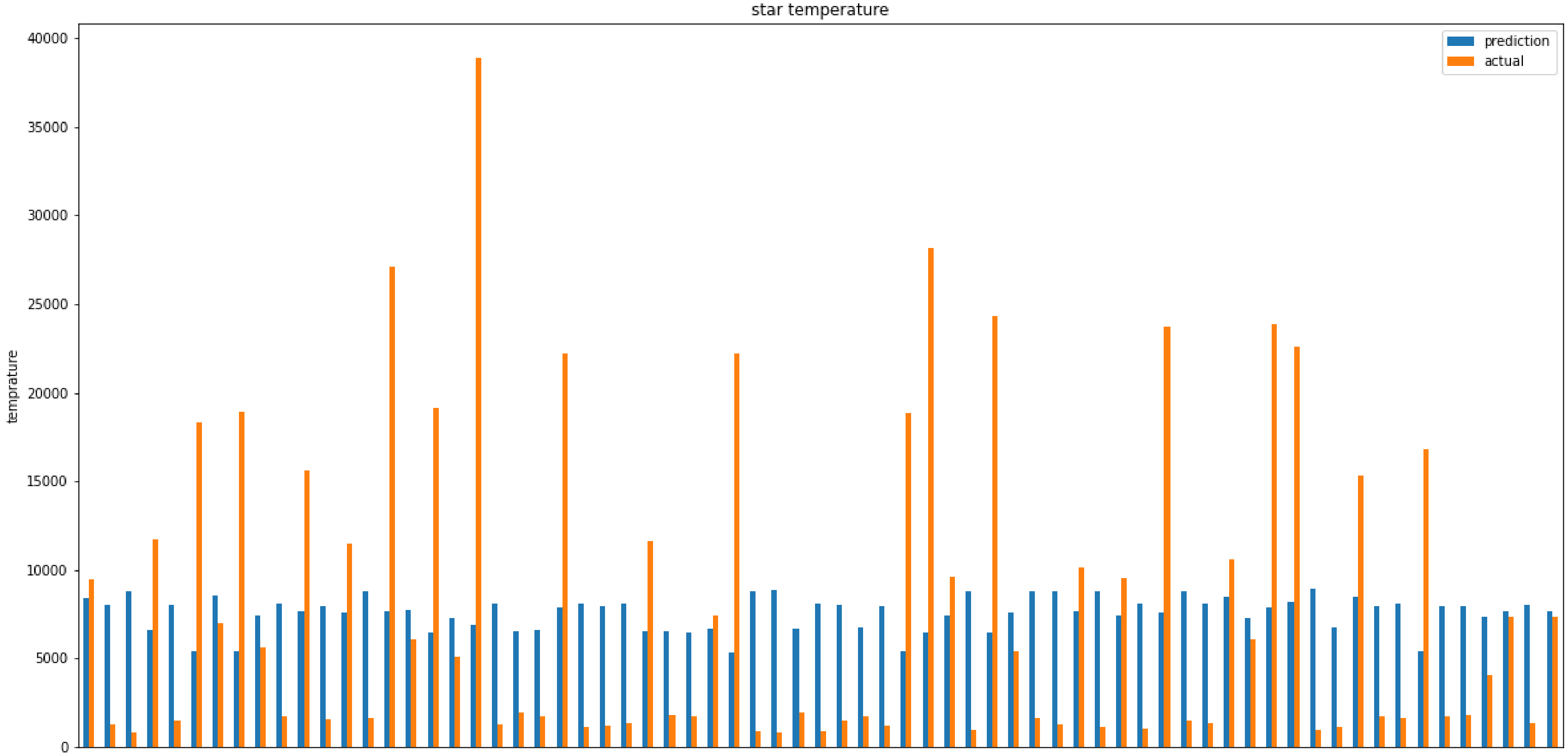
```
tensor(0.1117, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.1076, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.1040, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.1008, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0980, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0955, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0933, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0914, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0897, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0882, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0869, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0857, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0846, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0837, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0829, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0822, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0815, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0809, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0804, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0799, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [60]:

```
plot_result(test_preds_5,y_test)
```

```
   prediction        actual
0  8418.826172   9449.041992
1  7992.934082   1272.693848
2  8766.971680    799.768799
3  6583.833496  11718.031250
4  8045.629395   1472.373291
```

RMSE: 9329.265




```
In [61]: # based on net 2 building the net_5

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
```

```python
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.act1 = nn.LeakyReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.act2 = nn.LeakyReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.act2(x)
        x = self.fc3(x)
        x = self.act3(x)
        return x

net_5 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [62]:

```python
# training net5 (changes - optimizer - RMSprop)

optimizer = torch.optim.RMSprop(net_5.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_5.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_5.eval(),
            test_preds_5 = net_5.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_5) == y_test).float().mean().data
            print(accuracy)
```

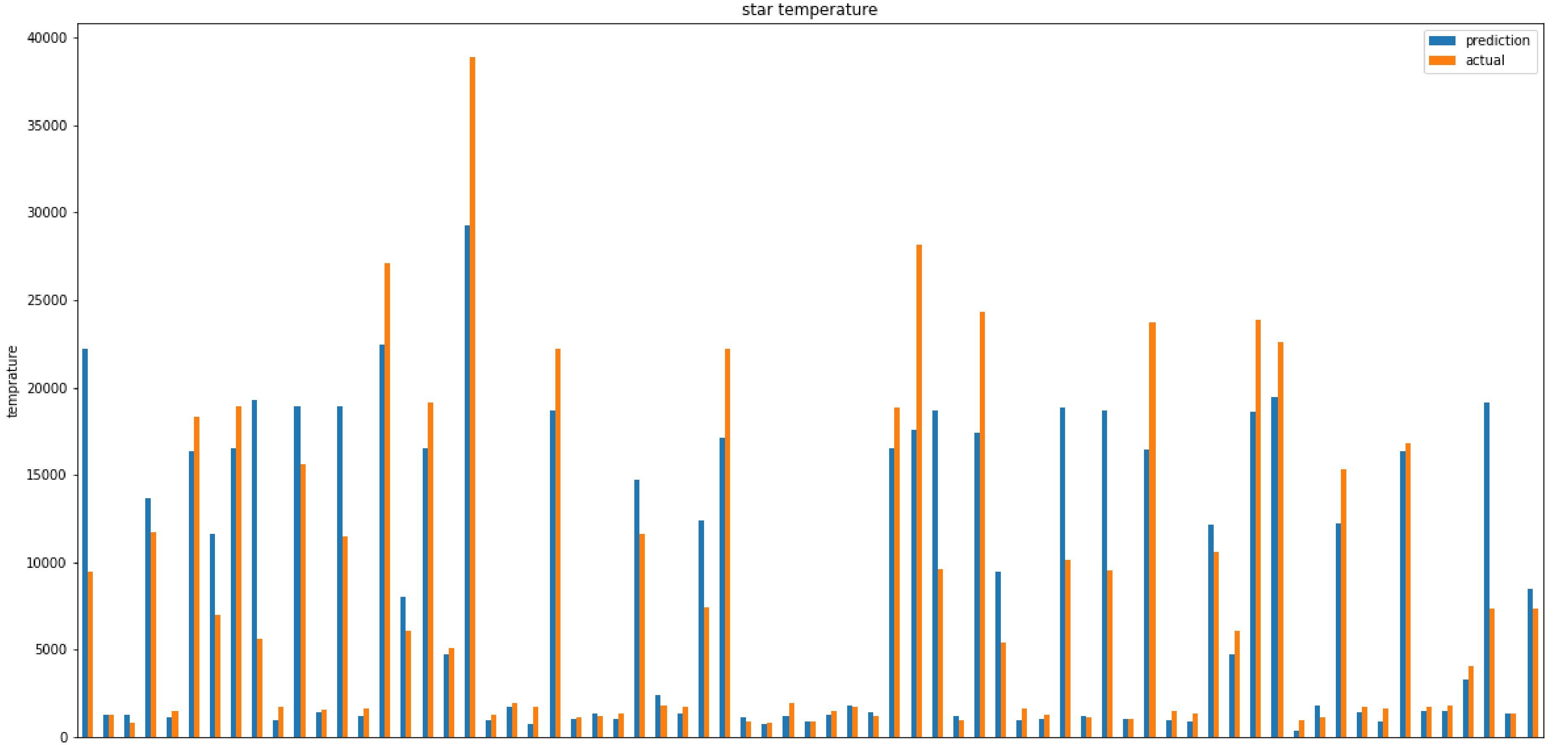
```
tensor(0.1117, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0342, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0228, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0181, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0141, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0132, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0129, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0127, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0126, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0125, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0124, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0122, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0121, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0120, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0118, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0117, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0115, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0114, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0112, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [63]:

```
plot_result(test_preds_5,y_test)
```

```
      prediction        actual
0  22199.255859   9449.041992
1   1284.554321   1272.693848
2   1227.034912    799.768799
3  13621.442383  11718.031250
4   1125.555298   1472.373291
```

```
RMSE: 4377.1074
```



Conclusion on optimiser changes

Changes of optimiser has not increase the RMSE sccore on both networks - adam optimiser will remain as the best for the networks and used for further optimisation.

Dropout tuning

In [64]:
```
# based on optimised net 1 building the net_4

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.2)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
#         self.dp2 = nn.Dropout(p = 0.2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)
#         self.dp3 = nn.Dropout(p = 0.2)

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.fc2(x)
#         x = self.dp2(x)
        x = self.fc3(x)
#         x = self.dp3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [65]:
```
# training net_4 (changes - added dp1, p = 0.2)

optimizer = torch.optim.Adam(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
```

```
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

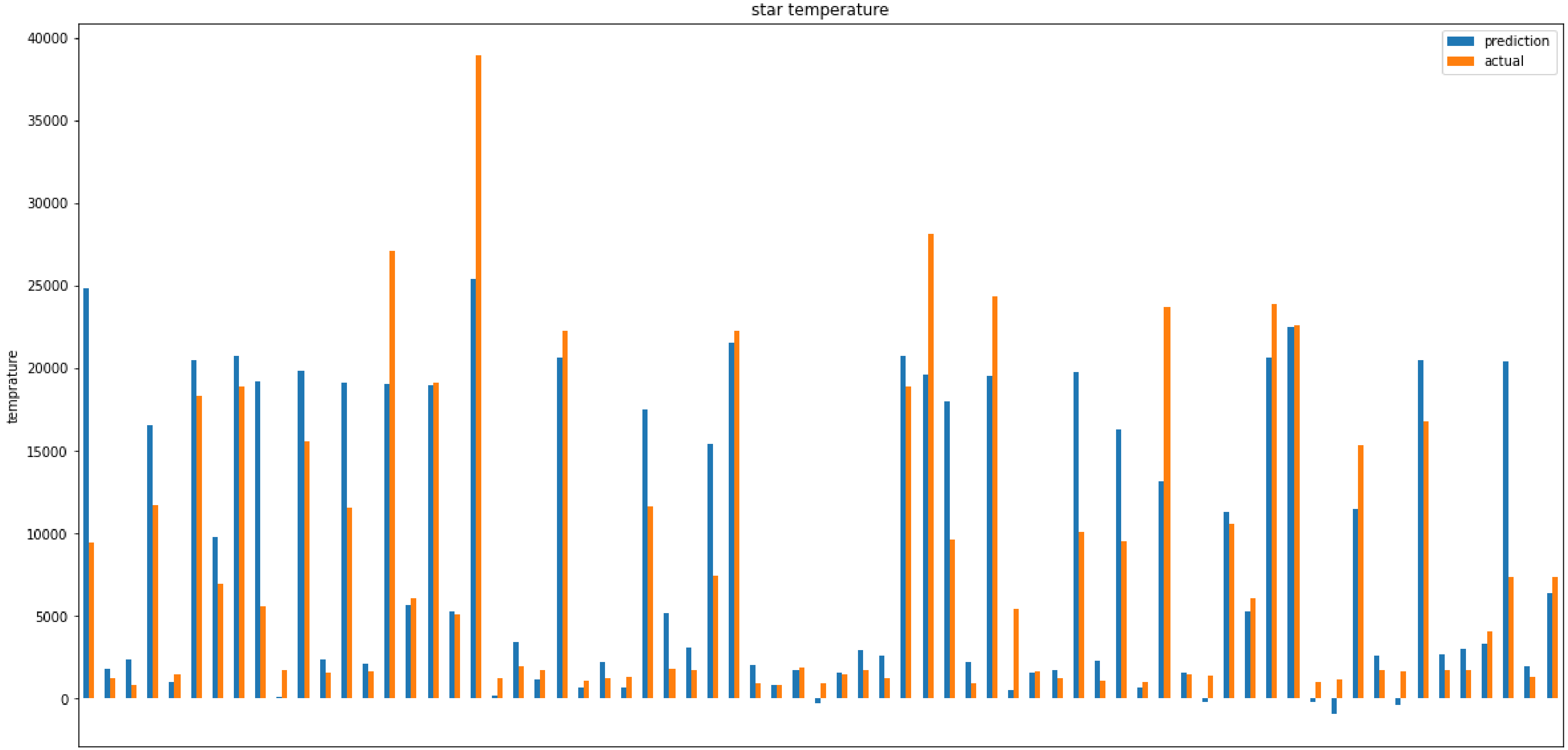
```
tensor(0.1317, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0166, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0162, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [66]:

```
plot_result(test_preds_4,y_test)
```

	prediction	actual
0	24865.228516	9449.041992
1	1804.252808	1272.693848
2	2341.591797	799.768799
3	16544.748047	11718.031250
4	977.463867	1472.373291

RMSE: 4803.806



In [67]:

```
# based on optimised net 1 building the net_4

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1
```

```
class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.2)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.dp2 = nn.Dropout(p = 0.5)
        self.fc3 = nn.Linear(hidden_size_2, output_size)
#         self.dp3 = nn.Dropout(p = 0.2)

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.fc2(x)
        x = self.dp2(x)
        x = self.fc3(x)
#         x = self.dp3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [68]:

```
# training net_4 (changes - added dp1, p = 0.2 u dp2, p = 0.5)

optimizer = torch.optim.Adam(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

