project-final ver

December 5, 2023

[1]:
```
import pandas as pd
import numpy as np
from sklearn.model_selection import KFold
from sklearn.model_selection import cross_val_score
from sklearn import metrics
from sklearn.tree import DecisionTreeClassifier
from sklearn import tree
from sklearn.model_selection import train_test_split
from sklearn.model_selection import GridSearchCV
from matplotlib import pyplot as plt
from sklearn.ensemble import AdaBoostClassifier
from sklearn.naive_bayes import GaussianNB
from sklearn.naive_bayes import ComplementNB
from sklearn import svm
from sklearn import preprocessing
from sklearn.preprocessing import LabelEncoder
from sklearn.impute import KNNImputer
from sklearn.linear_model import LogisticRegression
from sklearn.ensemble import RandomForestRegressor
```

[2]:
```
!pip install scikeras
```

```
Collecting scikeras
  Downloading scikeras-0.12.0-py3-none-any.whl (27 kB)
Requirement already satisfied: packaging>=0.21 in
/usr/local/lib/python3.10/dist-packages (from scikeras) (23.2)
Requirement already satisfied: scikit-learn>=1.0.0 in
/usr/local/lib/python3.10/dist-packages (from scikeras) (1.2.2)
Requirement already satisfied: numpy>=1.17.3 in /usr/local/lib/python3.10/dist-
packages (from scikit-learn>=1.0.0->scikeras) (1.23.5)
Requirement already satisfied: scipy>=1.3.2 in /usr/local/lib/python3.10/dist-
packages (from scikit-learn>=1.0.0->scikeras) (1.11.4)
Requirement already satisfied: joblib>=1.1.1 in /usr/local/lib/python3.10/dist-
packages (from scikit-learn>=1.0.0->scikeras) (1.3.2)
Requirement already satisfied: threadpoolctl>=2.0.0 in
/usr/local/lib/python3.10/dist-packages (from scikit-learn>=1.0.0->scikeras)
(3.2.0)
Installing collected packages: scikeras
```

```
Successfully installed scikeras-0.12.0
```

[3]:
```
from xgboost import XGBClassifier
from xgboost import plot_importance
```

[4]:
```
import tensorflow as tf
from keras.models import Sequential
from keras.layers import Dense
from keras.utils import to_categorical
from keras.optimizers import SGD
from scikeras.wrappers import KerasClassifier
```

[5]:
```
from imblearn.over_sampling import SMOTE
```

[6]:
```
from google.colab import files
uploaded = files.upload()
```

```
<IPython.core.display.HTML object>
```

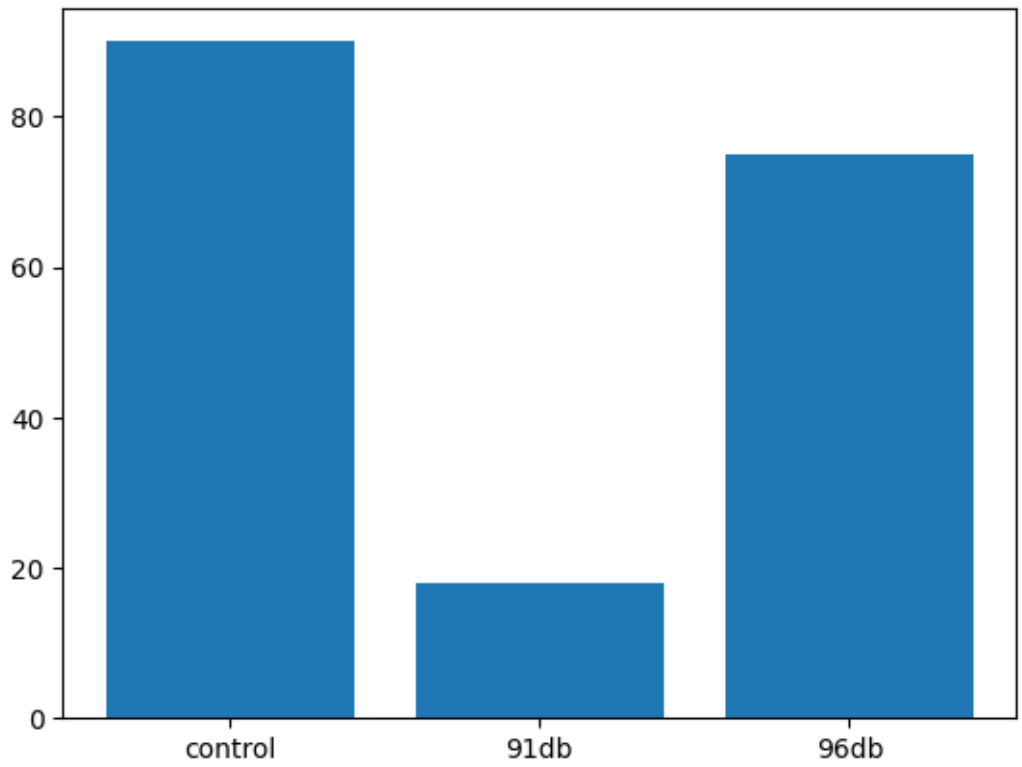
```
Saving FINAL Animal Data 2022.csv to FINAL Animal Data 2022.csv
```

[7]:
```
import io
data = pd.read_csv(io.BytesIO(uploaded["FINAL Animal Data 2022.csv"]))
```

[8]:
```
#drop unnecessary columns
data.drop(["SubjectID","Run"],axis=1,inplace=True)
oversample = SMOTE()
```

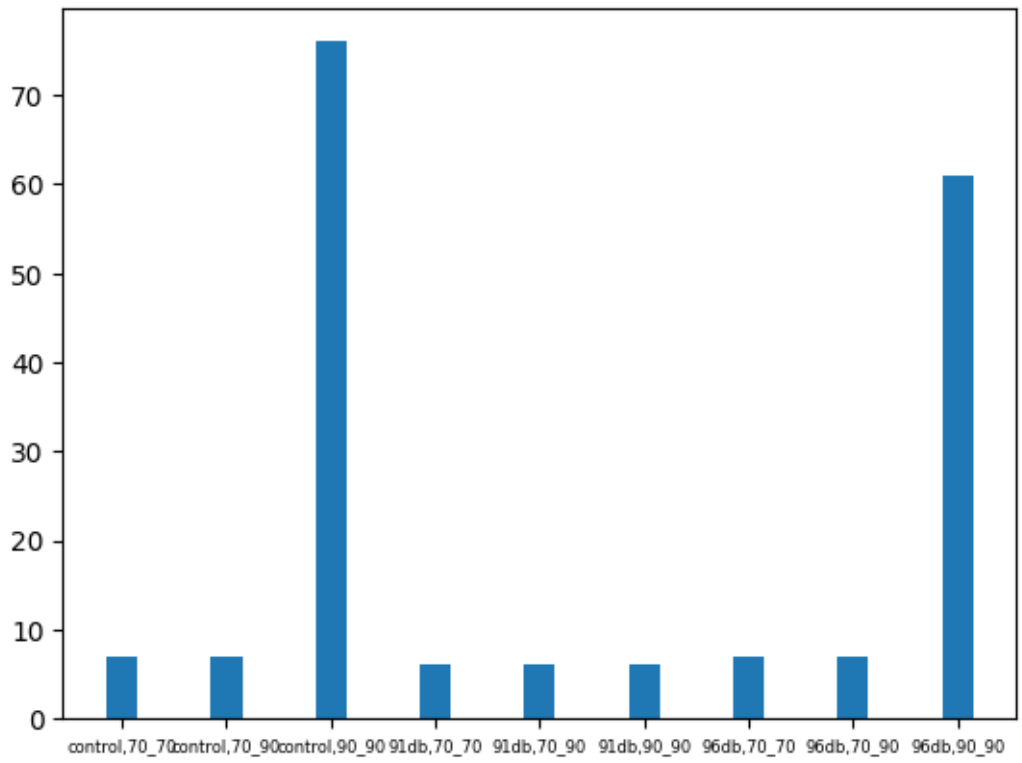
[9]:
```
#plot class distributions
groups = ['control','91db','96db']
group_len  =␣
 ↪[len(data[(data["Group"]=="control")]),len(data[(data["Group"]=="91db")]),len(data[(data["G
plt.bar(x= groups,height = group_len)
```

[9]:
```
<BarContainer object of 3 artists>
```



[10]:
```
#plot class distributions
groups =␣
 ↪['control,70_70','control,70_90','control,90_90','91db,70_70','91db,70_90','91db,90_90','96
group_len  = [len(data[(data["Group"]=="control") &␣
 ↪(data["Levels"]=="70_70")]),len(data[(data["Group"]=="control") &␣
 ↪(data["Levels"]=="70_90")]),len(data[(data["Group"]=="control") &␣
 ↪(data["Levels"]=="90_90")]),len(data[(data["Group"]=="91db") &␣
 ↪(data["Levels"]=="70_70")]),len(data[(data["Group"]=="91db") &␣
 ↪(data["Levels"]=="70_90")]),len(data[(data["Group"]=="91db") &␣
 ↪(data["Levels"]=="90_90")]),
            len(data[(data["Group"]=="96db") &␣
 ↪(data["Levels"]=="70_70")]),len(data[(data["Group"]=="96db") &␣
 ↪(data["Levels"]=="70_90")]),len(data[(data["Group"]=="96db") &␣
 ↪(data["Levels"]=="90_90")])]
plt.xticks(fontsize = 6)
plt.bar(x= groups,height = group_len,width = 0.3)
```

[10]: <BarContainer object of 9 artists>



[11]:
```
#find rows with missing values
data[data.isnull().any(axis=1)]
```

[11]:

	Group	Levels	A_C1W1T0	A_C2W1T0	L_C1W1T0	L_C2W1T0	A_C1W2T0	\
1	control	70_90	0.000002	0.000005	1.311475	11.188525	0.000005	
18	control	70_70	0.000005	0.000005	1.352459	11.270492	0.000006	
44	96db	90_90	0.000007	0.000007	1.229508	11.147541	0.000012	
53	96db	90_90	0.000004	0.000004	1.188525	11.106557	0.000012	
63	control	90_90	0.000005	0.000003	1.393443	11.352459	0.000006	
..	…	…	…	…	…	…	…	
178	96db	90_90	0.000004	0.000004	1.311475	11.147541	0.000005	
179	96db	90_90	0.000005	0.000004	1.311475	11.147541	0.000006	
180	96db	90_90	0.000006	0.000003	1.393443	11.311475	0.000007	
181	96db	90_90	0.000007	0.000003	1.352459	11.311475	0.000007	
182	96db	90_90	0.000007	0.000004	1.352459	11.229508	0.000006	

	A_C2W2T0	L_C1W2T0	L_C2W2T0	…	rC_C2W2T2	lC_C2W3T2	cC_C2W3T2	\
1	0.000008	2.008197	11.885246	…	0.000430	0.000320	0.000375	
18	0.000007	2.172131	12.049180	…	0.000149	0.000155	0.000216	
44	0.000011	1.967213	11.885246	…	0.000329	0.000113	0.000242	
53	0.000013	1.967213	11.885246	…	0.000248	0.000138	0.000200	
63	0.000007	1.885246	11.803279	…	0.000061	0.000224	0.000381	

```
..        …       …         …  …        …         …         …
178  0.000004  1.967213  11.844262  …   0.000092  0.000081  0.000144
179  0.000004  1.967213  11.844262  …   0.000089  0.000084  0.000141
180  0.000007  1.844262  11.762295  …   0.000154  0.000108  0.000190
181  0.000006  1.844262  11.762295  …   0.000147  0.000095  0.000182
182  0.000005  1.844262  11.762295  …   0.000150  0.000093  0.000178

     rC_C2W3T2     lC_C2W4T2  cC_C2W4T2  rC_C2W4T2  lC_C2W5T2  cC_C2W5T2  \
1     0.000228  9.020000e-05   0.000122   0.000080   0.000059   0.000041
18    0.000102  2.930000e-05   0.000049   0.000039   0.000048   0.000036
44    0.000221  3.340000e-05   0.000035   0.000044   0.000032   0.000028
53    0.000193           NaN        NaN        NaN   0.000051   0.000059
63    0.000227  5.240000e-05   0.000073   0.000055   0.000021   0.000028
..         …           …         …         …         …         …
178   0.000088  6.320000e-06   0.000017   0.000019   0.000012   0.000013
179   0.000080  2.860000e-07   0.000007   0.000013   0.000013   0.000018
180   0.000157  4.410000e-05   0.000040   0.000022   0.000027   0.000039
181   0.000165  4.190000e-05   0.000035   0.000019   0.000028   0.000039
182   0.000166  4.280000e-05   0.000035   0.000016   0.000015   0.000039

     rC_C2W5T2
1     0.000010
18    0.000029
44    0.000025
53    0.000013
63    0.000019
..         …
178   0.000008
179   0.000004
180   0.000023
181   0.000021
182   0.000033

[76 rows x 102 columns]
```

[12]:
```
#order the variables with the most missing values
order = []
for i in data.columns[data.isna().any()]:
    order.append((data[i].isna().sum(),i))
order.sort(reverse=True)
print(order)
```

```
[(22, 'A_C2W5T2'), (21, 'A_C2W5T0'), (20, 'rC_C2W5T2'), (20, 'lC_C2W5T2'), (20,
'cC_C2W5T2'), (20, 'L_C2W5T2'), (15, 'A_C2W4T0'), (15, 'A_C1W5T2'), (13,
'rC_C2W5T0'), (13, 'lC_C2W5T0'), (13, 'cC_C2W5T0'), (12, 'L_C2W5T0'), (9,
'A_C1W2T2'), (8, 'rC_C1W5T2'), (8, 'lC_C1W5T2'), (8, 'cC_C1W5T2'), (8,
'L_C1W5T2'), (8, 'A_C1W5T0'), (7, 'A_C2W4T2'), (7, 'A_C1W4T2'), (4, 'A_C1W2T0'),
(3, 'rC_C1W5T0'), (3, 'rC_C1W4T2'), (3, 'lC_C1W5T0'), (3, 'lC_C1W4T2'), (3,
```

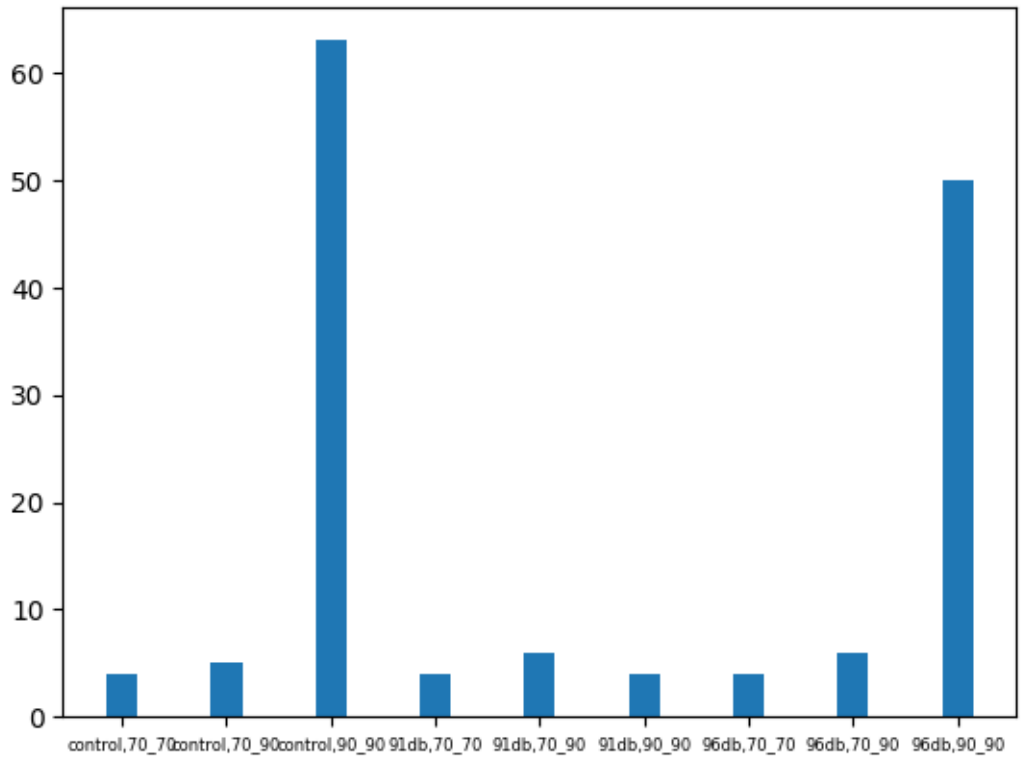
```
'cC_C1W5T0'), (3, 'cC_C1W4T2'), (3, 'L_C1W5T0'), (3, 'L_C1W4T2'), (3,
'A_C2W3T0'), (3, 'A_C1W3T2'), (3, 'A_C1W1T2'), (2, 'A_C2W3T2'), (1,
'rC_C2W4T2'), (1, 'lC_C2W4T2'), (1, 'cC_C2W4T2'), (1, 'L_C2W4T2'), (1,
'A_C2W1T2')]
```

0.1 impute for train and test separately.