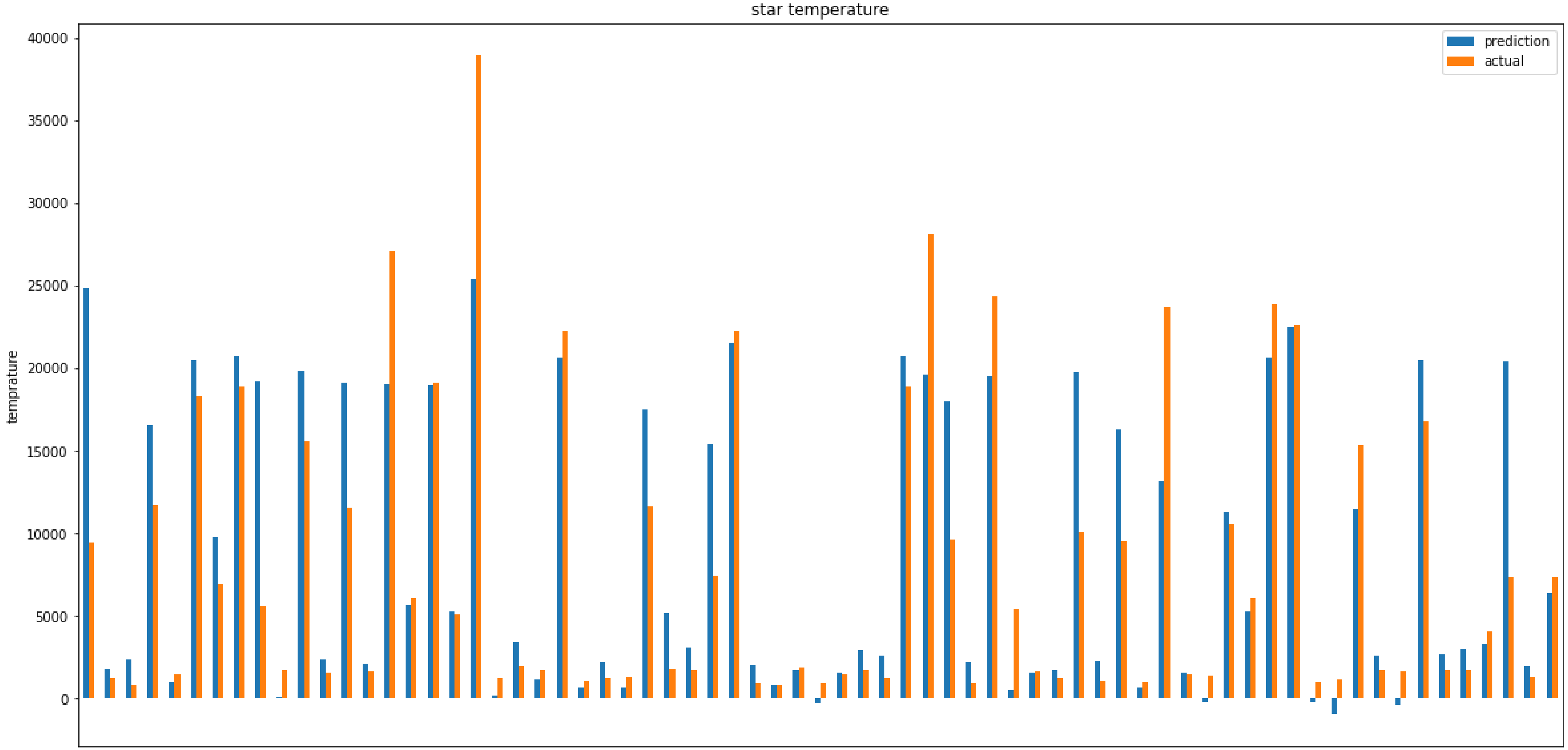
```
tensor(0.1405, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0170, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [69]:

```
plot_result(test_preds_4,y_test)
```

```
     prediction        actual
0  24865.097656   9449.041992
1   1804.310059   1272.693848
2   2341.790039    799.768799
3  16544.482422  11718.031250
4    977.392517   1472.373291
```

```
RMSE: 4803.809
```



In [70]:

```
# based on optimised net 1 building the net_4

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1
```

```
class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.2)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
#         self.dp2 = nn.Dropout(p = 0.2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.dp3 = nn.Dropout(p = 0.5)

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.fc2(x)
#         x = self.dp2(x)
        x = self.fc3(x)
        x = self.dp3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [71]:
```
# training net_4 (changes - added dp1  u dp3, p = 0.5)

optimizer = torch.optim.Adam(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

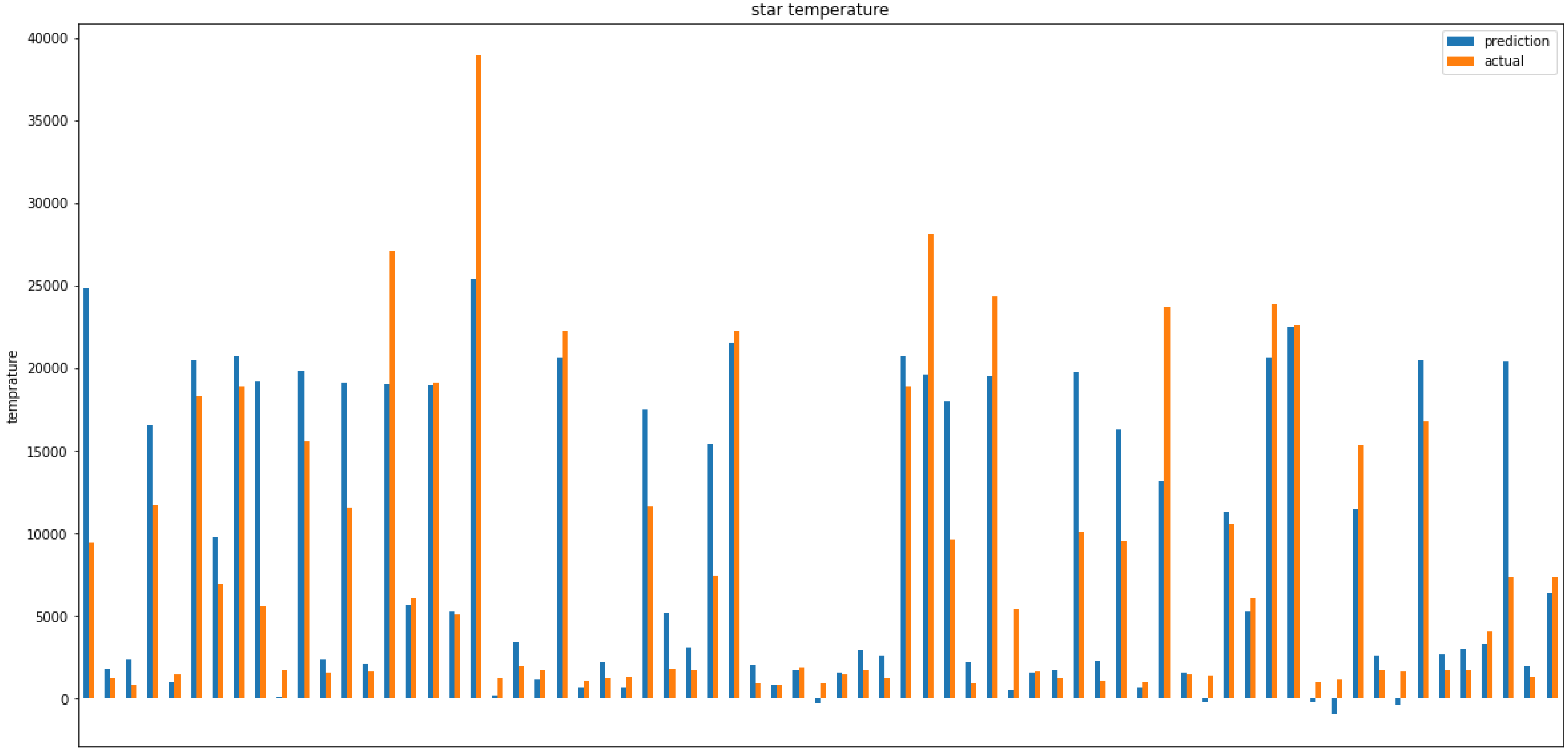
```
tensor(0.1319, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0167, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0162, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [72]:

```
plot_result(test_preds_4,y_test)
```

	prediction	actual
0	24864.966797	9449.041992
1	1804.372925	1272.693848
2	2341.990723	799.768799
3	16544.232422	11718.031250
4	977.327820	1472.373291

RMSE: 4803.8115



In [73]:

```
# based on optimised net 1 building the net_4

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1
```

```python
class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.2)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.dp2 = nn.Dropout(p = 0.5)
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.dp3 = nn.Dropout(p = 0.2)

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.fc2(x)
        x = self.dp2(x)
        x = self.fc3(x)
        x = self.dp3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [74]:
```python
# training net_4 (changes - added  dp1, dp2  u dp3, p = 0.2, 0.5, 0.2)

optimizer = torch.optim.Adam(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

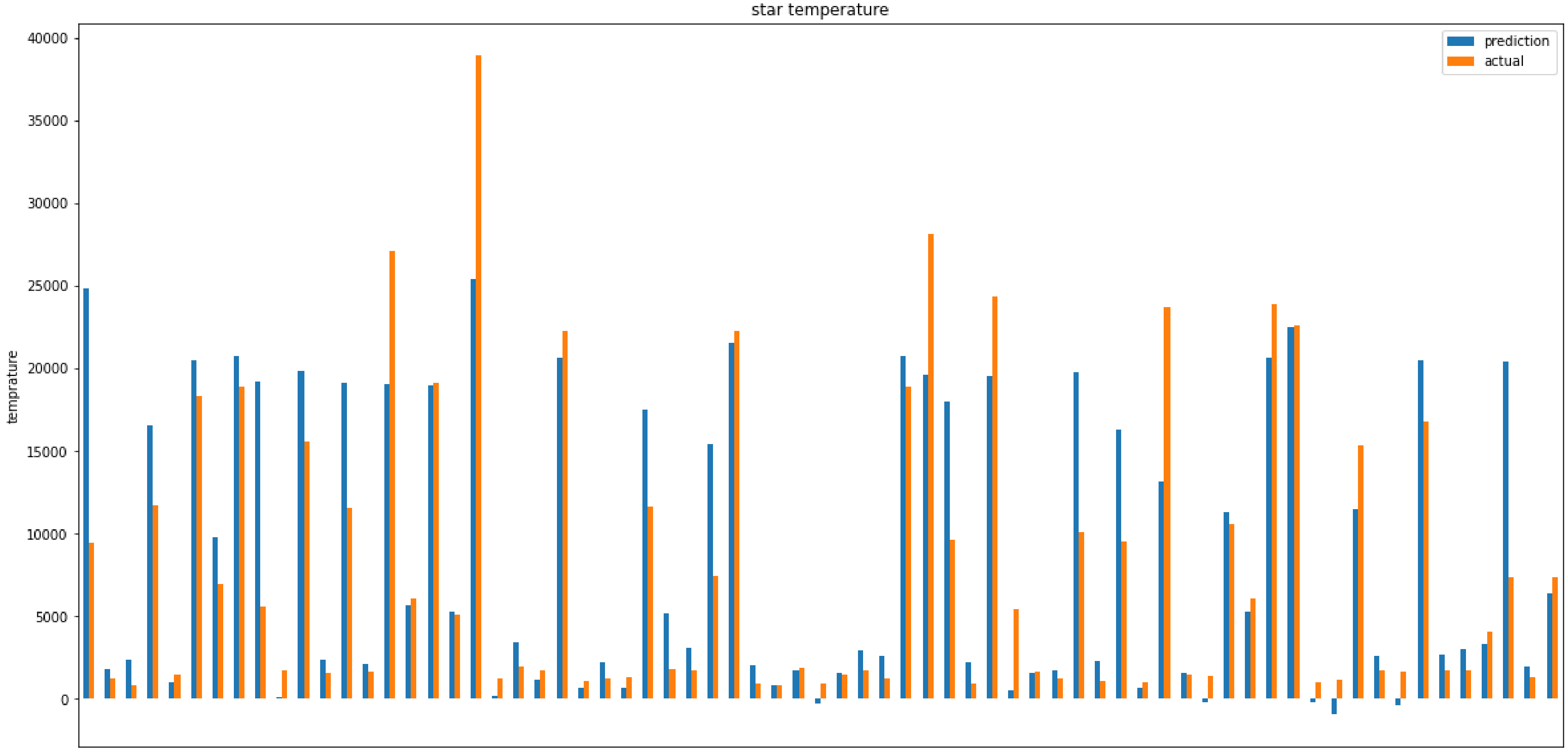
```
tensor(0.1473, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0180, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [75]:

```
plot_result(test_preds_4,y_test)
```

	prediction	actual
0	24865.683594	9449.041992
1	1804.027466	1272.693848
2	2340.869141	799.768799
3	16545.644531	11718.031250
4	977.693787	1472.373291

RMSE: 4803.796



Cocnlusion on dropout for net_4

Score increase obtained only in case of apply dp1 = 0.2

Other settings has not increase the RMS scoe for the net 4

In [76]:
```
# based on optimised net 2 building the net_5

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.1)
        self.act1 = nn.LeakyReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
#         self.dp2 = nn.Dropout(p = 0.2)
        self.act2 = nn.LeakyReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
#         self.dp3 = nn.Dropout(p = 0.2)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.act1(x)
        x = self.fc2(x)
#         x = self.dp2(x)
        x = self.act2(x)
        x = self.fc3(x)
#         x = self.dp3(x)
        x = self.act3(x)
        return x

net_5 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [77]:
```
# training net_5 (changes - added dp1, p = 0.1)

optimizer = torch.optim.Adam(net_5.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500
```

```
for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_5.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_5.eval(),
            test_preds_5 = net_5.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_5) == y_test).float().mean().data
            print(accuracy)
```

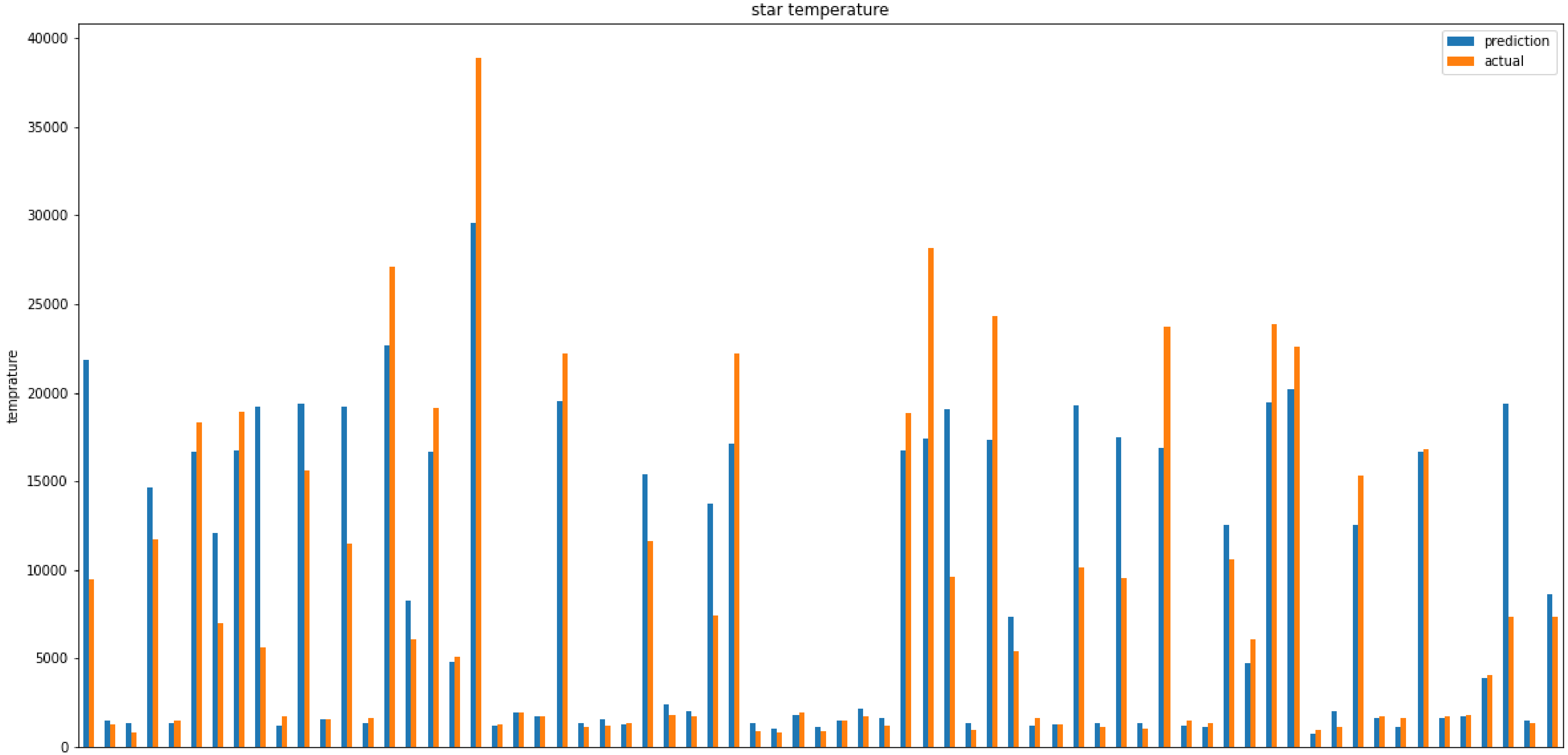
```
tensor(0.1119, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0810, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0614, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0445, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0313, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0251, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0220, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0197, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0179, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0163, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0149, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0141, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0135, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0131, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0128, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0126, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0124, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0122, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0119, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0117, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [78]:

```
plot_result(test_preds_5,y_test)
```

```
     prediction        actual
0  21826.535156   9449.041992
1   1492.371826   1272.693848
2   1367.966187    799.768799
3  14648.825195  11718.031250
4   1352.701904   1472.373291
```

```
RMSE: 4337.173
```



In [79]:

```
# based on optimised net 2 building the net_5

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
```

```python
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.1)
        self.act1 = nn.LeakyReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.dp2 = nn.Dropout(p = 0.1)
        self.act2 = nn.LeakyReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
#         self.dp3 = nn.Dropout(p = 0.2)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.dp2(x)
        x = self.act2(x)
        x = self.fc3(x)
#         x = self.dp3(x)
        x = self.act3(x)
        return x

net_5 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [80]:

```python
# training net_5 (changes - added dp1, p = 0.1 , dp2, p=0.1)

optimizer = torch.optim.Adam(net_5.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_5.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
```

```
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_5.eval(),
            test_preds_5 = net_5.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_5) == y_test).float().mean().data
            print(accuracy)
```

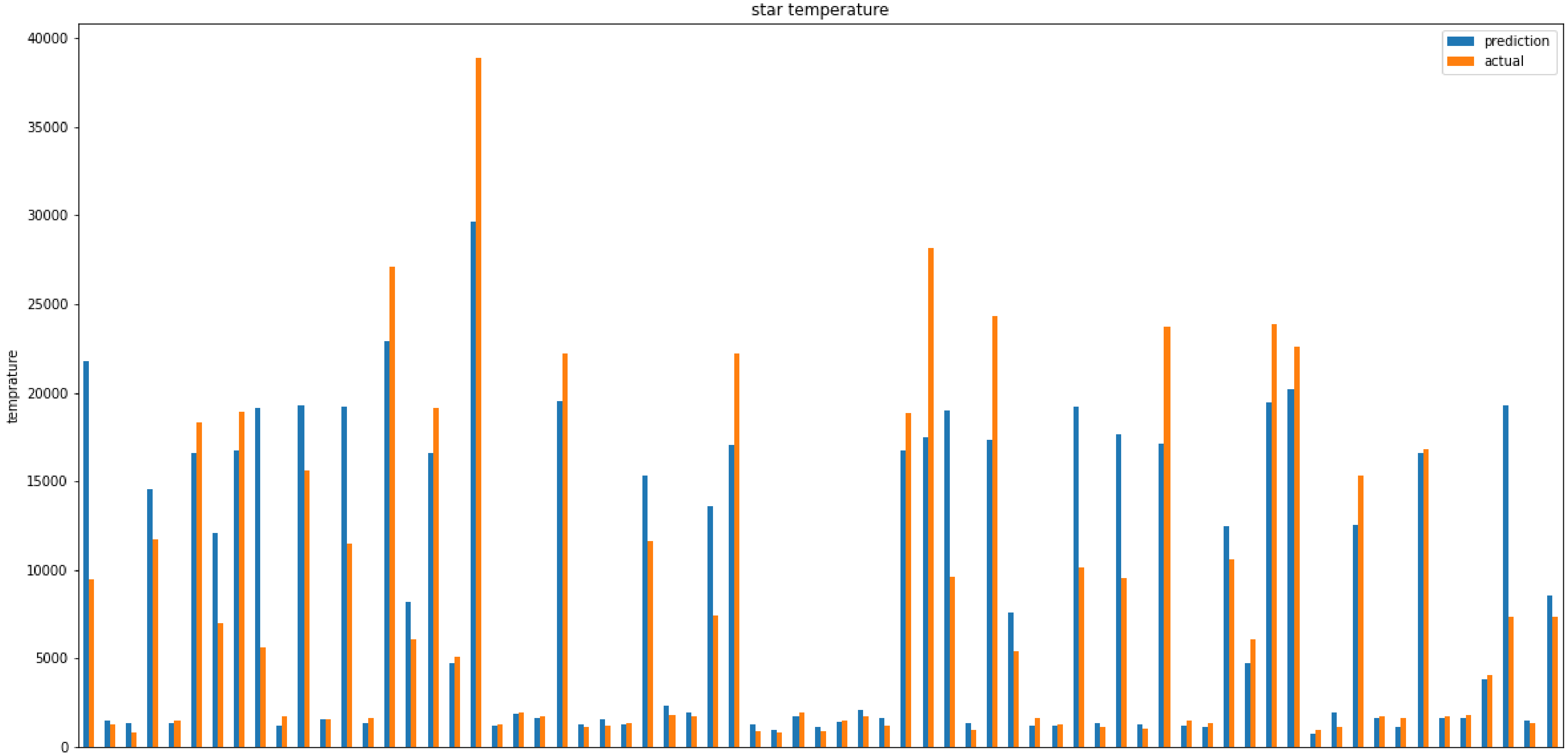
```
tensor(0.1130, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0809, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0614, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0444, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0313, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0250, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0219, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0196, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0178, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0162, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0149, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0140, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0135, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0131, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0128, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0126, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0124, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0121, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0119, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0117, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [81]:

```
plot_result(test_preds_5,y_test)
```

	prediction	actual
0	21789.283203	9449.041992
1	1470.095215	1272.693848
2	1351.251099	799.768799
3	14539.531250	11718.031250
4	1329.332153	1472.373291

RMSE: 4318.3047



In [82]:

```
# based on optimised net 2 building the net_5

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
```

```
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.1)
        self.act1 = nn.LeakyReLU()
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.dp2 = nn.Dropout(p = 0.05)
        self.act2 = nn.LeakyReLU()
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.dp3 = nn.Dropout(p = 0.05)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.act1(x)
        x = self.fc2(x)
        x = self.dp2(x)
        x = self.act2(x)
        x = self.fc3(x)
        x = self.dp3(x)
        x = self.act3(x)
        return x

net_5 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [83]:

```
# training net_5 (changes - added  dp1, p = 0.1 , dp2, p=0.05, dp3 = 0.05)

optimizer = torch.optim.Adam(net_5.parameters(),lr=0.001)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_5.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
```

```
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_5.eval(),
            test_preds_5 = net_5.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_5) == y_test).float().mean().data
            print(accuracy)
```