[13]:
```
#imputting process using KNN
train, test = train_test_split(data, test_size=0.2, random_state=42)
data_add_train = pd.DataFrame(columns=data.columns)
data_add_test = pd.DataFrame(columns=data.columns)
for i in ["control","91db","96db"]:
    for j in ["70_70","70_90","90_90"]:
        group_data = train[(train["Group"]==i) & (train["Levels"]==j)].iloc[:,2:
 ↪]
        imputer = KNNImputer(n_neighbors=6)
        temp = train[(train["Group"]==i) & (train["Levels"]==j)].iloc[:,:2]
        temp = temp.reset_index(drop=True)
        temp = pd.concat([temp,pd.DataFrame(imputer.
 ↪fit_transform(group_data),columns = train.columns[2:])],axis=1)
        data_add_train = pd.concat([data_add_train,temp],axis=0)
        group_data = test[(test["Group"]==i) & (test["Levels"]==j)].iloc[:,2:]
        if(len(group_data)>0):
          imputer = KNNImputer(n_neighbors=6)
          temp = test[(test["Group"]==i) & (test["Levels"]==j)].iloc[:,:2]
          temp = temp.reset_index(drop=True)
          temp = pd.concat([temp,pd.DataFrame(imputer.
 ↪fit_transform(group_data),columns = test.columns[2:])],axis=1)
          data_add_test = pd.concat([data_add_test,temp],axis=0)
```

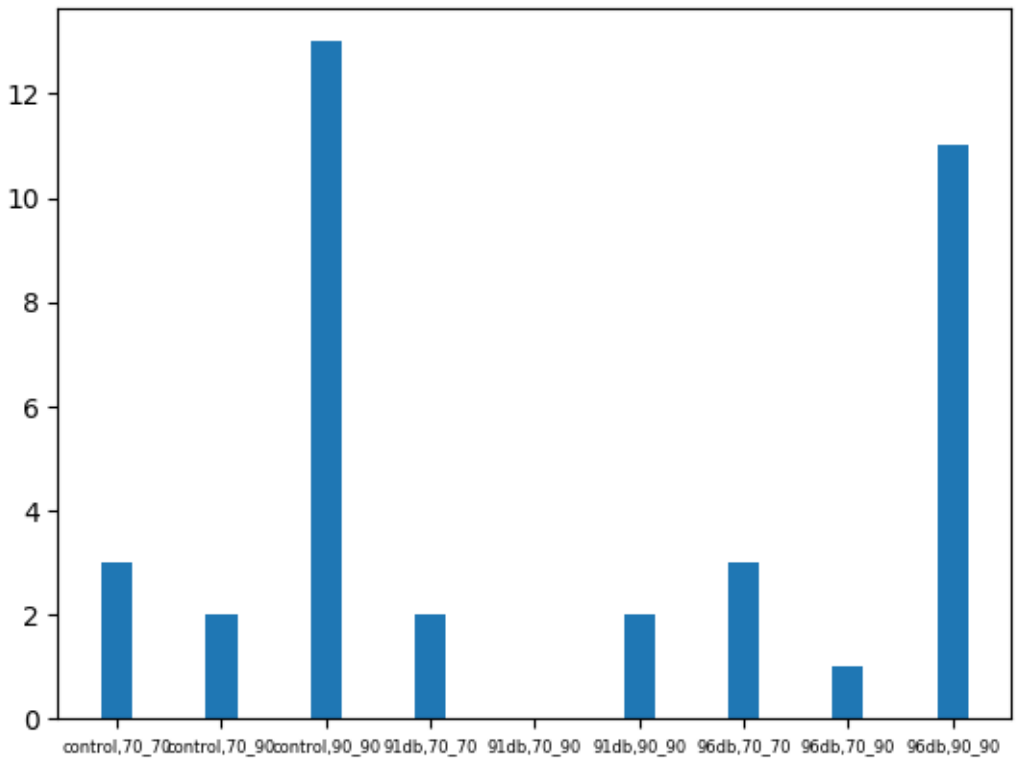
[14]:
```
#plot class distributions for train dataset
groups =␣
 ↪['control,70_70','control,70_90','control,90_90','91db,70_70','91db,70_90','91db,90_90','96
group_len  = [len(train[(train["Group"]=="control") &␣
 ↪(train["Levels"]=="70_70")]),len(train[(train["Group"]=="control") &␣
 ↪(train["Levels"]=="70_90")]),len(train[(train["Group"]=="control") &␣
 ↪(train["Levels"]=="90_90")]),len(train[(train["Group"]=="91db") &␣
 ↪(train["Levels"]=="70_70")]),len(train[(train["Group"]=="91db") &␣
 ↪(train["Levels"]=="70_90")]),len(train[(train["Group"]=="91db") &␣
 ↪(train["Levels"]=="90_90")]),
            len(train[(train["Group"]=="96db") &␣
 ↪(train["Levels"]=="70_70")]),len(train[(train["Group"]=="96db") &␣
 ↪(train["Levels"]=="70_90")]),len(train[(train["Group"]=="96db") &␣
 ↪(train["Levels"]=="90_90")])]
plt.xticks(fontsize = 6)
plt.bar(x= groups,height = group_len,width = 0.3)
```

[14]: <BarContainer object of 9 artists>



[15]:
```
#plot class distributions for test dataset
groups =␣
 ↪['control,70_70','control,70_90','control,90_90','91db,70_70','91db,70_90','91db,90_90','96
group_len  = [len(test[(test["Group"]=="control") &␣
 ↪(test["Levels"]=="70_70")]),len(test[(test["Group"]=="control") &␣
 ↪(test["Levels"]=="70_90")]),len(test[(test["Group"]=="control") &␣
 ↪(test["Levels"]=="90_90")]),len(test[(test["Group"]=="91db") &␣
 ↪(test["Levels"]=="70_70")]),len(test[(test["Group"]=="91db") &␣
 ↪(test["Levels"]=="70_90")]),len(test[(test["Group"]=="91db") &␣
 ↪(test["Levels"]=="90_90")]),
            len(test[(test["Group"]=="96db") &␣
 ↪(test["Levels"]=="70_70")]),len(test[(test["Group"]=="96db") &␣
 ↪(test["Levels"]=="70_90")]),len(test[(test["Group"]=="96db") &␣
 ↪(test["Levels"]=="90_90")])]
plt.xticks(fontsize = 6)
plt.bar(x= groups,height = group_len,width = 0.3)
```

[15]: <BarContainer object of 9 artists>

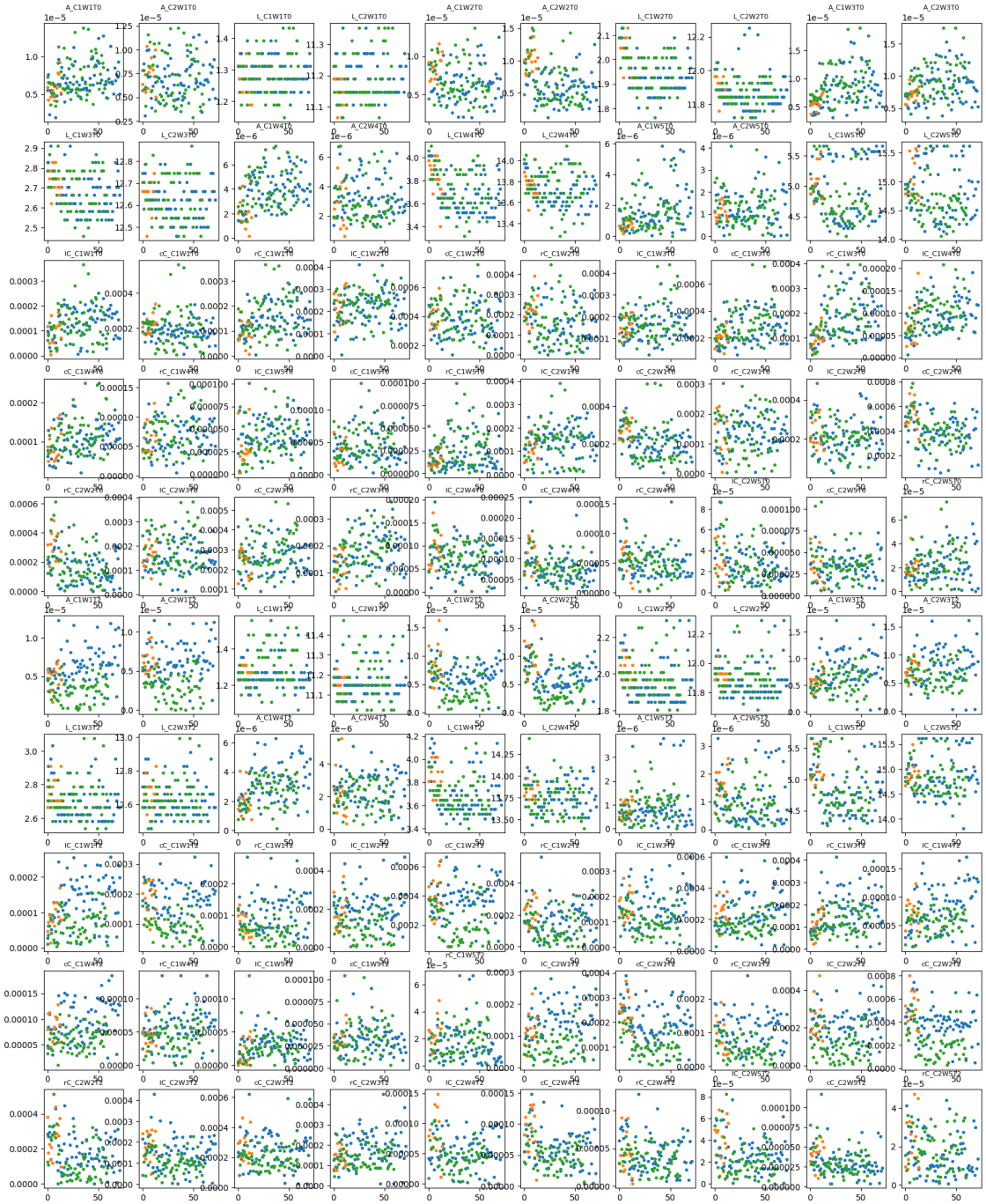


Blue: control group

Orange: 91db group

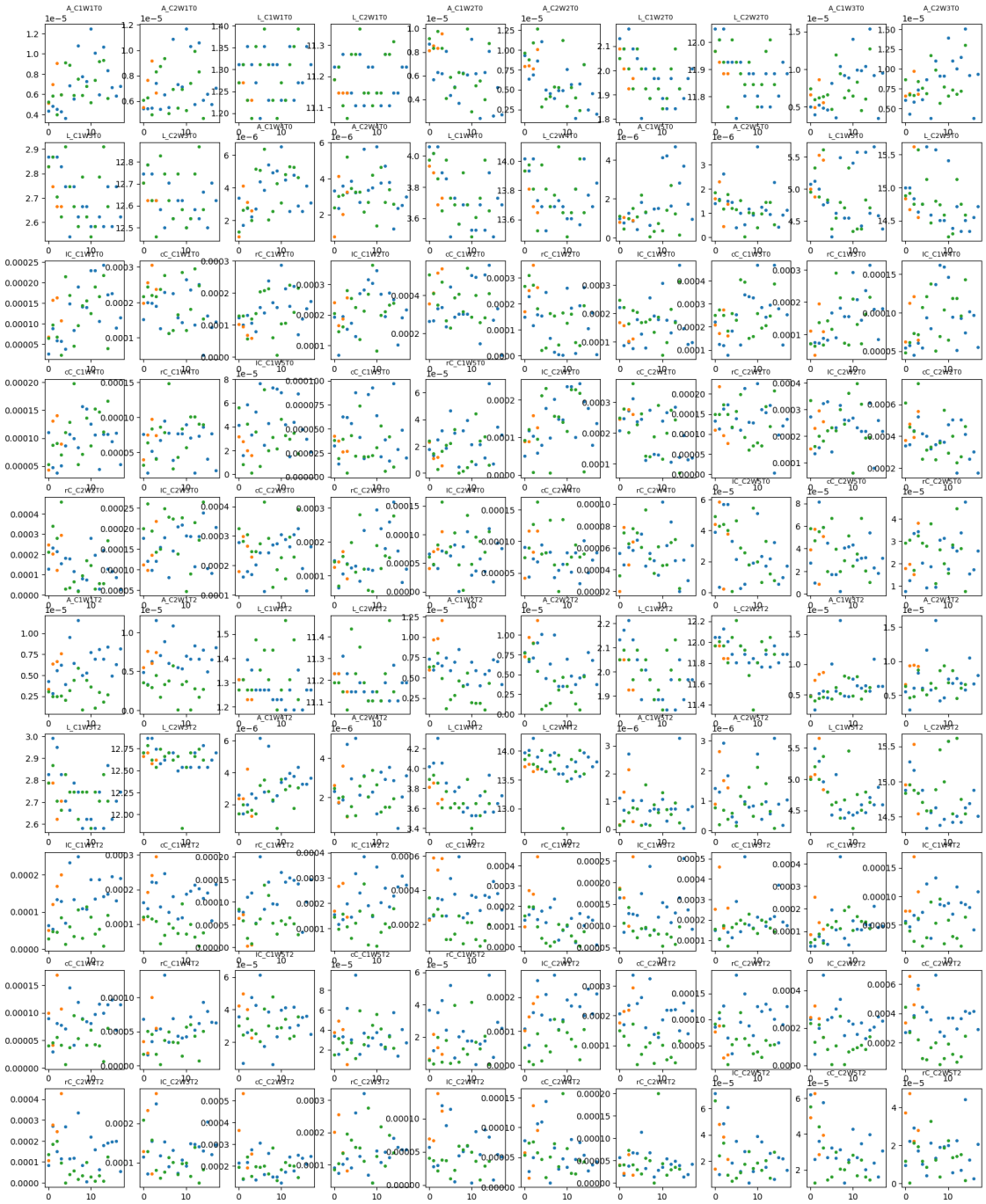
Green: 96db group

[16]:
```
#plot values distributions for each vars in train dataset
g_c = data_add_train[(data_add_train["Group"]=="control")]
g_91 = data_add_train[(data_add_train["Group"]=="91db")]
g_96 = data_add_train[(data_add_train["Group"]=="96db")]
fig, axes = plt.subplots(nrows=10, ncols=10,figsize=(20,25))
for i in range(100):
  axes[int(i/10),i%10].scatter(x=range(len(g_c.iloc[:,i+2])),y = g_c.iloc[:
 ↪,i+2],s=8,color = 'tab:blue')
  axes[int(i/10),i%10].scatter(x=range(len(g_91.iloc[:,i+2])),y = g_91.iloc[:
 ↪,i+2],s=8,color = 'tab:orange')
  axes[int(i/10),i%10].scatter(x=range(len(g_96.iloc[:,i+2])),y = g_96.iloc[:
 ↪,i+2],s=8,color = 'tab:green')
  axes[int(i/10),i%10].set_title(data_add_train.columns[i+2],fontsize = 8)
```



[129]:
```
#plot values distributions for each vars in test dataset
g_c = data_add_test[(data_add_test["Group"]=="control")]
g_91 = data_add_test[(data_add_test["Group"]=="91db")]
g_96 = data_add_test[(data_add_test["Group"]=="96db")]
fig, axes = plt.subplots(nrows=10, ncols=10,figsize=(20,25))
for i in range(100):
```

```
 axes[int(i/10),i%10].scatter(x=range(len(g_c.iloc[:,i+2])),y = g_c.iloc[:
↪,i+2],s=8,color = 'tab:blue')
 axes[int(i/10),i%10].scatter(x=range(len(g_91.iloc[:,i+2])),y = g_91.iloc[:
↪,i+2],s=8,color = 'tab:orange')
 axes[int(i/10),i%10].scatter(x=range(len(g_96.iloc[:,i+2])),y = g_96.iloc[:
↪,i+2],s=8,color = 'tab:green')
 axes[int(i/10),i%10].set_title(data_add_test.columns[i+2],fontsize = 8)
```



[17]:
```
le = LabelEncoder()
#y_train: 0-91db, 1-96db, 2-control
X_train,y_train,X_test,y_test = data_add_train.iloc[:,1:],le.
 ↪fit_transform(data_add_train.iloc[:,0]),data_add_test.iloc[:,1:],le.
 ↪fit_transform(data_add_test.iloc[:,0])
```

[18]:
```
#get dummies for the categorical values stimulus level
X_train = pd.concat([pd.get_dummies(X_train.iloc[:,0]),X_train.iloc[:,1:
 ↪]],axis=1)
X_test = pd.concat([pd.get_dummies(X_test.iloc[:,0]),X_test.iloc[:,1:]],axis=1)
```

[19]:
```
#define Kfolds
kfolds = KFold(5,shuffle=True,random_state=1)
```

[79]:
```
#store accuracies and f1 scores
Accuracies_all = []
F1_all = []
```

For each algorithm, following these steps:

1. tune the paramters with grids
2. list each model's paramters
3. plot each model's performance(score)
4. fit the best model with train dataset, and then train the X_test

(5.) some models can plot the variances importances. If possible,plot them

There are many duplicated codes for scaling and oversampling:

scaling the data: scaler = preprocessing.StandardScaler()

oversampling the train set : X, y = oversample.fit_resample(X_train_scaled,y_train)

0.2 XGBoost Algorithm

[20]:
```
#tune the paramters with grids
grid = {
    'max_depth': [2,4,6,9],
    'n_estimators':[50,100,150],
    'learning_rate':[0.3,0.5,1],
    'reg_alpha':[0,0.01,0.1,0.5],
    'reg_lambda':[0,0.1,1]
}
models = GridSearchCV(estimator=XGBClassifier(), param_grid=grid, cv= kfolds)
models.fit(X_train, y_train)
models.best_params_
```

[20]:
```
{'learning_rate': 0.5,
 'max_depth': 4,
 'n_estimators': 50,
 'reg_alpha': 0,
 'reg_lambda': 1}
```

[21]:
```
#list every model's parameters
models.cv_results_['params']
```

[21]:
```
[{'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
  'reg_alpha': 0,
  'reg_lambda': 0},
 {'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
  'reg_alpha': 0,
  'reg_lambda': 0.1},
 {'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
  'reg_alpha': 0,
  'reg_lambda': 1},
 {'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
  'reg_alpha': 0.01,
  'reg_lambda': 0},
 {'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
  'reg_alpha': 0.01,
  'reg_lambda': 0.1},
 {'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
  'reg_alpha': 0.01,
  'reg_lambda': 1},
 {'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
  'reg_alpha': 0.1,
  'reg_lambda': 0},
 {'learning_rate': 0.3,
  'max_depth': 2,
  'n_estimators': 50,
```

```
 'reg_alpha': 0.1,
 'reg_lambda': 0.1},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 50,
 'reg_alpha': 0.1,
 'reg_lambda': 1},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 50,
 'reg_alpha': 0.5,
 'reg_lambda': 0},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 50,
 'reg_alpha': 0.5,
 'reg_lambda': 0.1},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 50,
 'reg_alpha': 0.5,
 'reg_lambda': 1},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 100,
 'reg_alpha': 0,
 'reg_lambda': 0},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 100,
 'reg_alpha': 0,
 'reg_lambda': 0.1},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 100,
 'reg_alpha': 0,
 'reg_lambda': 1},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 100,
 'reg_alpha': 0.01,
 'reg_lambda': 0},
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 100,
 'reg_alpha': 0.01,
 'reg_lambda': 0.1},
```

```
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 100,
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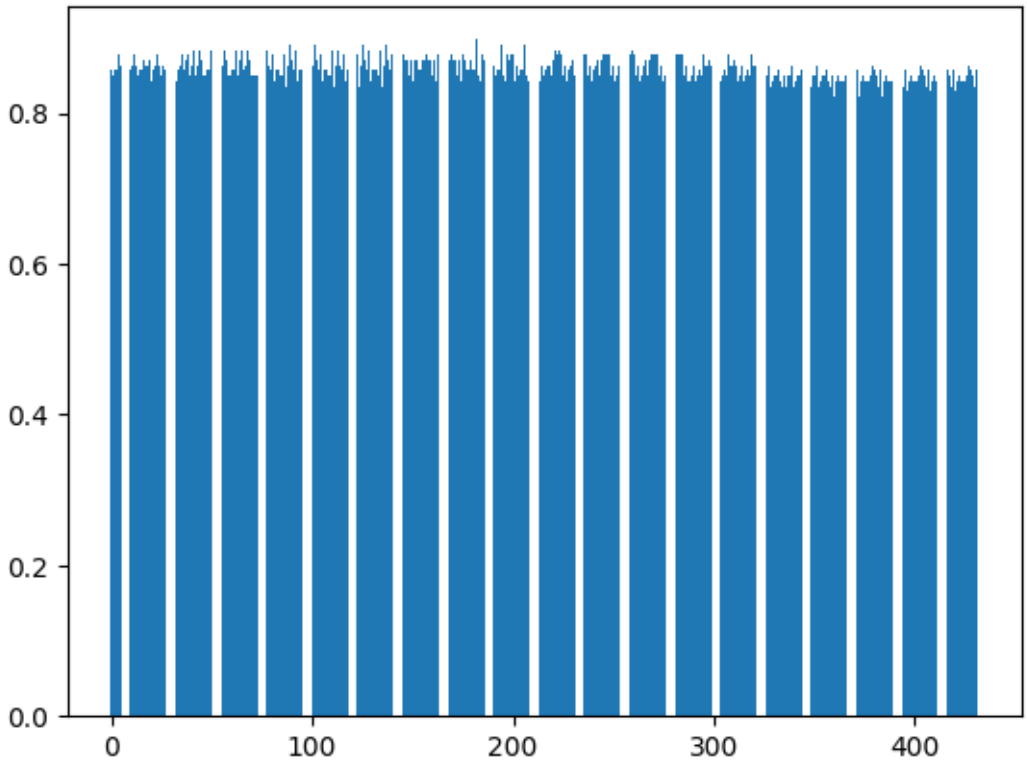
```

[22]:
```
#plot the scores(performance) for each model
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
 ↪cv_results_['mean_test_score'])
```

[22]:
```
<BarContainer object of 432 artists>
```



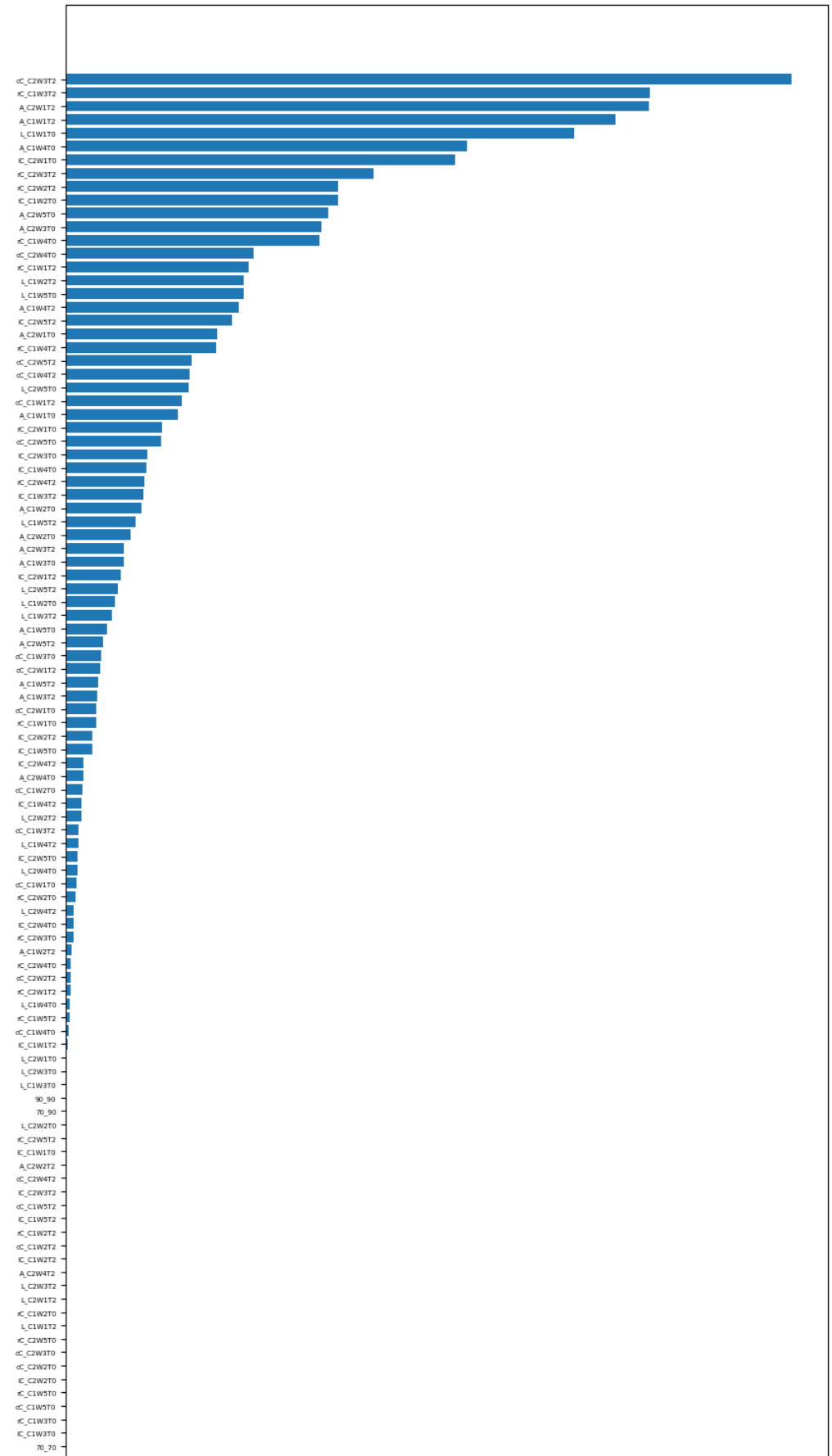
[80]:
```
#fit the best model with train dataset, and then train the X_test
model = XGBClassifier(max_depth = 4, learning_rate = 0.5, n_estimators=␣
 ↪50,reg_lambda = 1,reg_alpha = 0)
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
```

```
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
  ↪predict(X_train)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
  ↪predict(X_train),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
Accuracies_all.append(accuracy)
F1_all.append(f1)
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train.columns)[indices])
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.918918918918919
f1 score on test Dataset:  0.8977130977130977
              precision    recall  f1-score   support

           0       1.00      0.25      0.40         4
           1       1.00      1.00      1.00        15
           2       0.86      1.00      0.92        18

    accuracy                           0.92        37
   macro avg       0.95      0.75      0.77        37
weighted avg       0.93      0.92      0.90        37
```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0.07
0.08

Compare our model with default parameter

[87]:
```
model = XGBClassifier()
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.9459459459459459
f1 score on test Dataset:  0.9383594120436227
              precision    recall  f1-score   support

           0       1.00      0.50      0.67         4
           1       1.00      1.00      1.00        15
           2       0.90      1.00      0.95        18

    accuracy                           0.95        37
   macro avg       0.97      0.83      0.87        37
weighted avg       0.95      0.95      0.94        37
```

0.3 Adaboost

same steps as XGBoost

[86]:
```
grid = {
    'algorithm': ["SAMME","SAMME.R"],
    'n_estimators':[10,30,50,70,100,150],
    'learning_rate':[0.5,1,1.5,2]
}
models = GridSearchCV(estimator = AdaBoostClassifier(), param_grid=grid, cv=␣
 ↪kfolds)
models.fit(X_train, y_train)
print(models.best_params_,models.best_score_)
```

```
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0.8565517241379311
```

[88]:
```
models.cv_results_['params']
```

[88]:
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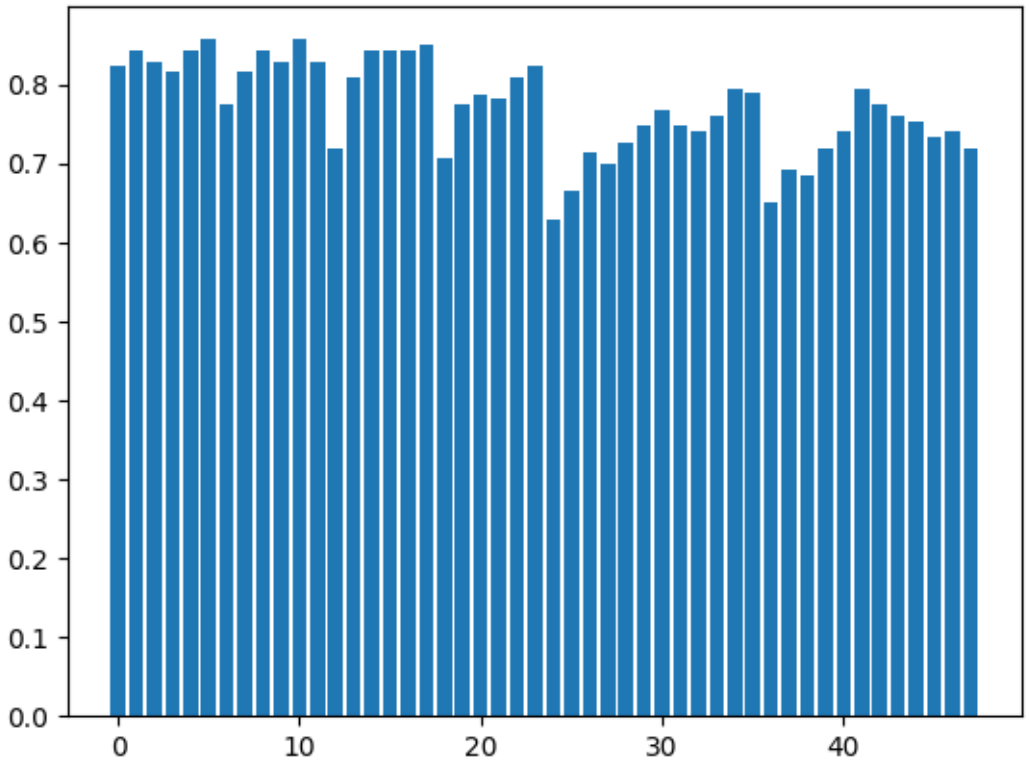
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 100},
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 150},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 10},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 30},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 50},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 70},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 100},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 150},
 {'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 10},
 {'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 30},
 {'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 50},
 {'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 70},
 {'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 100},
 {'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 150},
 {'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 10},
 {'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 30},
 {'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 50},
 {'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 70},
 {'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 100},
 {'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 150},
 {'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 10},
 {'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 30},
 {'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 50},
```

```
 {'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 70},
 {'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 100},
 {'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 150}]
```

[89]:
```
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
 ↪cv_results_['mean_test_score'])
```

[89]:
```
<BarContainer object of 48 artists>
```



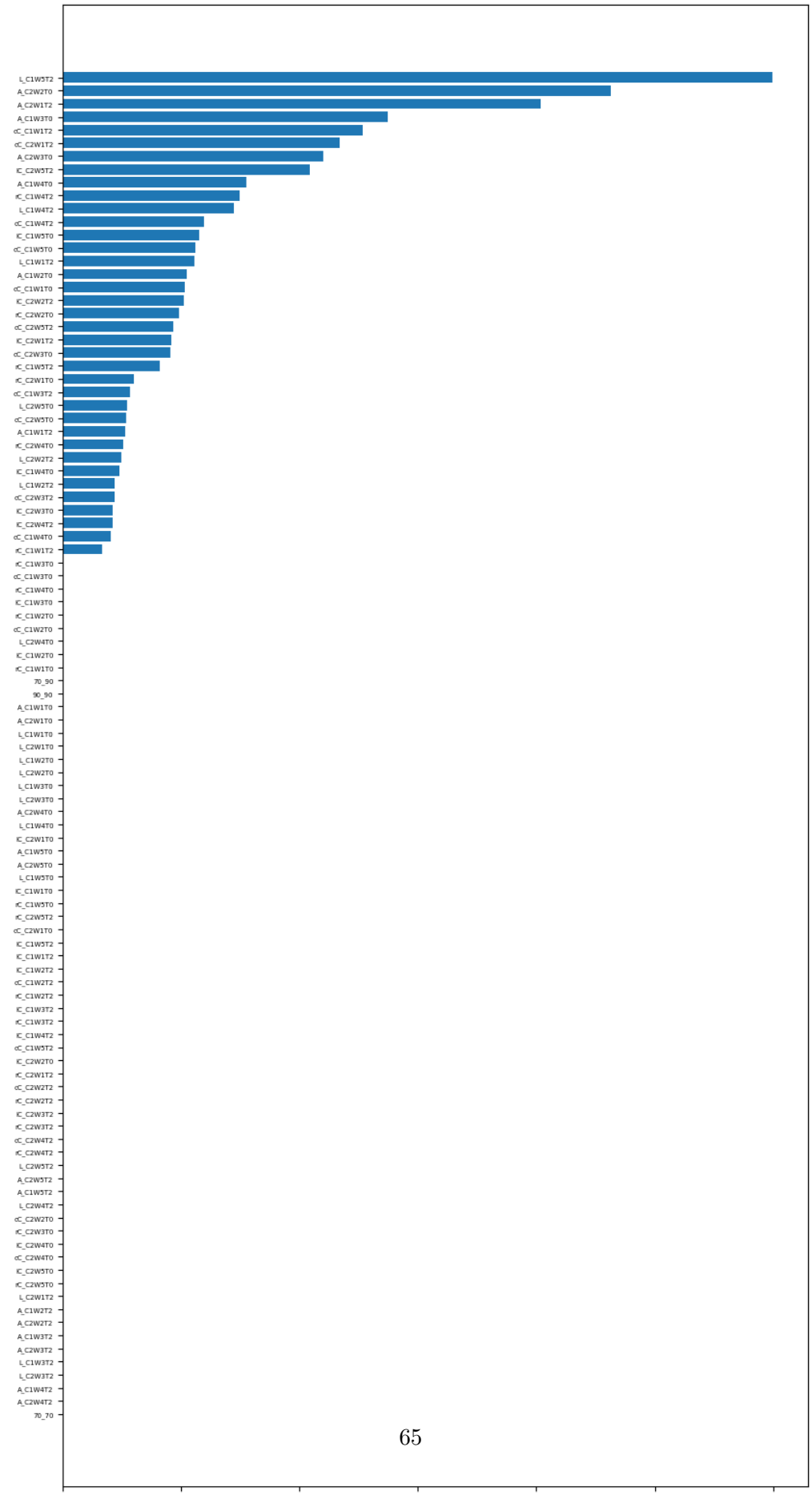
[81]:
```
model = AdaBoostClassifier(algorithm = 'SAMME', learning_rate = 1,␣
 ↪n_estimators= 100)
model.fit(X_train, y_train)
y_pred = model.predict(X_test)
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
# print("Accuracy: ",accuracy)
# print("f1 score: ",f1)
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
```

```
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
Accuracies_all.append(accuracy)
F1_all.append(f1)
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train.columns)[indices])
```

```
Accuracy on train Dataset:  0.9931506849315068
f1 score on train Dataset:  0.9931550392322497
Accuracy on test Dataset:  0.8648648648648649
f1 score on test Dataset:  0.8603811184456346
              precision    recall  f1-score   support

           0       0.67      0.50      0.57         4
           1       0.88      0.93      0.90        15
           2       0.89      0.89      0.89        18

    accuracy                           0.86        37
   macro avg       0.81      0.77      0.79        37
weighted avg       0.86      0.86      0.86        37
```


L_C1W5T2
A_C2W2T0
A_C2W1T2
A_C1W3T0
cC_C1W1T2
cC_C2W1T2
A_C2W3T0
IC_C2W5T2
A_C1W4T0
xC_C1W4T2
L_C1W4T2
cC_C1W4T2
IC_C1W5T0
cC_C1W5T0
L_C1W1T2
A_C1W2T0
cC_C1W1T0
IC_C2W2T2
xC_C2W2T0
cC_C2W5T2
IC_C2W1T2
cC_C2W3T0
IC_C1W5T2
xC_C2W1T0
cC_C1W3T2
L_C2W5T0
cC_C2W5T0
A_C1W1T2
xC_C2W4T0
L_C2W2T2
IC_C1W4T0
L_C1W2T2
cC_C2W3T2
IC_C2W3T0
IC_C2W4T2
cC_C1W4T0
xC_C1W1T2
xC_C1W3T0
cC_C1W3T0
xC_C1W4T0
IC_C1W3T0
xC_C1W2T0
cC_C1W2T0
L_C2W4T0
IC_C1W2T0
xC_C1W1T0
70_90
90_90
A_C1W1T0
A_C2W1T0
L_C1W1T0
L_C2W1T0
L_C1W2T0
L_C2W2T0
L_C1W3T0
L_C2W3T0
A_C2W4T0
L_C1W4T0
IC_C2W1T0
A_C1W5T0
A_C2W5T0
L_C1W5T0
IC_C1W1T0
xC_C1W5T0
xC_C2W5T2
cC_C2W1T0
IC_C1W5T2
IC_C1W1T2
IC_C1W2T2
cC_C1W2T2
xC_C1W2T2
IC_C1W3T2
xC_C1W3T2
IC_C1W4T2
cC_C1W5T2
IC_C2W2T0
xC_C2W1T2
cC_C2W2T2
xC_C2W2T2
IC_C2W3T2
xC_C2W3T2
cC_C2W4T2
xC_C2W4T2
L_C2W5T2
A_C2W5T2
A_C1W5T2
L_C2W4T2
cC_C2W2T0
xC_C2W3T0
IC_C2W4T0
cC_C2W4T0
IC_C2W5T0
xC_C2W5T0
L_C2W1T2
A_C1W2T2
A_C2W2T2
A_C1W3T2
A_C2W3T2
L_C1W3T2
L_C2W3T2
A_C1W4T2
A_C2W4T2
70_70
0.00
0.02
0.04
0.06
0.08
0.10
0.12

0.4 Naive Bayes

Naive Bayes, including three sub models:

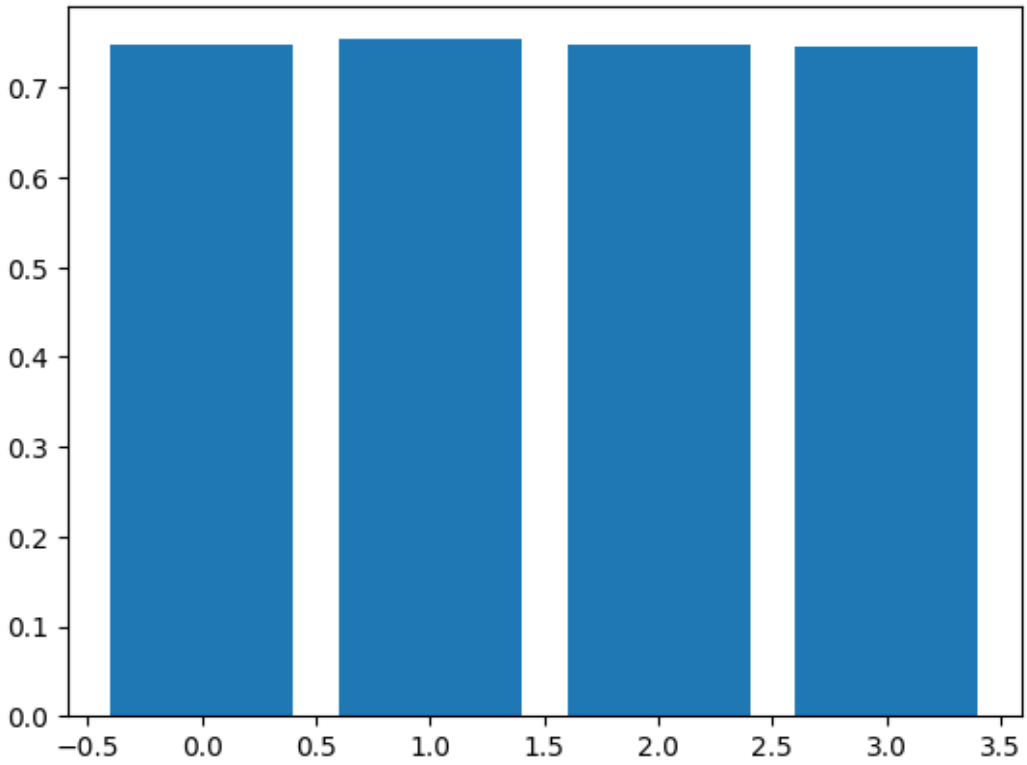
1. Not dealing with imbalance issue using GaussianNB
2. dealing with imbalance issue using GaussianNB
3. ComplementNB

[20]:
```
grid = {
    'priors': [None,[0.34,0.33,0.33],[len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/
 ↪len(y_train),len(y_train[y_train==[2]])/
 ↪len(y_train)],[len(y_train[y_train==[2]])/
 ↪len(y_train),len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/len(y_train)]]
}
models = GridSearchCV(estimator = GaussianNB(), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
models.fit(X_train_scaled, y_train)
print(models.best_params_,models.best_score_)
```

```
{'priors': [0.34, 0.33, 0.33]} 0.7535632183908045
```

[127]:
```
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
 ↪cv_results_['mean_test_score'])
```

[127]:
```
<BarContainer object of 4 artists>
```



[22]:
```
#not using SMOTE
model = GaussianNB(priors = [0.34, 0.33, 0.33])
model.fit(X_train_scaled, y_train)
y_pred = model.predict(X_test_scaled)
accuracy = metrics.accuracy_score(y_pred, y_test)
f1 = metrics.f1_score(y_pred, y_test,average="weighted")
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_scaled)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_scaled),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  0.7945205479452054
f1 score on train Dataset:  0.8035729725392702
Accuracy on test Dataset:  0.7027027027027027
f1 score on test Dataset:  0.6830955624059072
              precision    recall  f1-score   support