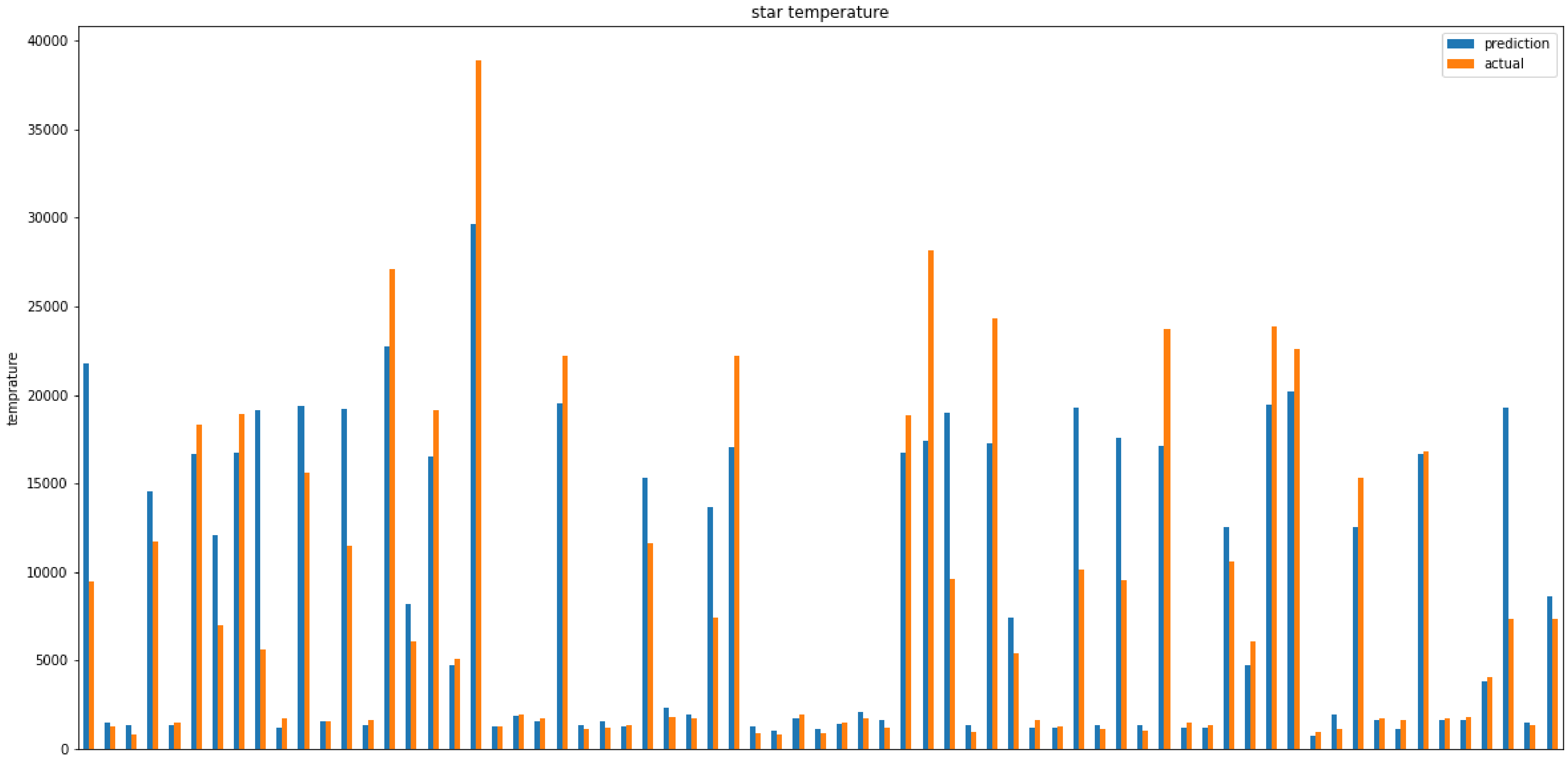
```
tensor(0.1126, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0809, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0614, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0445, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0313, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0251, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0219, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0196, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0178, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0162, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0148, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0140, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0135, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0131, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0128, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0126, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0124, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0122, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0119, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0117, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [84]:

```
plot_result(test_preds_5,y_test)
```

```
   prediction        actual
0  21795.246094   9449.041992
1   1478.717285   1272.693848
2   1351.359741    799.768799
3  14566.385742  11718.031250
4   1346.858398   1472.373291
```

```
RMSE: 4328.24
```



Conclusion on dropout tuning on net_5

Best score achieved adding the following layers:

- dp1 p = 0.1
- dp2 p = 0.05

- dp3 p = 0.05

The changes to be used for further network optimisation

BatchNorm Tuning

In [85]:
```
# based on optimised net 1 building the net_4

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.2)
        self.bn1 = nn.BatchNorm1d(hidden_size_1)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.bn1(x)
        x = self.fc2(x)
        x = self.fc3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [86]:
```
# training net_4 (changes - added bn1)

optimizer = torch.optim.Adam(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
```

```
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

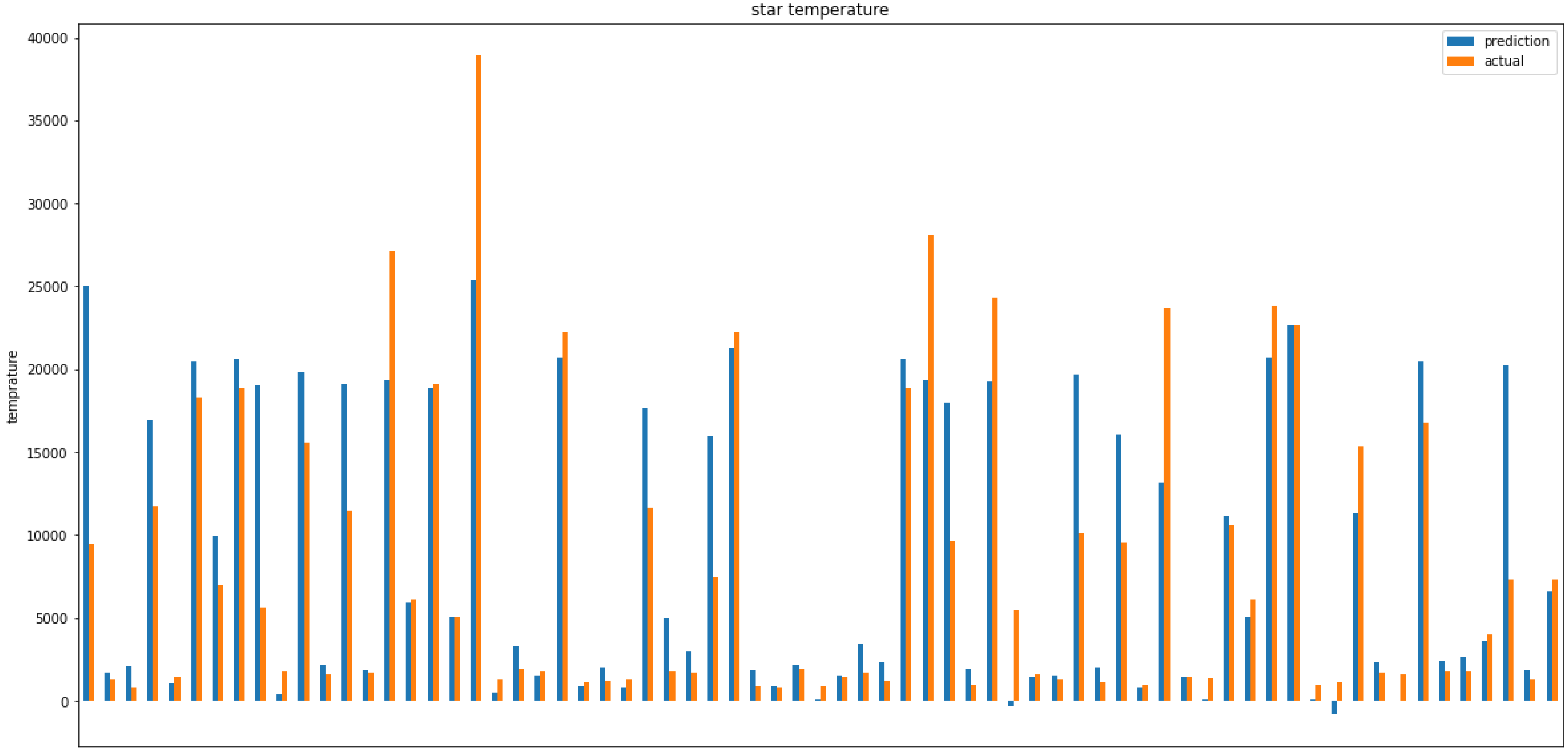
```
tensor(0.3048, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0194, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0164, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0156, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [87]:

```
plot_result(test_preds_4,y_test)
```

```
   prediction        actual
0  25039.654297   9449.041992
1   1715.798096   1272.693848
2   2056.192139    799.768799
3  16910.980469  11718.031250
4   1071.918335   1472.373291

RMSE: 4807.141
```