           0       0.33      0.75      0.46         4
           1       0.79      0.73      0.76        15
```

```
           2       0.86      0.67      0.75        18

    accuracy                           0.70        37
   macro avg       0.66      0.72      0.66        37
weighted avg       0.77      0.70      0.72        37
```

[139]:
```
#Using Smote to deal with imbalance issue
grid = {
    'priors': [None,[0.34,0.33,0.33],[len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/
 ↪len(y_train),len(y_train[y_train==[2]])/
 ↪len(y_train)],[len(y_train[y_train==[2]])/
 ↪len(y_train),len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/len(y_train)]]
}
models = GridSearchCV(estimator = GaussianNB(), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
X, y = oversample.fit_resample(X_train_scaled,y_train)
models.fit(X, y)
print(models.best_params_,models.best_score_)
```

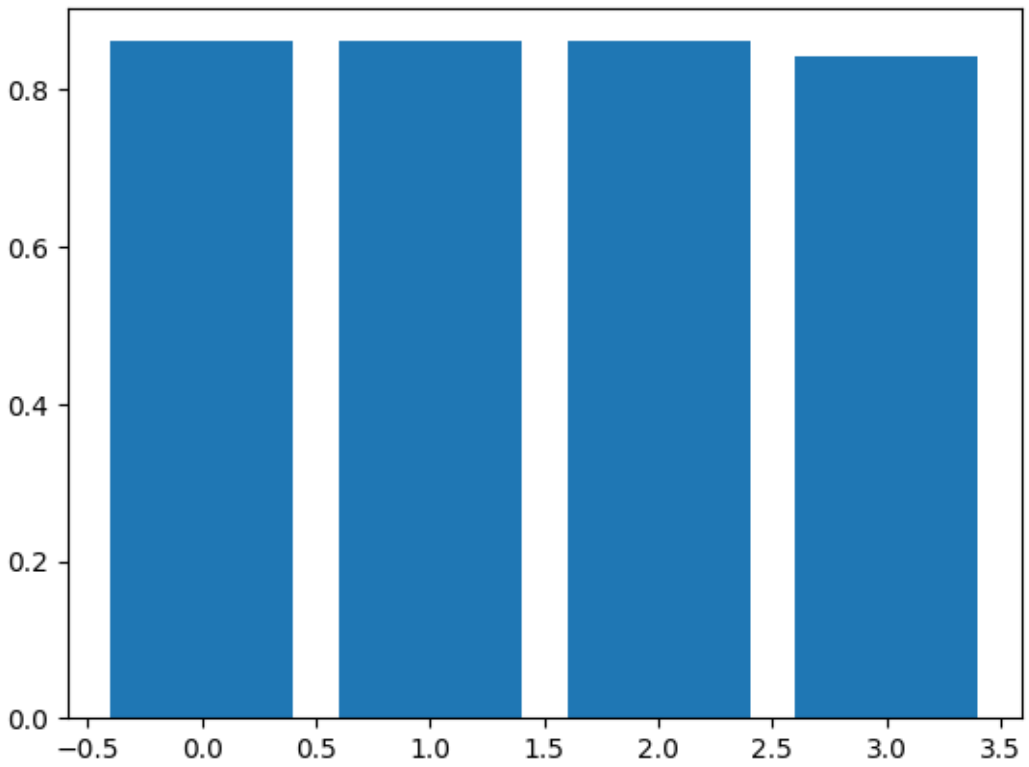
```
{'priors': [0.0958904109589041, 0.410958904109589, 0.4931506849315068]}
0.856553911205074
```

[118]:
```
models.cv_results_['params']
```

[118]:
```
[{'priors': None},
 {'priors': [0.34, 0.33, 0.33]},
 {'priors': [0.0958904109589041, 0.410958904109589, 0.4931506849315068]},
 {'priors': [0.4931506849315068, 0.0958904109589041, 0.410958904109589]}]
```

[28]:
```
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
 ↪cv_results_['mean_test_score'])
```

[28]:
```
<BarContainer object of 4 artists>
```



[142]:
```
model = GaussianNB(priors = [0.0958904109589041, 0.410958904109589, 0.
 ↪4931506849315068])
model.fit(X, y)
y_pred = model.predict(X_test_scaled)
accuracy = metrics.accuracy_score(y_pred, y_test)
f1 = metrics.f1_score(y_pred, y_test,average="weighted")
print("Accuracy on train Dataset: ",metrics.accuracy_score(y, model.predict(X)))
print("f1 score on train Dataset: ",metrics.f1_score(y, model.
 ↪predict(X),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
Accuracies_all.append(accuracy)
F1_all.append(f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  0.8796296296296297
f1 score on train Dataset:  0.8774780397783307
Accuracy on test Dataset:  0.7297297297297297
f1 score on test Dataset:  0.7162162162162162
              precision    recall  f1-score   support

           0       0.38      0.75      0.50         4
```

```
           1       0.80      0.80      0.80        15
           2       0.86      0.67      0.75        18

    accuracy                           0.73        37
   macro avg       0.68      0.74      0.68        37
weighted avg       0.78      0.73      0.74        37
```

Compare Gaussian NB with ComplementNB, Complement NB performs worse than Gaussian

[58]:
```
model = ComplementNB()
X, y = oversample.fit_resample(X_train,y_train)
model.fit(X, y)
y_pred = model.predict(X_test_scaled)
accuracy = metrics.accuracy_score(y_pred, y_test)
f1 = metrics.f1_score(y_pred, y_test,average="weighted")
print("Accuracy on train Dataset: ",metrics.accuracy_score(y, model.predict(X)))
print("f1 score on train Dataset: ",metrics.f1_score(y, model.
 ↪predict(X),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  0.5462962962962963
f1 score on train Dataset:  0.44661620516751305
Accuracy on test Dataset:  0.6486486486486487
f1 score on test Dataset:  0.6028098028098028
              precision    recall  f1-score   support

           0       0.18      0.50      0.27         4
           1       0.91      0.67      0.77        15
           2       0.80      0.67      0.73        18

    accuracy                           0.65        37
   macro avg       0.63      0.61      0.59        37
weighted avg       0.78      0.65      0.69        37


/usr/local/lib/python3.10/dist-packages/sklearn/base.py:439: UserWarning: X does
not have valid feature names, but ComplementNB was fitted with feature names
  warnings.warn(
```

0.5 SVM

[84]:
```
scaler = preprocessing.StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
params_grid = [{'kernel': ['rbf'], 'gamma': [1e-4,1e-3,0.01,0.1,0.5],'C': [0.
 ↪1,1,1.5,10]},
```

```
 {'kernel': ['linear'], 'C': [0.1,1,1.5,10]}]
svm_model = GridSearchCV(svm.SVC(), params_grid, cv=kfolds)
svm_model.fit(X_train_scaled, y_train)
```

[84]:
```
GridSearchCV(cv=KFold(n_splits=5, random_state=1, shuffle=True),
             estimator=SVC(),
             param_grid=[{'C': [0.1, 1, 1.5, 10],
                          'gamma': [0.0001, 0.001, 0.01, 0.1, 0.5],
                          'kernel': ['rbf']},
                         {'C': [0.1, 1, 1.5, 10], 'kernel': ['linear']}])
```

[85]:
```
print('Best score for training data:', svm_model.best_score_)
# View the best parameters for the model found using grid search
print('Best C:',svm_model.best_estimator_.C)
print('Best Kernel:',svm_model.best_estimator_.kernel)
print('Best Gamma:',svm_model.best_estimator_.gamma)
model = svm_model.best_estimator_
y_pred = model.predict(X_test_scaled)
```

```
Best score for training data: 0.911264367816092
Best C: 1
Best Kernel: linear
Best Gamma: scale
```

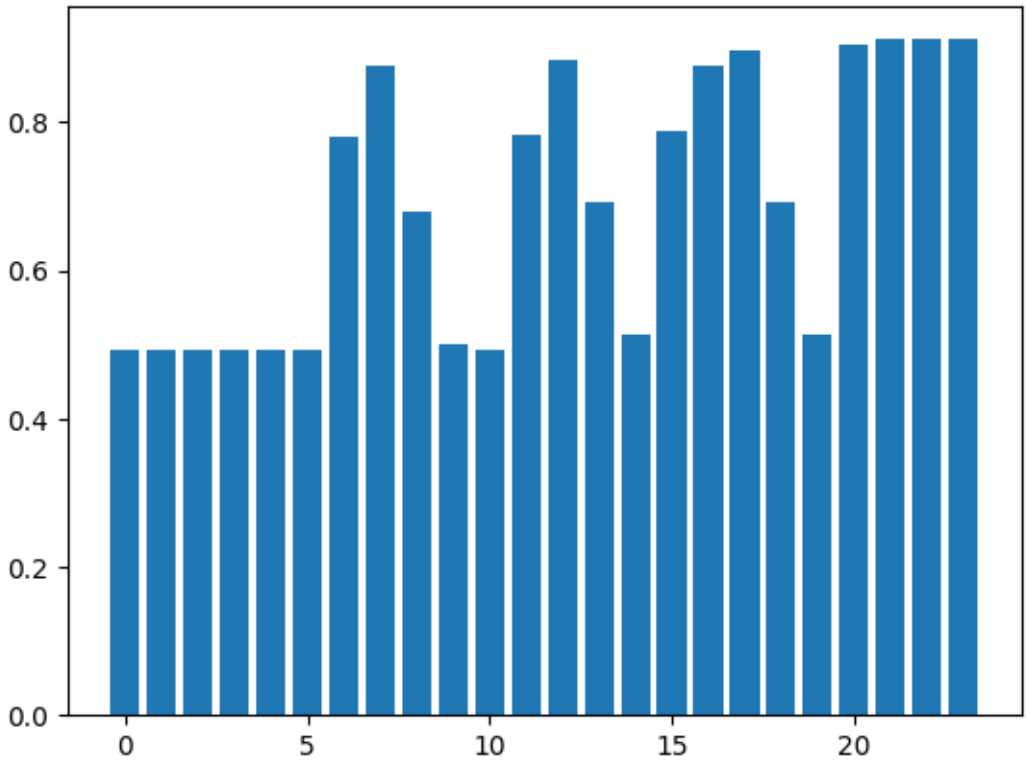
[31]:
```
svm_model.cv_results_['params']
```

[31]:
```
[{'C': 0.1, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 0.1, 'kernel': 'linear'},
 {'C': 1, 'kernel': 'linear'},
```

```
 {'C': 1.5, 'kernel': 'linear'},
 {'C': 10, 'kernel': 'linear'}]
```

[32]:
```
plt.bar(range(len(svm_model.cv_results_['mean_test_score'])),svm_model.
 ↪cv_results_['mean_test_score'])
```

[32]: <BarContainer object of 24 artists>



[86]:
```
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test, y_pred, average='weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_scaled)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_scaled),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
Accuracies_all.append(accuracy)
F1_all.append(f1)
print(metrics.classification_report(y_test,y_pred))
```

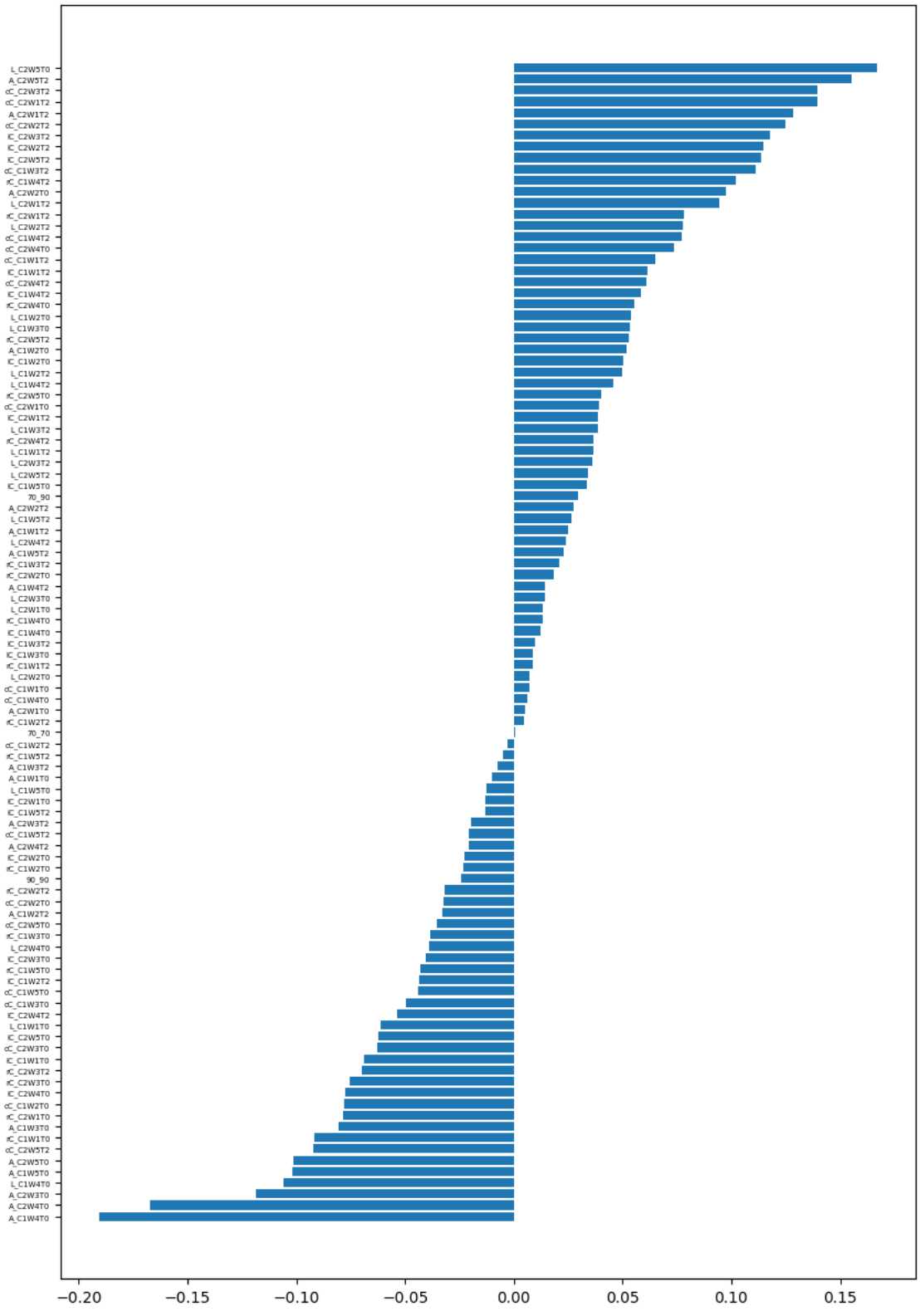
```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
```

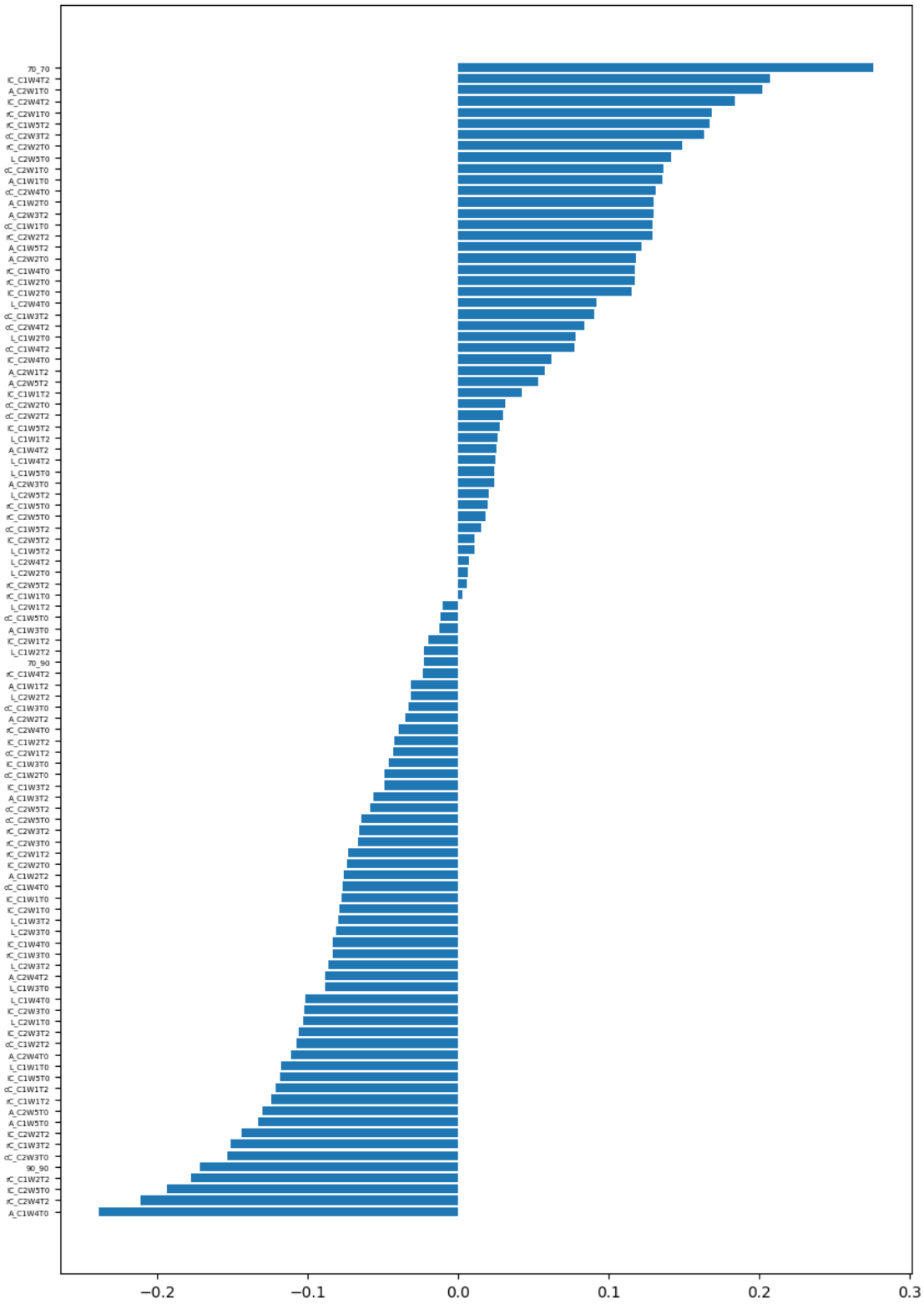
```
Accuracy on test Dataset:  0.9459459459459459
f1 score on test Dataset:  0.9497615262321144
              precision    recall  f1-score   support