In [88]:

```
# based on optimised net 1 building the net_4

torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1
```

```
class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.2)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.bn2 = nn.BatchNorm1d(hidden_size_2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.fc2(x)
        x = self.bn2(x)
        x = self.fc3(x)
        return x

net_4 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [89]:

```
# training net_4 (changes - added bn2)

optimizer = torch.optim.Adam(net_4.parameters(),lr=0.011)

loss = torch.nn.MSELoss()

num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_4.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_4.eval(),
            test_preds_4 = net_4.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_4) == y_test).float().mean().data
            print(accuracy)
```

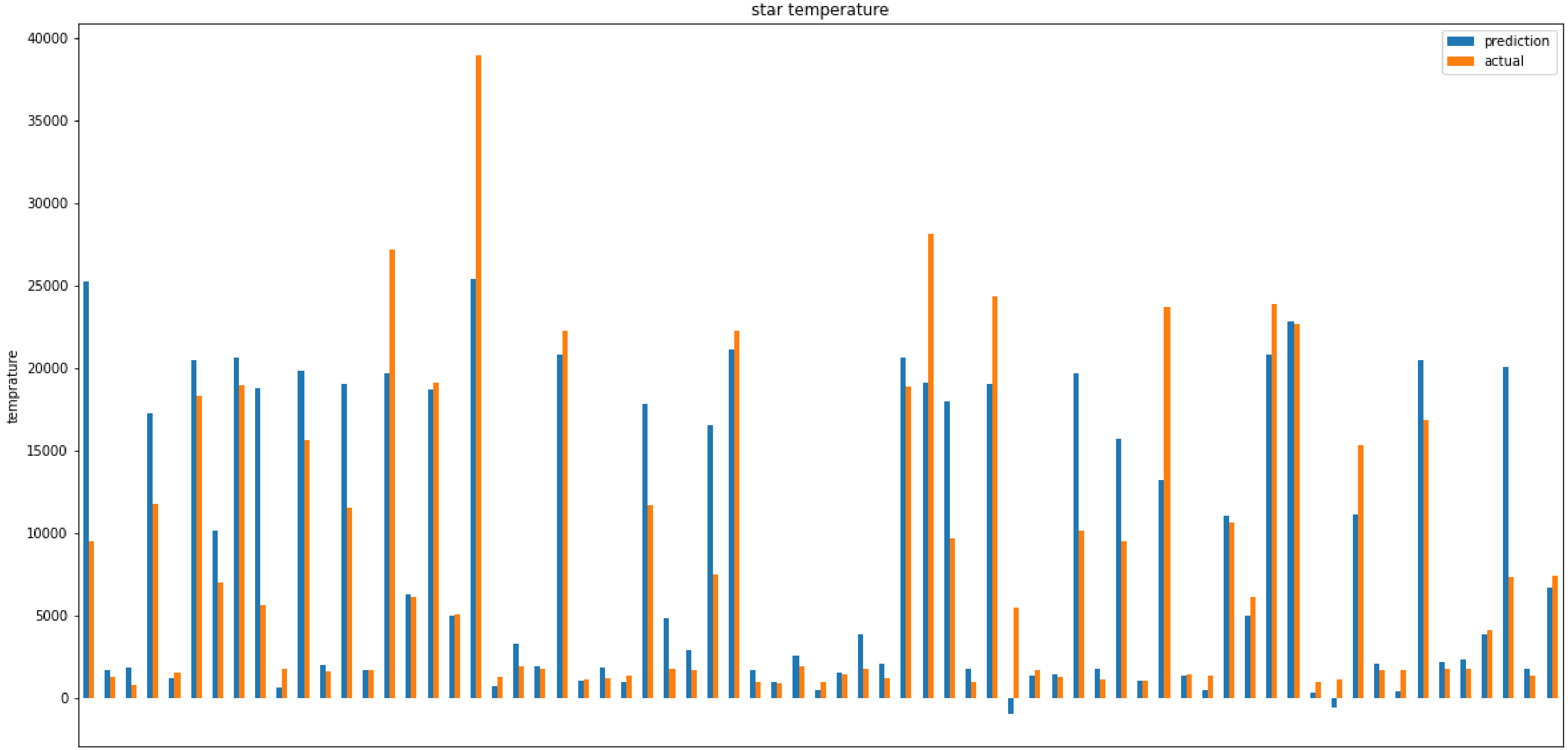
```
tensor(0.5774, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0244, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0165, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0161, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0160, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0159, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0158, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0157, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [90]:

```
plot_result(test_preds_4,y_test)
```

```
      prediction        actual
0   25218.388672   9449.041992
1    1640.124023   1272.693848
2    1796.611572    799.768799
3   17222.617188  11718.031250
4    1156.061279   1472.373291
```

```
RMSE: 4819.2676
```



Conclusion on using of Batchnorm on net_4

Best score network has achivied with applied bn2.

In [91]:
```
# based on optimised net 2 building the net_5
```

```python
torch.manual_seed(1234)
input_size = 14
hidden_size_1 = 12
hidden_size_2 = 8
output_size = 1

class NeuralNet(nn.Module):
    def __init__(self, input_size, hidden_size_1, hidden_size_2, output_size):
        super(NeuralNet, self).__init__()
        self.fc1 = nn.Linear(input_size, hidden_size_1)
        self.dp1 = nn.Dropout(p = 0.1)
        self.act1 = nn.LeakyReLU()
        self.bn1 = nn.BatchNorm1d(hidden_size_1)
        self.fc2 = nn.Linear(hidden_size_1, hidden_size_2)
        self.dp2 = nn.Dropout(p = 0.05)
        self.act2 = nn.LeakyReLU()
        self.bn2 = nn.BatchNorm1d(hidden_size_2)
        self.fc3 = nn.Linear(hidden_size_2, output_size)
        self.dp3 = nn.Dropout(p = 0.05)
        self.act3 = nn.LeakyReLU()

    def forward(self, x):
        x = self.fc1(x)
        x = self.dp1(x)
        x = self.act1(x)
        x = self.bn1(x)
        x = self.fc2(x)
        x = self.dp2(x)
        x = self.act2(x)
        x = self.bn2(x)
        x = self.fc3(x)
        x = self.dp3(x)
        x = self.act3(x)
        return x

net_5 = NeuralNet(input_size, hidden_size_1, hidden_size_2, output_size)
```