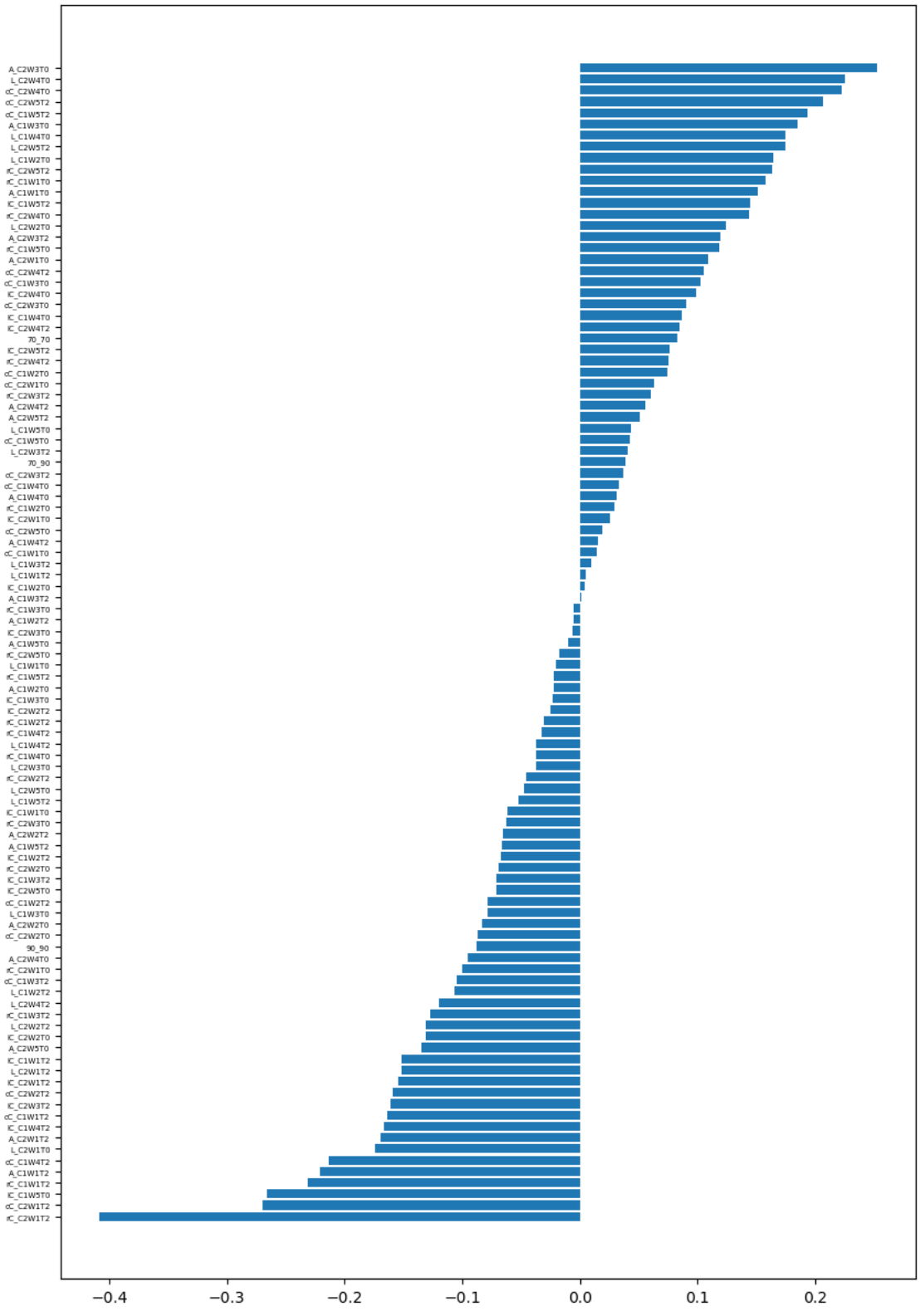
           0       0.67      1.00      0.80         4
           1       1.00      1.00      1.00        15
           2       1.00      0.89      0.94        18

    accuracy                           0.95        37
   macro avg       0.89      0.96      0.91        37
weighted avg       0.96      0.95      0.95        37
```

[134]:
```python
#plot the variable importances
def f_importances(coef, names):
    imp = coef
    imp,names = zip(*sorted(zip(imp,names)))
    # fig, ax = plt.subplots(figsize=(10,15))
    # ax.barh(range(len(names)), imp,align = 'center')
    # ax.tick_params(axis='y', labelsize=8)
    # _ = ax.set_yticklabels(names)
    plt.figure(figsize=(10,15))
    plt.barh(range(len(names)), imp, align='center')
    plt.tick_params(axis='y', labelsize=5)
    plt.yticks(range(len(names)), names)
    plt.show()
f_importances(model.coef_[0], X_train.columns)
f_importances(model.coef_[1], X_train.columns)
f_importances(model.coef_[2], X_train.columns)
```


L_C2W5T0
A_C2W5T2
cC_C2W3T2
cC_C2W1T2
A_C2W1T2
cC_C2W2T2
IC_C2W3T2
IC_C2W2T2
IC_C2W5T2
cC_C1W3T2
rC_C1W4T2
A_C2W2T0
L_C2W1T2
rC_C2W1T2
L_C2W2T2
cC_C1W4T2
cC_C2W4T0
cC_C1W1T2
IC_C1W1T2
cC_C2W4T2
IC_C1W4T2
rC_C2W4T0
L_C1W2T0
L_C1W3T0
rC_C2W5T2
A_C1W2T0
IC_C1W2T0
L_C1W2T2
L_C1W4T2
rC_C2W5T0
cC_C2W1T0
IC_C2W1T2
L_C1W3T2
rC_C2W4T2
L_C1W1T2
L_C2W3T2
L_C2W5T2
IC_C1W5T0
70_90
A_C2W2T2
L_C1W5T2
A_C1W1T2
L_C2W4T2
A_C1W5T2
rC_C1W3T2
rC_C2W2T0
A_C1W4T2
L_C2W3T0
L_C2W1T0
rC_C1W4T0
IC_C1W4T0
IC_C1W3T2
IC_C1W3T0
rC_C1W1T2
L_C2W2T0
cC_C1W1T0
cC_C1W4T0
A_C2W1T0
rC_C1W2T2
70_70
cC_C1W2T2
rC_C1W5T2
A_C1W3T2
A_C1W1T0
L_C1W5T0
IC_C2W1T0
IC_C1W5T2
A_C2W3T2
cC_C1W5T2
A_C2W4T2
IC_C2W2T0
rC_C1W2T0
90_90
rC_C2W2T2
cC_C2W2T0
A_C1W2T2
cC_C2W5T0
rC_C1W3T0
L_C2W4T0
IC_C2W3T0
rC_C1W5T0
IC_C1W2T2
cC_C1W5T0
cC_C1W3T0
IC_C2W4T2
L_C1W1T0
IC_C2W5T0
cC_C2W3T0
IC_C1W1T0
rC_C2W3T2
rC_C2W3T0
IC_C2W4T0
cC_C1W2T0
rC_C2W1T0
A_C1W3T0
rC_C1W1T0
cC_C2W5T2
A_C2W5T0
A_C1W5T0
L_C1W4T0
A_C2W3T0
A_C2W4T0
A_C1W4T0
−0.20
−0.15
−0.10
−0.05
0.00
0.05
0.10
0.15


70_70
IC_C1W4T2
A_C2W1T0
IC_C2W4T2
nC_C2W1T0
nC_C1W5T2
oC_C2W3T2
nC_C2W2T0
L_C2W5T0
oC_C2W1T0
A_C1W1T0
oC_C2W4T0
A_C1W2T0
A_C2W3T2
oC_C1W1T0
nC_C2W2T2
A_C1W5T2
A_C2W2T0
nC_C1W4T0
nC_C1W2T0
IC_C1W2T0
L_C2W4T0
oC_C1W3T2
oC_C2W4T2
L_C1W2T0
oC_C1W4T2
IC_C2W4T0
A_C2W1T2
A_C2W5T2
IC_C1W1T2
oC_C2W2T0
oC_C2W2T2
IC_C1W5T2
L_C1W1T2
A_C1W4T2
L_C1W4T2
L_C1W5T0
A_C2W3T0
L_C2W5T2
nC_C1W5T0
nC_C2W5T0
oC_C1W5T2
IC_C2W5T2
L_C1W5T2
L_C2W4T2
L_C2W2T0
nC_C2W5T2
nC_C1W1T0
L_C2W1T2
oC_C1W5T0
A_C1W3T0
IC_C2W1T2
L_C1W2T2
70_90
nC_C1W4T2
A_C1W1T2
L_C2W2T2
oC_C1W3T0
A_C2W2T2
nC_C2W4T0
IC_C1W2T2
oC_C2W1T2
IC_C1W3T0
oC_C1W2T0
IC_C1W3T2
A_C1W3T2
oC_C2W5T2
oC_C2W5T0
nC_C2W3T2
nC_C2W3T0
nC_C2W1T2
IC_C2W2T0
A_C1W2T2
oC_C1W4T0
IC_C1W1T0
IC_C2W1T0
L_C1W3T2
L_C2W3T0
IC_C1W4T0
nC_C1W3T0
L_C2W3T2
A_C2W4T2
L_C1W3T0
L_C1W4T0
IC_C2W3T0
L_C2W1T0
IC_C2W3T2
oC_C1W2T2
A_C2W4T0
L_C1W1T0
IC_C1W5T0
oC_C1W1T2
nC_C1W1T2
A_C2W5T0
A_C1W5T0
IC_C2W2T2
nC_C1W3T2
oC_C2W3T0
90_90
nC_C1W2T2
IC_C2W5T0
nC_C2W4T2
A_C1W4T0
−0.2
−0.1
0.0
0.1
0.2
0.3


A_C2W3T0
L_C2W4T0
cC_C2W4T0
cC_C2W5T2
cC_C1W5T2
A_C1W3T0
L_C1W4T0
L_C2W5T2
L_C1W2T0
rC_C2W5T2
rC_C1W1T0
A_C1W1T0
lC_C1W5T2
rC_C2W4T0
L_C2W2T0
A_C2W3T2
rC_C1W5T0
A_C2W1T0
cC_C2W4T2
cC_C1W3T0
lC_C2W4T0
cC_C2W3T0
lC_C1W4T0
lC_C2W4T2
70_70
lC_C2W5T2
rC_C2W4T2
cC_C1W2T0
cC_C2W1T0
rC_C2W3T2
A_C2W4T2
A_C2W5T2
L_C1W5T0
cC_C1W5T0
L_C2W3T2
70_90
cC_C2W3T2
cC_C1W4T0
A_C1W4T0
rC_C1W2T0
lC_C2W1T0
cC_C2W5T0
A_C1W4T2
cC_C1W1T0
L_C1W3T2
L_C1W1T2
lC_C1W2T0
A_C1W3T2
rC_C1W3T0
A_C1W2T2
lC_C2W3T0
A_C1W5T0
rC_C2W5T0
L_C1W1T0
rC_C1W5T2
A_C1W2T0
lC_C1W3T0
lC_C2W2T2
rC_C1W2T2
rC_C1W4T2
L_C1W4T2
rC_C1W4T0
L_C2W3T0
rC_C2W2T2
L_C2W5T0
L_C1W5T2
lC_C1W1T0
rC_C2W3T0
A_C2W2T2
A_C1W5T2
lC_C1W2T2
rC_C2W2T0
lC_C1W3T2
lC_C2W5T0
cC_C1W2T2
L_C1W3T0
A_C2W2T0
cC_C2W2T0
90_90
A_C2W4T0
rC_C2W1T0
cC_C1W3T2
L_C1W2T2
L_C2W4T2
rC_C1W3T2
L_C2W2T2
lC_C2W2T0
A_C2W5T0
lC_C1W1T2
L_C2W1T2
lC_C2W1T2
cC_C2W2T2
lC_C2W3T2
cC_C1W1T2
lC_C1W4T2
A_C2W1T2
L_C2W1T0
cC_C1W4T2
A_C1W1T2
rC_C1W1T2
lC_C1W5T0
cC_C2W1T2
rC_C2W1T2
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2

0.6 Neural Network

[40]:
```
in_dim = len(X_train.columns)
oversample = SMOTE()
X, y = oversample.fit_resample(X_train,data_add_train.iloc[:,0])
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
test_features = scaler.transform(X_test)
```

Build model because we cannot tune the NNmodel directly with paramters

[39]:
```
def NNModel(nodes,layer,actf,optimz):
  model = Sequential()
  for i in range(layer):
    model.add(Dense(100, input_dim = in_dim, activation = actf))
  model.add(Dense(3, activation = 'softmax'))
  if(optimz=="SGD"):
    opt = SGD(learning_rate = 0.01)
  else:
    opt = 'Adam'
  model.compile(loss = 'categorical_crossentropy', optimizer = opt, metrics =␣
 ↪['accuracy'])
  return model
```

use Neurons(50/100),activation function(relu/sigmoid),optimization function(SGD/Adam) to compare the performance manually

[41]:
```
accuracies = []
model = NNModel(50,3,'relu','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(50,3,'relu','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
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 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(50,3,'sigmoid','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
```

```
accuracies.append(results.mean())
model = NNModel(50,3,'sigmoid','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'relu','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'relu','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
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print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
```

```
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
being deleted with unrestored values. See the following logs for the specific
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See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor
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WARNING:tensorflow:Value in checkpoint could not be found in the restored
```

```
object: (root).keras_api.metrics.1.total
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object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
WARNING:tensorflow:5 out of the last 13 calls to <function
Model.make_predict_function.<locals>.predict_function at 0x7b12b563cf70>
triggered tf.function retracing. Tracing is expensive and the excessive number
of tracings could be due to (1) creating @tf.function repeatedly in a loop, (2)
passing tensors with different shapes, (3) passing Python objects instead of
tensors. For (1), please define your @tf.function outside of the loop. For (2),
@tf.function has reduce_retracing=True option that can avoid unnecessary
retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.

*****Model Accuracy: 83.00% (16.64%)

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Model.make_predict_function.<locals>.predict_function at 0x7b12b4b1e050>
triggered tf.function retracing. Tracing is expensive and the excessive number
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```

```
retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.
```

```
*****Model Accuracy: 96.29% (1.87%)
```

```
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object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
```

```
*****Model Accuracy: 33.36% (16.20%)

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being deleted with unrestored values. See the following logs for the specific
values in question. To silence these warnings, use `status.expect_partial()`.
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*****Model Accuracy: 95.37% (2.55%)

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```

```
*****Model Accuracy: 93.97% (3.16%)
*****Model Accuracy: 96.29% (2.38%)
```

```
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*****Model Accuracy: 28.71% (8.15%)

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*****Model Accuracy: 94.90% (2.72%)
```

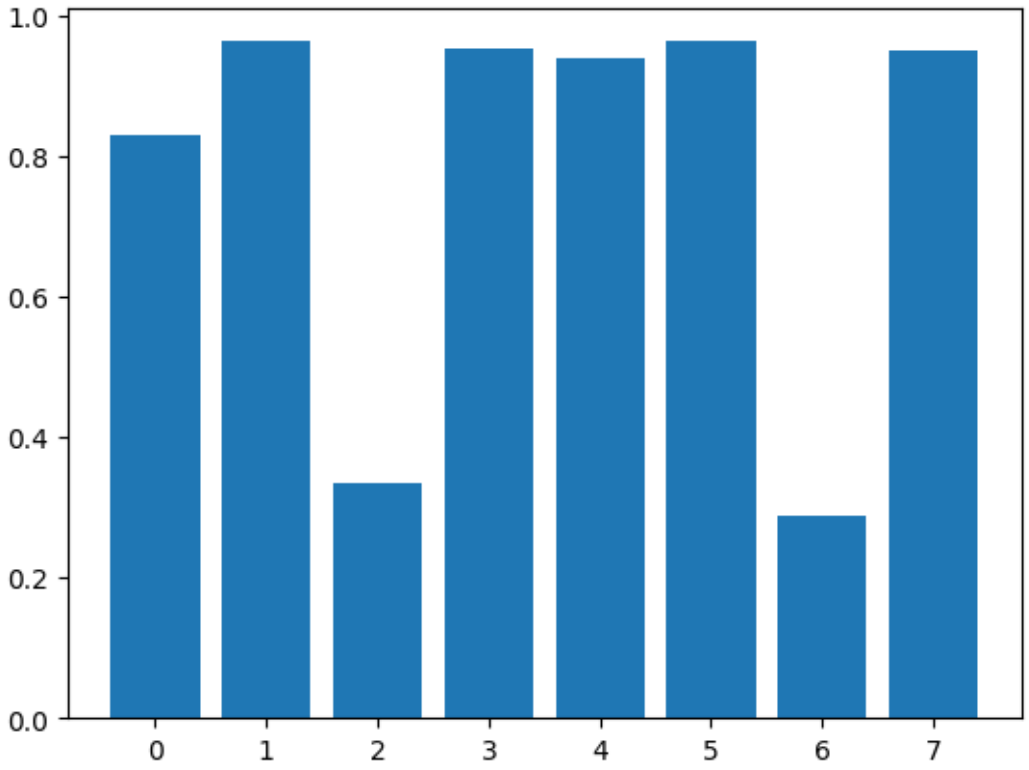
[42]:
```
print('Accuracies in order:\n',
      '50 Neurons/layer,relu,SGD\n','50 Neurons/layer,relu,Adam,\n','50 Neurons/
 ↪layer,sigmoid,SGD\n','50 Neurons/layer,sigmoid,Adam,\n','50 Neurons/
 ↪layer,relu,SGD\n','50 Neurons/layer,relu,Adam,\n','50 Neurons/
 ↪layer,sigmoid,SGD\n','50 Neurons/layer,sigmoid,Adam,\n')
```

```
Accuracies in order:
 50 Neurons/layer,relu,SGD
 50 Neurons/layer,relu,Adam,
```

```
50 Neurons/layer,sigmoid,SGD
50 Neurons/layer,sigmoid,Adam,
50 Neurons/layer,relu,SGD
50 Neurons/layer,relu,Adam,
50 Neurons/layer,sigmoid,SGD
50 Neurons/layer,sigmoid,Adam,
```

[43]:
```
plt.bar(range(len(accuracies)),accuracies)
```

[43]:
```
<BarContainer object of 8 artists>
```



[126]:
```
in_dim = len(X_train.columns)
oversample = SMOTE()
X, y = oversample.fit_resample(X_train,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
test_features = scaler.transform(X_test)
#build the best model from previous selection
model = Sequential()
model.add(Dense(100, input_dim = in_dim, activation = 'relu'))
model.add(Dense(100, activation = 'relu'))
```

```
model.add(Dense(100, activation = 'relu'))
model.add(Dense(3, activation = 'softmax'))
model.compile(loss = 'categorical_crossentropy', optimizer = 'Adam', metrics =␣
 ↪['accuracy'])
model.fit(train_features, pd.get_dummies(y), epochs = 30, batch_size =␣
 ↪16,verbose = 2)
scores = model.evaluate(test_features, pd.get_dummies(y_test))
for i, m in enumerate(model.metrics_names): #print loss and accuracy
    print("\n%s: %.3f"% (m, scores[i]))
y_pred = model.predict(test_features).round() #to get the predicted class for␣
 ↪X_test after scaling
f1 = metrics.f1_score(y_pred,pd.get_dummies(y_test),average = 'weighted')
print(f1)
print(metrics.classification_report(pd.DataFrame(y_pred),pd.
 ↪get_dummies(y_test)))
Accuracies_all.append(scores[1])
F1_all.append(f1)
```