In [92]:

```python
# training net_5 (changes - added bn1 и bn2)

optimizer = torch.optim.RMSprop(net_5.parameters(),lr=0.001)

loss = torch.nn.MSELoss()
```

```
num_epochs = 500

for epoch in range(num_epochs):
    optimizer.zero_grad()
    preds = net_5.forward(X_train).flatten()
    loss_value = loss(preds,y_train)
    loss_value.backward()
    optimizer.step()
    if (epoch % 25 == 0) or (epoch == 500) :
            print(loss_value)
            net_5.eval(),
            test_preds_5 = net_5.forward(X_test).flatten()
            accuracy = (torch.round(test_preds_5) == y_test).float().mean().data
            print(accuracy)
```

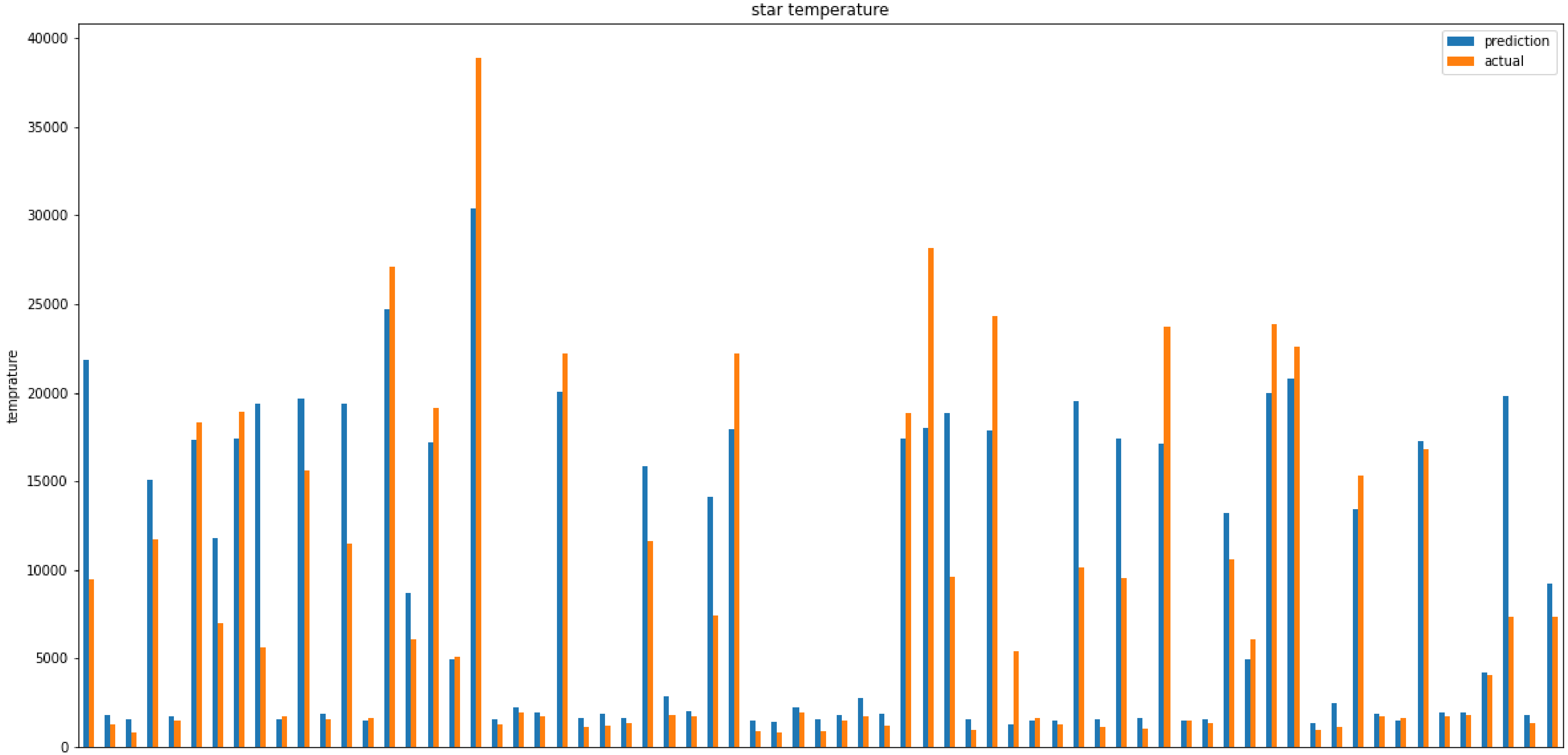
```
tensor(0.1984, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0548, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0319, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0224, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0192, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0170, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0155, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0145, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0139, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0135, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0132, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0129, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0127, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0126, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0124, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0124, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0123, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0121, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0121, grad_fn=<MseLossBackward0>)
tensor(0.)
tensor(0.0120, grad_fn=<MseLossBackward0>)
tensor(0.)
```

In [93]:

```
plot_result(test_preds_5,y_test)
```

```
     prediction        actual
0  21879.076172   9449.041992
1   1796.710449   1272.693848
2   1542.364990    799.768799
3  15064.061523  11718.031250
4   1692.044678   1472.373291
```

```
 RMSE: 4300.2734
```



Conclusion on application of Batchnorm on network_5

Using Batchnorm on first and secon layers model has slightly increase score.

General Conclusion

Creation of table with neural networks and it's scores

In [94]:
```
table = []
for i in range(5):
    table.append('net_' + str(i+1))

print(table)
```

```
['net_1', 'net_2', 'net_3', 'net_4', 'net_5']
```

In [95]:
```
preds_nets = [test_preds_1,test_preds_2,test_preds_3,test_preds_4,test_preds_5]
```

In [96]:
```
for i in range(len(preds_nets)):
    preds_nets[i] = preds_nets[i].detach().numpy()
```

In [97]:
```
rmse_nets = []
for i in preds_nets:
    rmse_nets.append(mean_squared_error(y_test.detach().numpy() * df_stars['Temperature (K)'].max() ,i,squared = False))
```

In [98]:
```
df_result = pd.DataFrame(table,columns = ['net_name'])
```

In [99]:
```
df_result['prediction'] = preds_nets
```

In [100…
```
df_result['rmse'] = rmse_nets
```

During the project execution the data was imported, prepared and analyzed.

Five neural networks wer builded with following scores:

In [101…
```
df_result.sort_values(by = 'rmse',ascending = False)
```

Out[101]:

	net_name	prediction	rmse
0	net_1	[25638.512, 1454.7306, 1245.5305, 17902.568, 1...	4868.386230
1	net_2	[21669.697, 1492.6152, 1537.0199, 14472.895, 1...	4356.758301
2	net_3	[21032.305, 21063.041, 21090.668, 21094.648, 2...	15818.150391
3	net_4	[25218.389, 1640.124, 1796.6116, 17222.617, 11...	4819.267578
4	net_5	[21879.076, 1796.7104, 1542.365, 15064.062, 16...	4300.273438

Best score of neural network:

In [102…

```
df_result[df_result['rmse'] == df_result['rmse'].min()]
```

Out[102]:

	net_name	prediction	rmse
4	net_5	[21879.076, 1796.7104, 1542.365, 15064.062, 16...	4300.273438

Best scores was achivied in neural network No 5 with following parameters:

- lr =0.01
- num_epochs = 500
- optimizer RMS PROP
- activation function - nn.LeakyReLU()
- Dropout(p = 0.1) on first layer and p = 0.05 second and third layers;
- batchnorm - on first and second layers.

RMSE less than 4500 successfully achieved!