```
Epoch 1/30
14/14 - 3s - loss: 0.8290 - accuracy: 0.6574 - 3s/epoch - 187ms/step
Epoch 2/30
14/14 - 0s - loss: 0.3841 - accuracy: 0.9074 - 103ms/epoch - 7ms/step
Epoch 3/30
14/14 - 0s - loss: 0.1723 - accuracy: 0.9722 - 69ms/epoch - 5ms/step
Epoch 4/30
14/14 - 0s - loss: 0.0807 - accuracy: 0.9861 - 94ms/epoch - 7ms/step
Epoch 5/30
14/14 - 0s - loss: 0.0471 - accuracy: 1.0000 - 89ms/epoch - 6ms/step
Epoch 6/30
14/14 - 0s - loss: 0.0199 - accuracy: 1.0000 - 72ms/epoch - 5ms/step
Epoch 7/30
14/14 - 0s - loss: 0.0100 - accuracy: 1.0000 - 70ms/epoch - 5ms/step
Epoch 8/30
14/14 - 0s - loss: 0.0070 - accuracy: 1.0000 - 52ms/epoch - 4ms/step
Epoch 9/30
14/14 - 0s - loss: 0.0048 - accuracy: 1.0000 - 50ms/epoch - 4ms/step
Epoch 10/30
14/14 - 0s - loss: 0.0037 - accuracy: 1.0000 - 58ms/epoch - 4ms/step
Epoch 11/30
14/14 - 0s - loss: 0.0030 - accuracy: 1.0000 - 51ms/epoch - 4ms/step
Epoch 12/30
14/14 - 0s - loss: 0.0025 - accuracy: 1.0000 - 50ms/epoch - 4ms/step
Epoch 13/30
14/14 - 0s - loss: 0.0021 - accuracy: 1.0000 - 52ms/epoch - 4ms/step
Epoch 14/30
14/14 - 0s - loss: 0.0018 - accuracy: 1.0000 - 55ms/epoch - 4ms/step
Epoch 15/30
```

```
14/14 - 0s - loss: 0.0015 - accuracy: 1.0000 - 57ms/epoch - 4ms/step
Epoch 16/30
14/14 - 0s - loss: 0.0013 - accuracy: 1.0000 - 54ms/epoch - 4ms/step
Epoch 17/30
14/14 - 0s - loss: 0.0012 - accuracy: 1.0000 - 57ms/epoch - 4ms/step
Epoch 18/30
14/14 - 0s - loss: 0.0010 - accuracy: 1.0000 - 63ms/epoch - 5ms/step
Epoch 19/30
14/14 - 0s - loss: 8.9796e-04 - accuracy: 1.0000 - 60ms/epoch - 4ms/step
Epoch 20/30
14/14 - 0s - loss: 8.0680e-04 - accuracy: 1.0000 - 54ms/epoch - 4ms/step
Epoch 21/30
14/14 - 0s - loss: 7.2380e-04 - accuracy: 1.0000 - 57ms/epoch - 4ms/step
Epoch 22/30
14/14 - 0s - loss: 6.5865e-04 - accuracy: 1.0000 - 56ms/epoch - 4ms/step
Epoch 23/30
14/14 - 0s - loss: 5.9555e-04 - accuracy: 1.0000 - 55ms/epoch - 4ms/step
Epoch 24/30
14/14 - 0s - loss: 5.4437e-04 - accuracy: 1.0000 - 53ms/epoch - 4ms/step
Epoch 25/30
14/14 - 0s - loss: 4.9676e-04 - accuracy: 1.0000 - 54ms/epoch - 4ms/step
Epoch 26/30
14/14 - 0s - loss: 4.5966e-04 - accuracy: 1.0000 - 50ms/epoch - 4ms/step
Epoch 27/30
14/14 - 0s - loss: 4.2022e-04 - accuracy: 1.0000 - 52ms/epoch - 4ms/step
Epoch 28/30
14/14 - 0s - loss: 3.8784e-04 - accuracy: 1.0000 - 33ms/epoch - 2ms/step
Epoch 29/30
14/14 - 0s - loss: 3.5930e-04 - accuracy: 1.0000 - 31ms/epoch - 2ms/step
Epoch 30/30
14/14 - 0s - loss: 3.3342e-04 - accuracy: 1.0000 - 32ms/epoch - 2ms/step

WARNING:tensorflow:6 out of the last 11 calls to <function
Model.make_test_function.<locals>.test_function at 0x7cd71af68280> triggered
tf.function retracing. Tracing is expensive and the excessive number of tracings
could be due to (1) creating @tf.function repeatedly in a loop, (2) passing
tensors with different shapes, (3) passing Python objects instead of tensors.
For (1), please define your @tf.function outside of the loop. For (2),
@tf.function has reduce_retracing=True option that can avoid unnecessary
retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.

2/2 [==============================] - 0s 9ms/step - loss: 0.1344 - accuracy:
0.9459

WARNING:tensorflow:6 out of the last 11 calls to <function
Model.make_predict_function.<locals>.predict_function at 0x7cd7227280d0>
triggered tf.function retracing. Tracing is expensive and the excessive number
```

```
of tracings could be due to (1) creating @tf.function repeatedly in a loop, (2)
passing tensors with different shapes, (3) passing Python objects instead of
tensors. For (1), please define your @tf.function outside of the loop. For (2),
@tf.function has reduce_retracing=True option that can avoid unnecessary
retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.


loss: 0.134

accuracy: 0.946
2/2 [==============================] - 0s 9ms/step
0.9421303656597775
              precision    recall  f1-score   support

           0       1.00      0.67      0.80         6
           1       1.00      1.00      1.00        15
           2       0.89      1.00      0.94        16

   micro avg       0.95      0.95      0.95        37
   macro avg       0.96      0.89      0.91        37
weighted avg       0.95      0.95      0.94        37
 samples avg       0.95      0.95      0.95        37
```

0.7 Random Forest

[145]:
```
grid = {
    'criterion':["squared_error","absolute_error"],
    'max_depth': [2,3,5,7,10],
    'max_features': [3,10,"sqrt"],
    'n_estimators':[50,100,150]
}
model = GridSearchCV(estimator=RandomForestRegressor(), param_grid=grid, cv=␣
 ↪kfolds)
X, y = oversample.fit_resample(X_train,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
model.fit(train_features, y)
model.best_params_
```

[145]:
```
{'criterion': 'squared_error',
 'max_depth': 10,
 'max_features': 10,
 'n_estimators': 150}
```

[146]:
```
model.cv_results_['params']
```

```
[146]: [{'criterion': 'squared_error',
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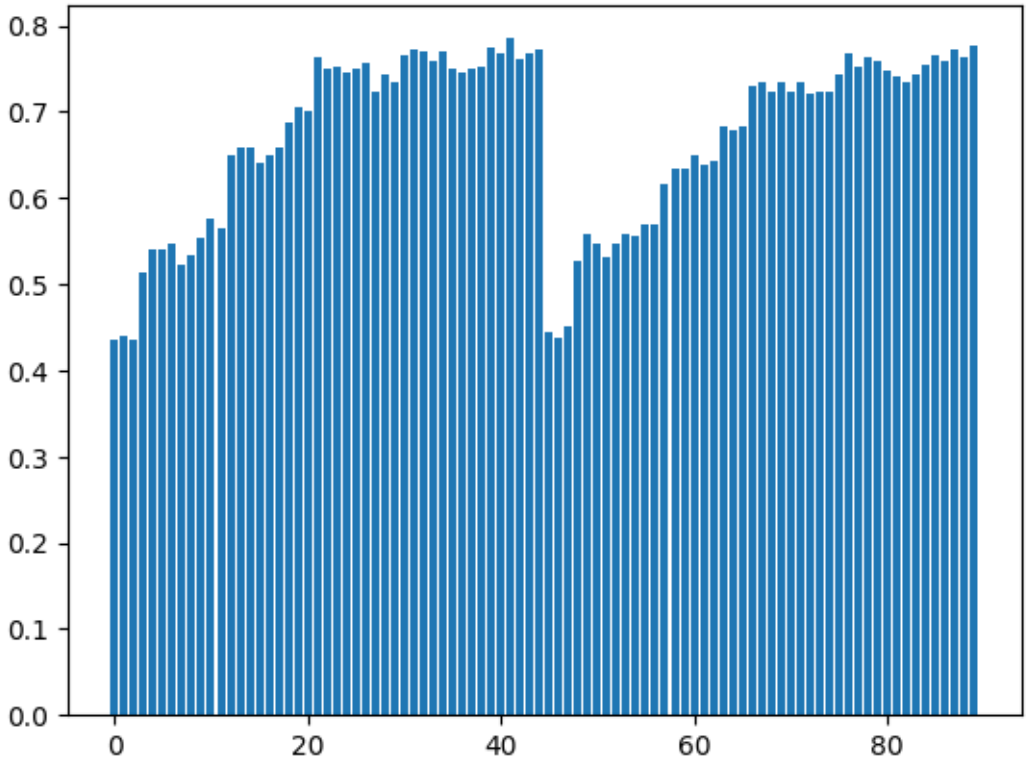
 'max_features': 'sqrt',
 'n_estimators': 150}]
```

[147]:
```
plt.bar(range(len(model.cv_results_['mean_test_score'])),model.
↪cv_results_['mean_test_score'])
```

```
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
being deleted with unrestored values. See the following logs for the specific
values in question. To silence these warnings, use `status.expect_partial()`.
See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor
details about the status object returned by the restore function.
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.count
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
```

[147]: <BarContainer object of 90 artists>



[119]:
```
model = RandomForestRegressor(criterion = 'squared_error',max_depth =␣
 ↪10,max_features = 10,n_estimators= 150)
X, y = oversample.fit_resample(X_train,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
test_features = scaler.transform(X_test)
model.fit(train_features, y)
y_pred = model.predict(test_features)
accuracy = metrics.accuracy_score(y_test, [round(i) for i in y_pred])
f1 = metrics.f1_score(y_test,[round(i) for i in y_pred], average='weighted')
print("Accuracy on Train dataset:", metrics.accuracy_score(y, [round(i) for i␣
 ↪in model.predict(train_features)]))
print("F1 on Train dataset:", metrics.f1_score(y, [round(i) for i in model.
 ↪predict(train_features)],average = 'weighted'))
print("Accuracy on Test dataset:", accuracy)
print("F1 on Test dataset:", f1)
print(metrics.classification_report(y_test,  [round(i) for i in y_pred]))
Accuracies_all.append(accuracy)
F1_all.append(f1)
```

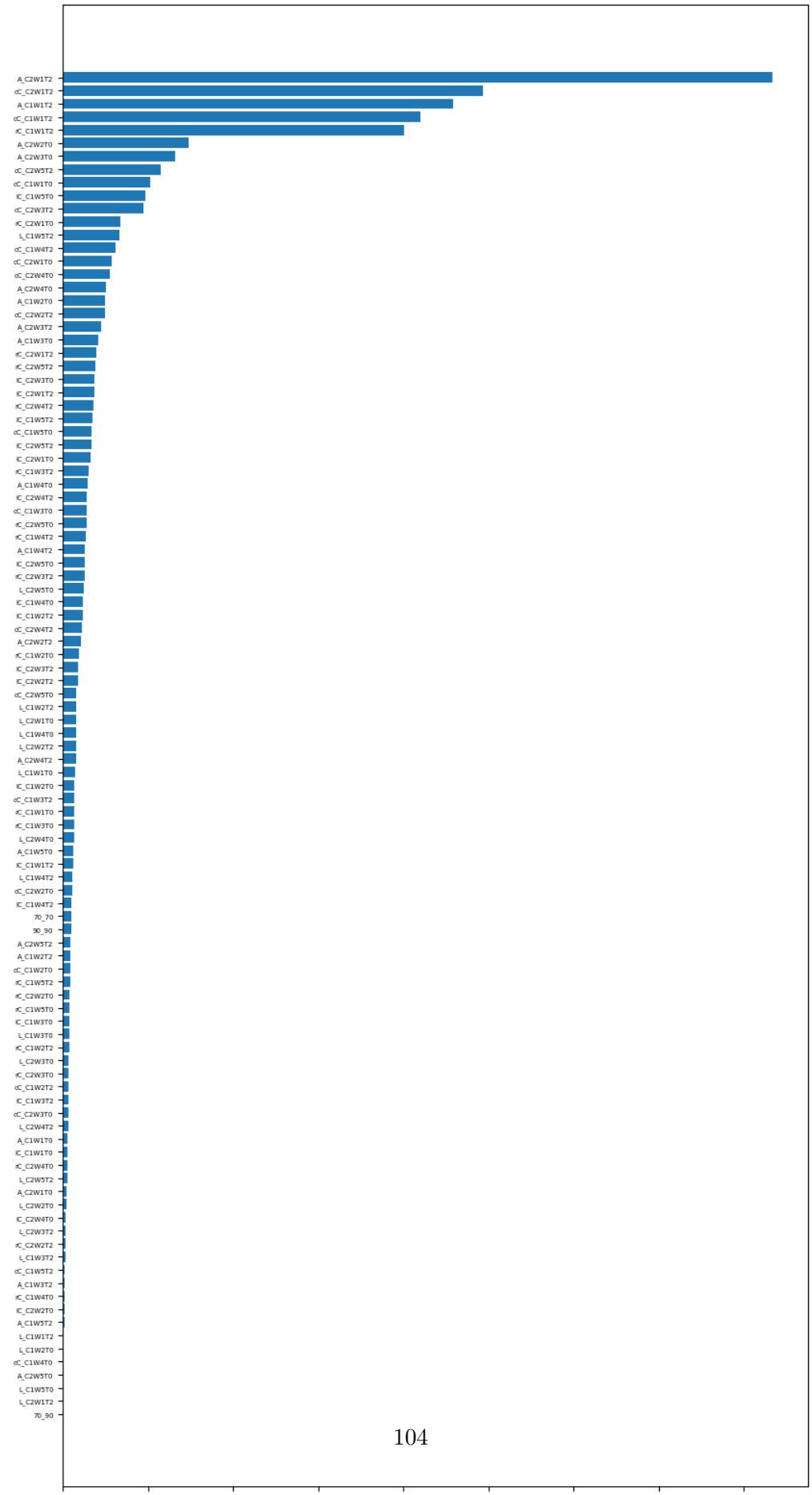
```
Accuracy on Train dataset: 0.9953703703703703
F1 on Train dataset: 0.9953701470942851
Accuracy on Test dataset: 0.7297297297297297
F1 on Test dataset: 0.6932432432432432
              precision    recall  f1-score   support

           0       0.00      0.00      0.00         4
           1       0.60      1.00      0.75        15
           2       1.00      0.67      0.80        18

    accuracy                           0.73        37
   macro avg       0.53      0.56      0.52        37
weighted avg       0.73      0.73      0.69        37

/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

[30]:
```
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train.columns)[indices])
```


A_C2W1T2
cC_C2W1T2
A_C1W1T2
cC_C1W1T2
iC_C1W1T2
A_C2W2T0
A_C2W3T0
cC_C2W5T2
cC_C1W1T0
iC_C1W5T0
cC_C2W3T2
iC_C2W1T0
L_C1W5T2
cC_C1W4T2
cC_C2W1T0
cC_C2W4T0
A_C2W4T0
A_C1W2T0
cC_C2W2T2
A_C2W3T2
A_C1W3T0
iC_C2W1T2
iC_C2W5T2
IC_C2W3T0
IC_C2W1T2
iC_C2W4T2
IC_C1W5T2
cC_C1W5T0
IC_C2W5T2
iC_C2W1T0
iC_C1W3T2
A_C1W4T0
IC_C2W4T2
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IC_C1W4T0
IC_C1W2T2
cC_C2W4T2
A_C2W2T2
iC_C1W2T0
IC_C2W3T2
IC_C2W2T2
cC_C2W5T0
L_C1W2T2
L_C2W1T0
L_C1W4T0
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cC_C2W2T0
IC_C1W4T2
70_70
90_90
A_C2W5T2
A_C1W2T2
cC_C1W2T0
iC_C1W5T2
iC_C2W2T0
iC_C1W5T0
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IC_C1W3T2
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L_C1W3T2
cC_C1W5T2
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iC_C1W4T0
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L_C1W1T2
L_C1W2T0
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L_C1W5T0
L_C2W1T2
70_90
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16

0.8 Logistic

[94]:
```
grid = {
    'penalty': ['l1', 'l2'],
    'C':[0.5,1,1.5],
    'tol':[0.0001,0.001,0.01,0.1]
}
models = GridSearchCV(estimator=LogisticRegression(solver =␣
 ↪'liblinear',multi_class = 'ovr'), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_scaled = scaler.fit_transform(X_train)
X_test_scaled = scaler.transform(X_test)
X, y = oversample.fit_resample(X_train_scaled,y_train)
models.fit(X, y)
models.best_params_
```

[94]:
```
{'C': 1, 'penalty': 'l1', 'tol': 0.01}
```

[33]:
```
models.cv_results_['params']
```

[33]:
```
[{'C': 0.5, 'penalty': 'l1', 'tol': 0.0001},
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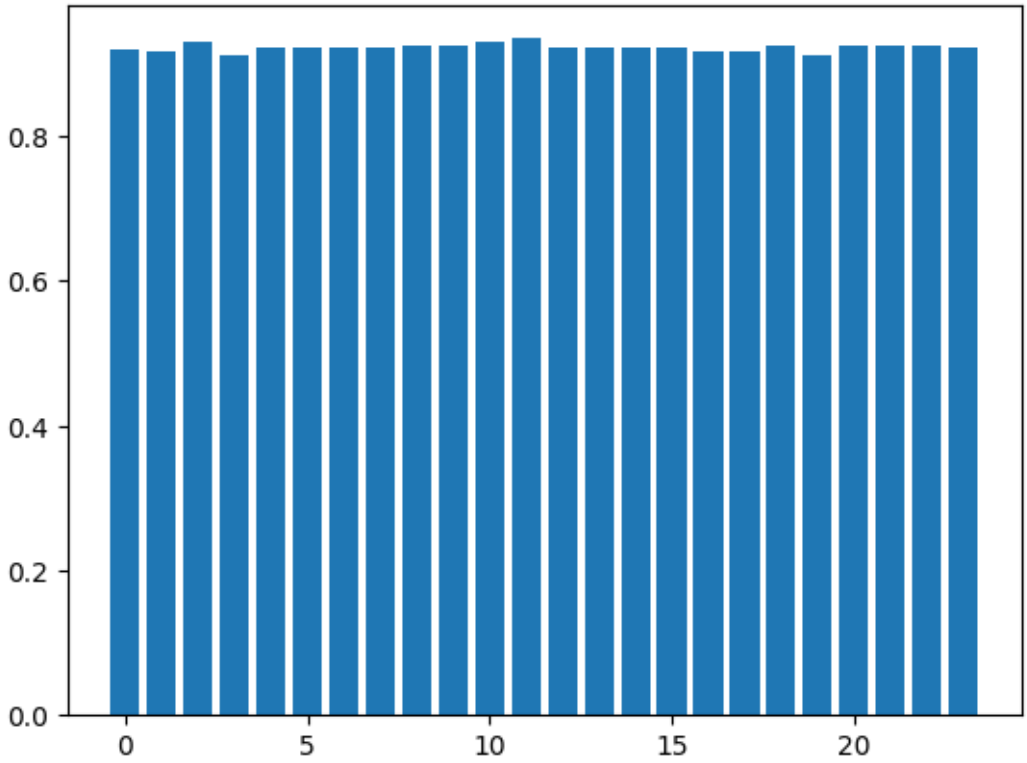
```

[34]:
```
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
  ↪cv_results_['mean_test_score'])
```

[34]:
```
<BarContainer object of 24 artists>
```



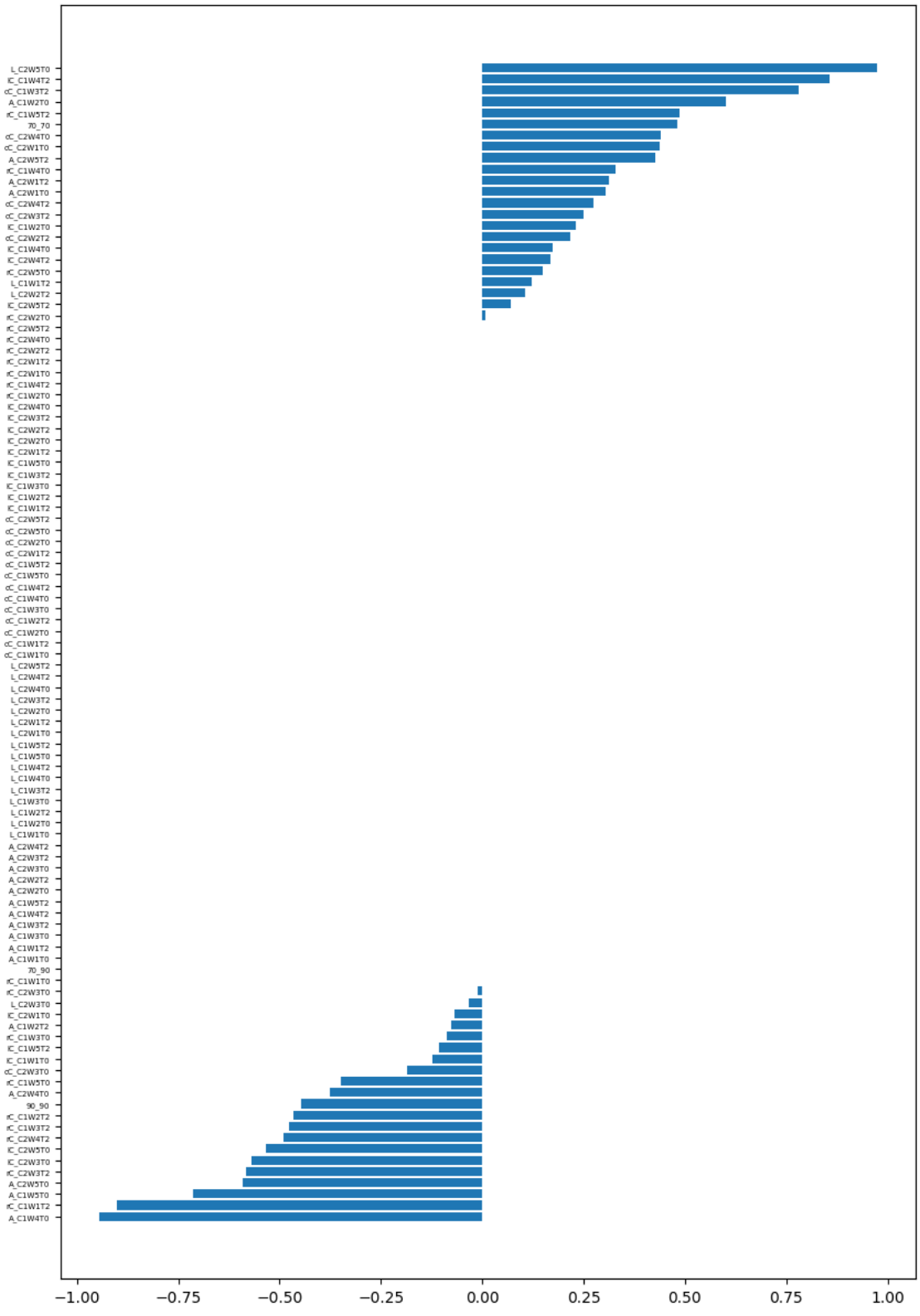
[96]:
```
model = LogisticRegression(solver = 'liblinear',multi_class = 'ovr', C =  1,␣
  ↪penalty = 'l1', tol = 0.01)
model.fit(X, y)
y_pred = model.predict(X_test_scaled)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y, model.predict(X)))
print("f1 score on train Dataset: ",metrics.f1_score(y, model.
  ↪predict(X),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
Accuracies_all.append(accuracy)
F1_all.append(f1)
def f_importances(coef, names):
    imp = coef
    imp,names = zip(*sorted(zip(imp,names)))
```

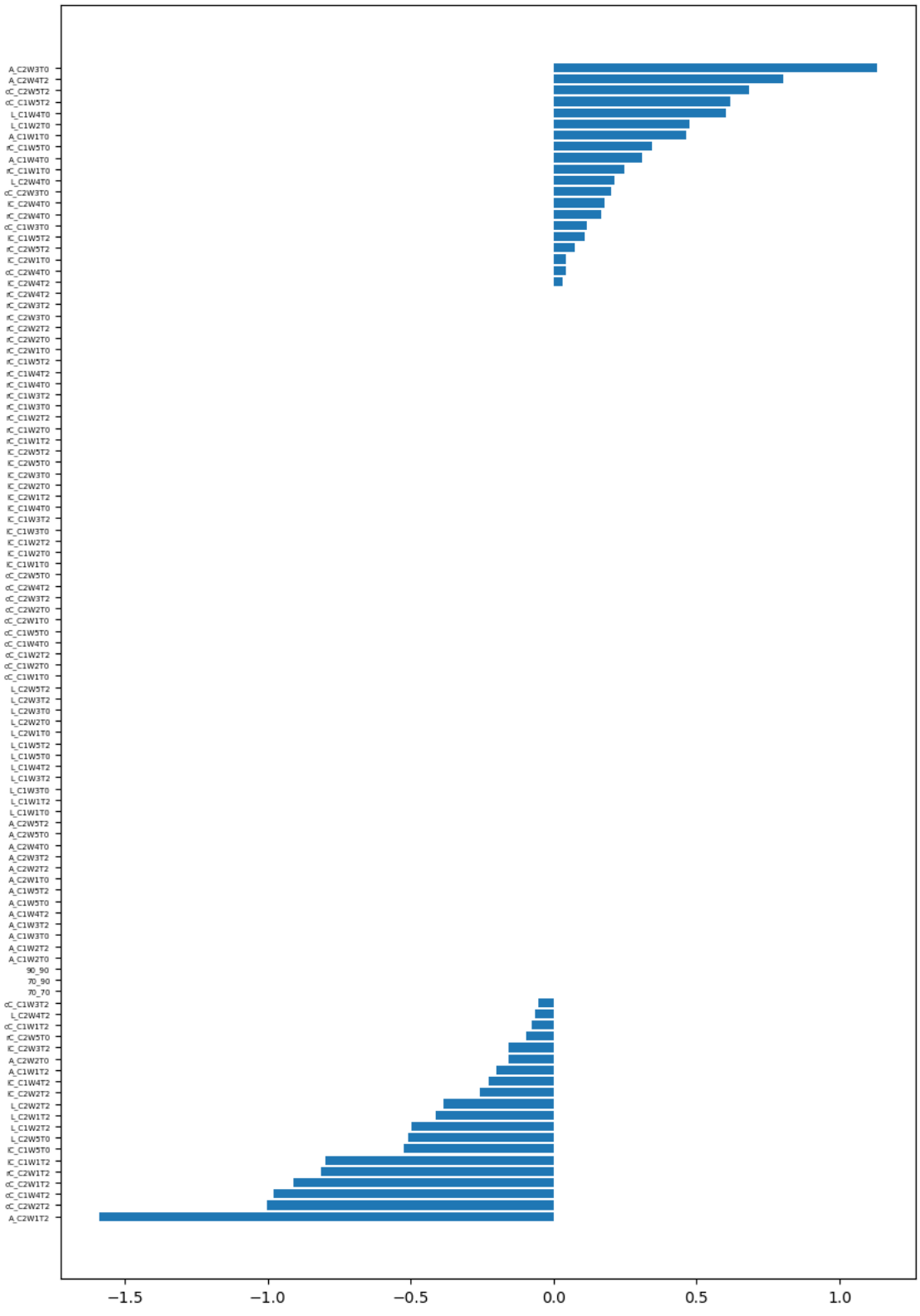
```
    plt.figure(figsize=(10,15))
    plt.barh(range(len(names)), imp, align='center')
    plt.tick_params(axis='y', labelsize=5)
    plt.yticks(range(len(names)), names)
    plt.show()
f_importances(model.coef_[0], X_train.columns)
f_importances(model.coef_[1], X_train.columns)
f_importances(model.coef_[2], X_train.columns)
```

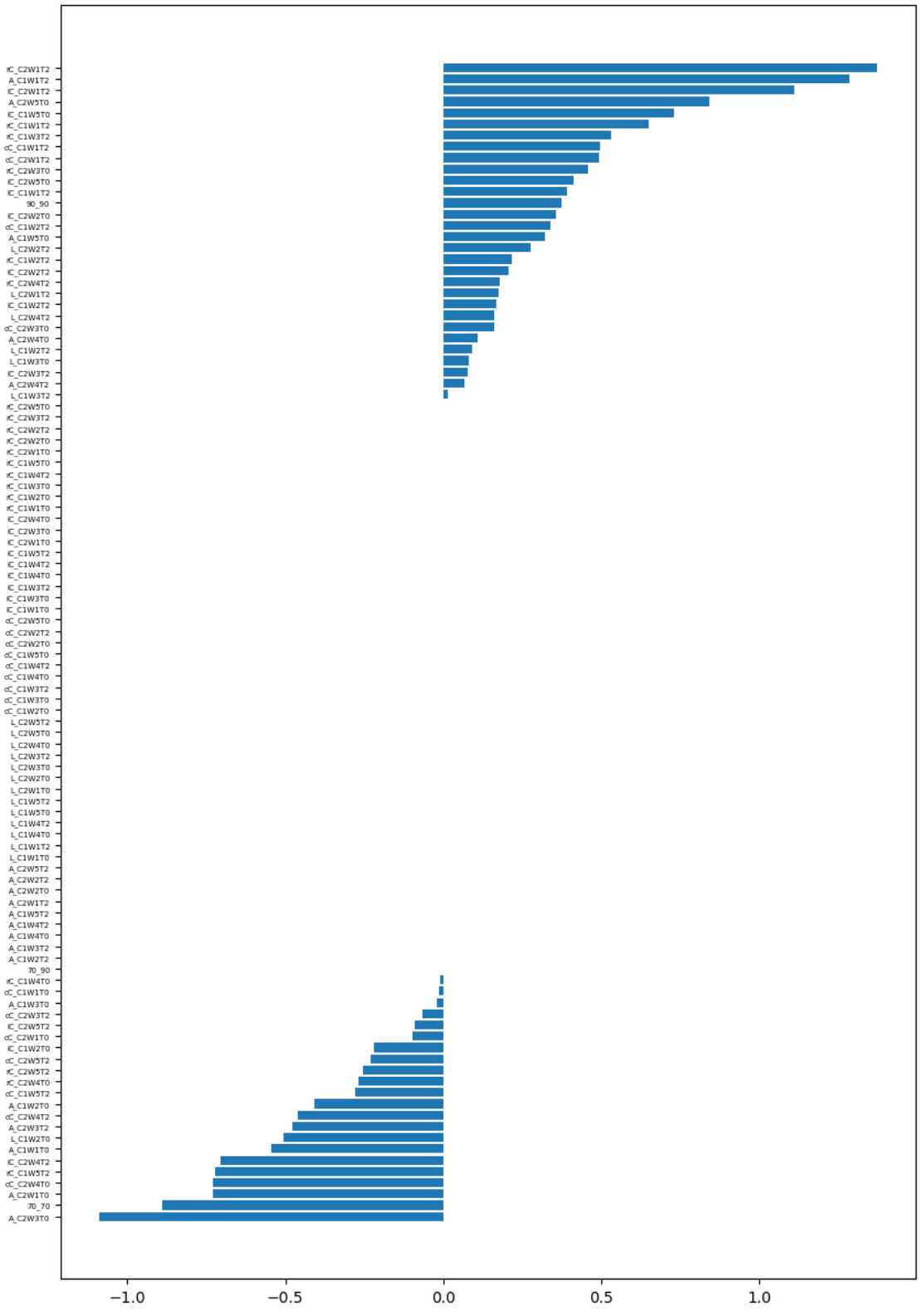
```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.918918918918919
f1 score on test Dataset:  0.9262899262899263
              precision    recall  f1-score   support

           0       0.57      1.00      0.73         4
           1       1.00      1.00      1.00        15
           2       1.00      0.83      0.91        18

    accuracy                           0.92        37
   macro avg       0.86      0.94      0.88        37
weighted avg       0.95      0.92      0.93        37
```


L_C2W5T0
lC_C1W4T2
cC_C1W3T2
A_C1W2T0
rC_C1W5T2
70_70
cC_C2W4T0
cC_C2W1T0
A_C2W5T2
rC_C1W4T0
A_C2W1T2
A_C2W1T0
cC_C2W4T2
cC_C2W3T2
lC_C1W2T0
cC_C2W2T2
lC_C1W4T0
lC_C2W4T2
rC_C2W5T0
L_C1W1T2
L_C2W2T2
lC_C2W5T2
rC_C2W2T0
rC_C2W5T2
rC_C2W4T0
rC_C2W2T2
rC_C2W1T2
rC_C2W1T0
rC_C1W4T2
rC_C1W2T0
lC_C2W4T0
lC_C2W3T2
lC_C2W2T2
lC_C2W2T0
lC_C2W1T2
lC_C1W5T0
lC_C1W3T2
lC_C1W3T0
lC_C1W2T2
lC_C1W1T2
cC_C2W5T2
cC_C2W5T0
cC_C2W2T0
cC_C2W1T2
cC_C1W5T2
cC_C1W5T0
cC_C1W4T2
cC_C1W4T0
cC_C1W3T0
cC_C1W2T2
cC_C1W2T0
cC_C1W1T2
cC_C1W1T0
L_C2W5T2
L_C2W4T2
L_C2W4T0
L_C2W3T2
L_C2W2T0
L_C2W1T2
L_C2W1T0
L_C1W5T2
L_C1W5T0
L_C1W4T2
L_C1W4T0
L_C1W3T2
L_C1W3T0
L_C1W2T2
L_C1W2T0
L_C1W1T0
A_C2W4T2
A_C2W3T2
A_C2W3T0
A_C2W2T2
A_C2W2T0
A_C1W5T2
A_C1W4T2
A_C1W3T2
A_C1W3T0
A_C1W1T2
A_C1W1T0
70_90
rC_C1W1T0
rC_C2W3T0
L_C2W3T0
lC_C2W1T0
A_C1W2T2
rC_C1W3T0
lC_C1W5T2
lC_C1W1T0
cC_C2W3T0
rC_C1W5T0
A_C2W4T0
90_90
rC_C1W2T2
rC_C1W3T2
rC_C2W4T2
lC_C2W5T0
lC_C2W3T0
rC_C2W3T2
A_C2W5T0
A_C1W5T0
rC_C1W1T2
A_C1W4T0
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00

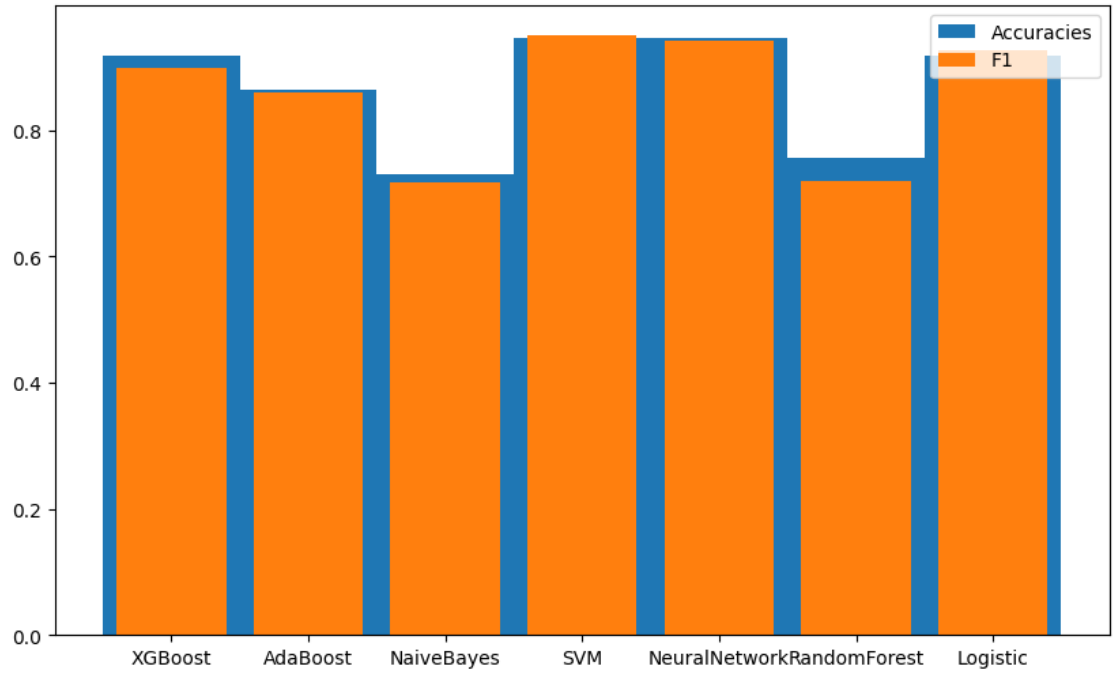

A_C2W3T0
A_C2W4T2
dC_C2W5T2
dC_C1W5T2
L_C1W4T0
L_C1W2T0
A_C1W1T0
fC_C1W5T0
A_C1W4T0
fC_C1W1T0
L_C2W4T0
dC_C2W3T0
lC_C2W4T0
fC_C2W4T0
dC_C1W3T0
lC_C1W5T2
fC_C2W5T2
lC_C2W1T0
dC_C2W4T0
lC_C2W4T2
fC_C2W4T2
fC_C2W3T2
fC_C2W3T0
fC_C2W2T2
fC_C2W2T0
fC_C2W1T0
fC_C1W5T2
fC_C1W4T2
fC_C1W4T0
fC_C1W3T2
fC_C1W3T0
fC_C1W2T2
fC_C1W2T0
fC_C1W1T2
lC_C2W5T2
lC_C2W5T0
lC_C2W3T0
lC_C2W2T0
lC_C2W1T2
lC_C1W4T0
lC_C1W3T2
lC_C1W3T0
lC_C1W2T2
lC_C1W2T0
lC_C1W1T0
dC_C2W5T0
dC_C2W4T2
dC_C2W3T2
dC_C2W2T0
dC_C2W1T0
dC_C1W5T0
dC_C1W4T0
dC_C1W2T2
dC_C1W2T0
dC_C1W1T0
L_C2W5T2
L_C2W3T2
L_C2W3T0
L_C2W2T0
L_C2W1T0
L_C1W5T2
L_C1W5T0
L_C1W4T2
L_C1W3T2
L_C1W3T0
L_C1W1T2
L_C1W1T0
A_C2W5T2
A_C2W5T0
A_C2W4T0
A_C2W3T2
A_C2W2T2
A_C2W1T0
A_C1W5T2
A_C1W5T0
A_C1W4T2
A_C1W3T2
A_C1W3T0
A_C1W2T2
A_C1W2T0
90_90
70_90
70_70
dC_C1W3T2
L_C2W4T2
dC_C1W1T2
fC_C2W5T0
lC_C2W3T2
A_C2W2T0
A_C1W1T2
lC_C1W4T2
lC_C2W2T2
L_C2W2T2
L_C2W1T2
L_C1W2T2
L_C2W5T0
lC_C1W5T0
lC_C1W1T2
fC_C2W1T2
dC_C2W1T2
dC_C1W4T2
dC_C2W2T2
A_C2W1T2
−1.5
−1.0
−0.5
0.0
0.5
1.0


rC_C2W1T2
A_C1W1T2
lC_C2W1T2
A_C2W5T0
lC_C1W5T0
rC_C1W1T2
rC_C1W3T2
cC_C1W1T2
cC_C2W1T2
rC_C2W3T0
lC_C2W5T0
lC_C1W1T2
90_90
lC_C2W2T0
cC_C1W2T2
A_C1W5T0
L_C2W2T2
rC_C1W2T2
lC_C2W2T2
rC_C2W4T2
L_C2W1T2
lC_C1W2T2
L_C2W4T2
cC_C2W3T0
A_C2W4T0
L_C1W2T2
L_C1W3T0
lC_C2W3T2
A_C2W4T2
L_C1W3T2
rC_C2W5T0
rC_C2W3T2
rC_C2W2T2
rC_C2W2T0
rC_C2W1T0
rC_C1W5T0
rC_C1W4T2
rC_C1W3T0
rC_C1W2T0
rC_C1W1T0
lC_C2W4T0
lC_C2W3T0
lC_C2W1T0
lC_C1W5T2
lC_C1W4T2
lC_C1W4T0
lC_C1W3T2
lC_C1W3T0
lC_C1W1T0
cC_C2W5T0
cC_C2W2T2
cC_C2W2T0
cC_C1W5T0
cC_C1W4T2
cC_C1W4T0
cC_C1W3T2
cC_C1W3T0
cC_C1W2T0
L_C2W5T2
L_C2W5T0
L_C2W4T0
L_C2W3T2
L_C2W3T0
L_C2W2T0
L_C2W1T0
L_C1W5T2
L_C1W5T0
L_C1W4T2
L_C1W4T0
L_C1W1T2
L_C1W1T0
A_C2W5T2
A_C2W2T2
A_C2W2T0
A_C2W1T2
A_C1W5T2
A_C1W4T2
A_C1W4T0
A_C1W3T2
A_C1W2T2
70_90
rC_C1W4T0
cC_C1W1T0
A_C1W3T0
cC_C2W3T2
lC_C2W5T2
cC_C2W1T0
lC_C1W2T0
cC_C2W5T2
rC_C2W5T2
rC_C2W4T0
cC_C1W5T2
A_C1W2T0
cC_C2W4T2
A_C2W3T2
L_C1W2T0
A_C1W1T0
lC_C2W4T2
rC_C1W5T2
cC_C2W4T0
A_C2W1T0
70_70
A_C2W3T0
−1.0
−0.5
0.0
0.5
1.0

0.9 Accuracies and F1 score for each algorithm

[127]:
```
algos =␣
  ↪['XGBoost','AdaBoost','NaiveBayes','SVM','NeuralNetwork','RandomForest','Logistic']
plt.figure(figsize=(10,6))
plt.bar(algos,Accuracies_all,width =1,label = 'Accuracies')
plt.bar(algos,F1_all,label = 'F1')
plt.legend()
```

[127]:
```
<matplotlib.legend.Legend at 0x7cd7201d0af0>
```



0.10 What happens if we only use the T2 variables?

0.11 Repeat above steps/algorithms with T2 variables(+stimulus level) olnly

[43]:
```
X_train_T2 = pd.concat([X_train.iloc[:,:3],X_train.iloc[:,53:]],axis=1)
X_test_T2 = pd.concat([X_test.iloc[:,:3],X_test.iloc[:,53:]],axis=1)
```

0.12 XGBoost for T2 only

[133]:
```
grid = {
    'max_depth': [2,4,6,9],
    'n_estimators':[100,150],
    'learning_rate':[0.3,0.5,1],
    'reg_alpha':[0,0.01,0.1,0.5],
```

```
    'reg_lambda':[0,0.1,1]
}
models = GridSearchCV(estimator=XGBClassifier(), param_grid=grid, cv= kfolds)
models.fit(X_train_T2, y_train)
models.best_params_
```

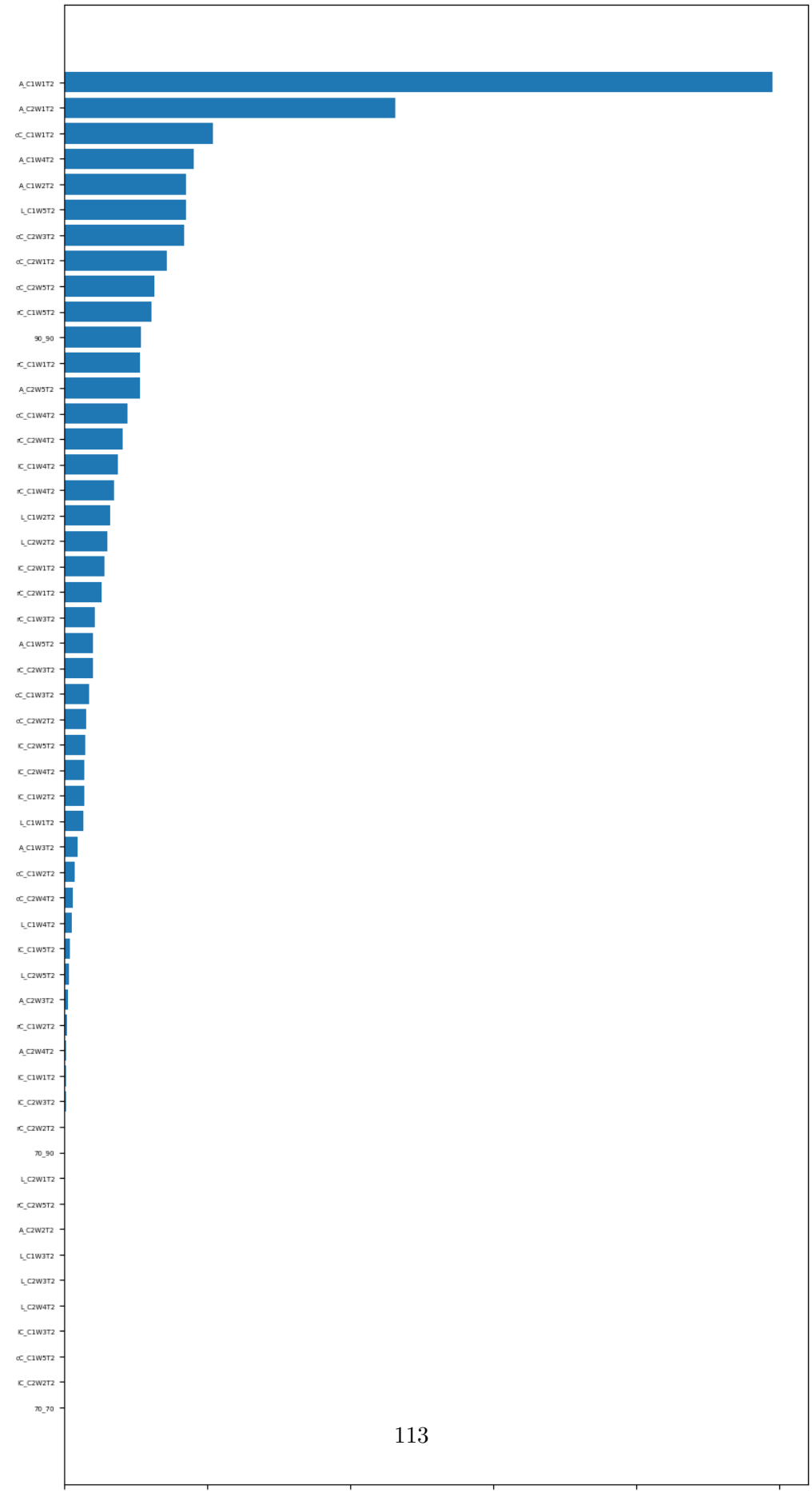
[133]:
```
{'learning_rate': 0.3,
 'max_depth': 2,
 'n_estimators': 100,
 'reg_alpha': 0.5,
 'reg_lambda': 0}
```

[138]:
```
model = XGBClassifier(max_depth = 2, learning_rate = 0.3, n_estimators=␣
 ↪100,reg_lambda =0,reg_alpha = 0.5)
model.fit(X_train_T2, y_train)
y_pred = model.predict(X_test_T2)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T2)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T2),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_T2.columns)[indices])
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.8378378378378378
f1 score on test Dataset:  0.8410117897783932
              precision    recall  f1-score   support

           0       0.40      0.50      0.44         4
           1       0.94      1.00      0.97        15
           2       0.88      0.78      0.82        18

    accuracy                           0.84        37
   macro avg       0.74      0.76      0.75        37
weighted avg       0.85      0.84      0.84        37
```

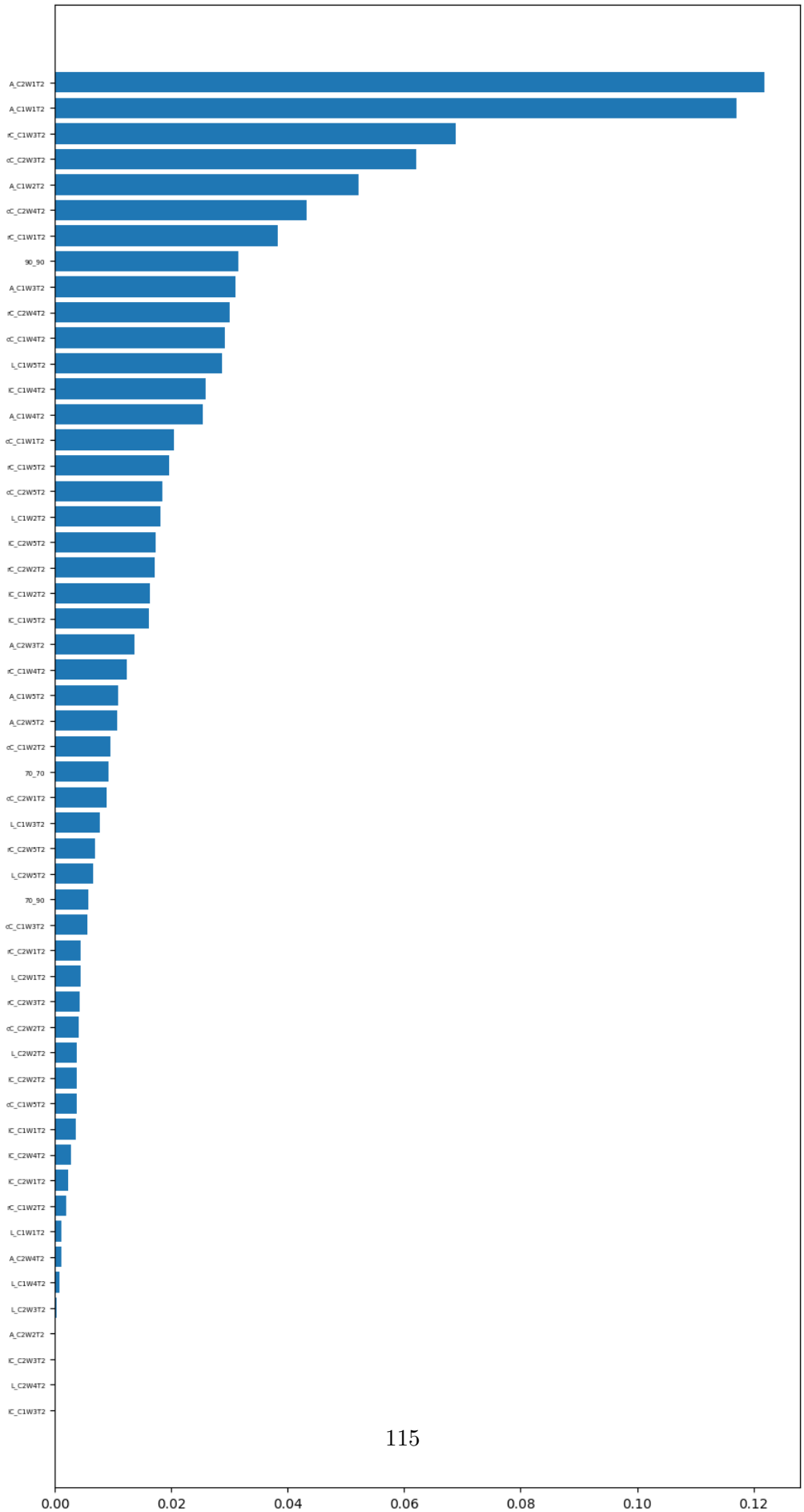

A_C1W1T2
A_C2W1T2
oC_C1W1T2
A_C1W4T2
A_C1W2T2
L_C1W5T2
oC_C2W3T2
oC_C2W1T2
oC_C2W5T2
xC_C1W5T2
90_90
xC_C1W1T2
A_C2W5T2
oC_C1W4T2
xC_C2W4T2
IC_C1W4T2
xC_C1W4T2
L_C1W2T2
L_C2W2T2
IC_C2W1T2
xC_C2W1T2
xC_C1W3T2
A_C1W5T2
xC_C2W3T2
oC_C1W3T2
oC_C2W2T2
IC_C2W5T2
IC_C2W4T2
IC_C1W2T2
L_C1W1T2
A_C1W3T2
oC_C1W2T2
oC_C2W4T2
L_C1W4T2
IC_C1W5T2
L_C2W5T2
A_C2W3T2
xC_C1W2T2
A_C2W4T2
IC_C1W1T2
IC_C2W3T2
xC_C2W2T2
70_90
L_C2W1T2
xC_C2W5T2
A_C2W2T2
L_C1W3T2
L_C2W3T2
L_C2W4T2
IC_C1W3T2
oC_C1W5T2
IC_C2W2T2
70_70
0.00
0.05
0.10
0.15
0.20
0.25

[49]:
```
#Now we compare with default parametrs, our chosen model performs better than␣
 ↪de the default model.
model = XGBClassifier()
model.fit(X_train_T2, y_train)
y_pred = model.predict(X_test_T2)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T2)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T2),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_T2.columns)[indices])
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.8378378378378378
f1 score on test Dataset:  0.8410117897783932
              precision    recall  f1-score   support

           0       0.40      0.50      0.44         4
           1       0.94      1.00      0.97        15
           2       0.88      0.78      0.82        18

    accuracy                           0.84        37
   macro avg       0.74      0.76      0.75        37
weighted avg       0.85      0.84      0.84        37
```


A_C2W1T2
A_C1W1T2
iC_C1W3T2
cC_C2W3T2
A_C1W2T2
cC_C2W4T2
iC_C1W1T2
90_90
A_C1W3T2
iC_C2W4T2
cC_C1W4T2
L_C1W5T2
IC_C1W4T2
A_C1W4T2
cC_C1W1T2
iC_C1W5T2
cC_C2W5T2
L_C1W2T2
IC_C2W5T2
iC_C2W2T2
IC_C1W2T2
IC_C1W5T2
A_C2W3T2
iC_C1W4T2
A_C1W5T2
A_C2W5T2
cC_C1W2T2
70_70
cC_C2W1T2
L_C1W3T2
iC_C2W5T2
L_C2W5T2
70_90
cC_C1W3T2
iC_C2W1T2
L_C2W1T2
iC_C2W3T2
cC_C2W2T2
L_C2W2T2
IC_C2W2T2
cC_C1W5T2
IC_C1W1T2
IC_C2W4T2
IC_C2W1T2
iC_C1W2T2
L_C1W1T2
A_C2W4T2
L_C1W4T2
L_C2W3T2
A_C2W2T2
IC_C2W3T2
L_C2W4T2
IC_C1W3T2
0.00
0.02
0.04
0.06
0.08
0.10
0.12

0.13 Adaboost for T2 only

[51]:
```
grid = {
    'algorithm': ["SAMME","SAMME.R"],
    'n_estimators':[10,30,50,70,100,150],
    'learning_rate':[0.5,1,1.5,2]
}
models = GridSearchCV(estimator = AdaBoostClassifier(), param_grid=grid, cv=␣
 ↪kfolds)
models.fit(X_train_T2, y_train)
print(models.best_params_,models.best_score_)
```

```
{'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 10}
0.8429885057471264
```

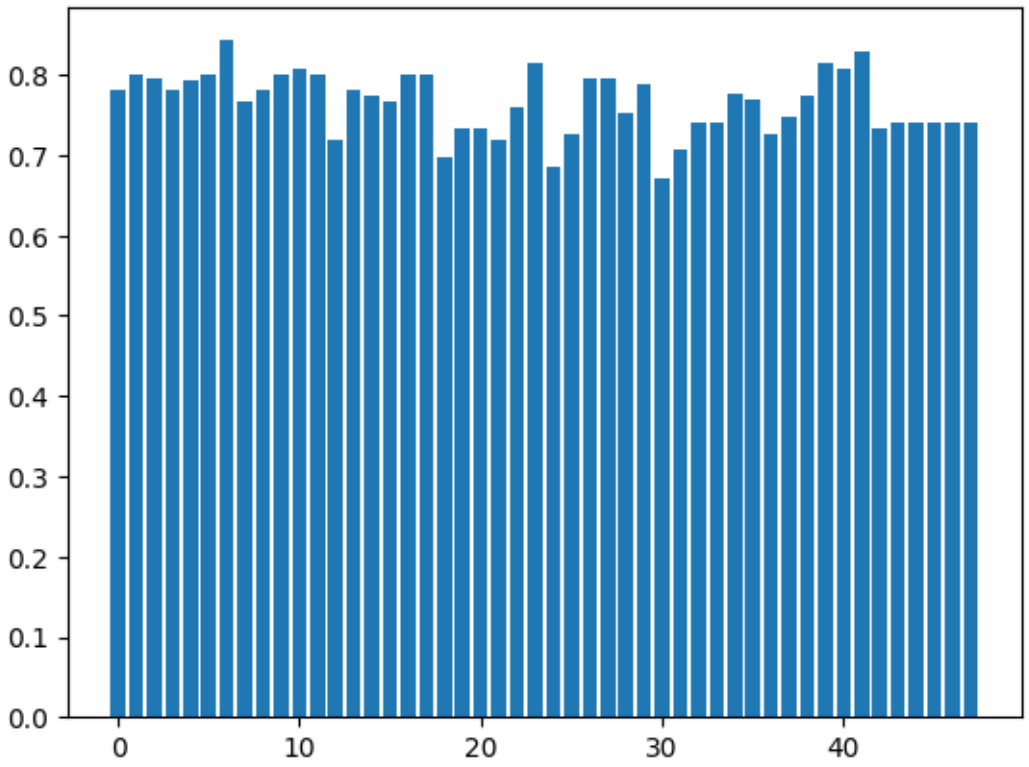
[54]:
```
models.cv_results_['params']
```

[54]:
```
[{'algorithm': 'SAMME', 'learning_rate': 0.5, 'n_estimators': 10},
 {'algorithm': 'SAMME', 'learning_rate': 0.5, 'n_estimators': 30},
 {'algorithm': 'SAMME', 'learning_rate': 0.5, 'n_estimators': 50},
 {'algorithm': 'SAMME', 'learning_rate': 0.5, 'n_estimators': 70},
 {'algorithm': 'SAMME', 'learning_rate': 0.5, 'n_estimators': 100},
 {'algorithm': 'SAMME', 'learning_rate': 0.5, 'n_estimators': 150},
 {'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 10},
 {'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 30},
 {'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 50},
 {'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 70},
 {'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 100},
 {'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 150},
 {'algorithm': 'SAMME', 'learning_rate': 1.5, 'n_estimators': 10},
 {'algorithm': 'SAMME', 'learning_rate': 1.5, 'n_estimators': 30},
 {'algorithm': 'SAMME', 'learning_rate': 1.5, 'n_estimators': 50},
 {'algorithm': 'SAMME', 'learning_rate': 1.5, 'n_estimators': 70},
 {'algorithm': 'SAMME', 'learning_rate': 1.5, 'n_estimators': 100},
 {'algorithm': 'SAMME', 'learning_rate': 1.5, 'n_estimators': 150},
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 10},
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 30},
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 50},
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 70},
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 100},
 {'algorithm': 'SAMME', 'learning_rate': 2, 'n_estimators': 150},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 10},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 30},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 50},
 {'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 70},
```

```
{'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 100},
{'algorithm': 'SAMME.R', 'learning_rate': 0.5, 'n_estimators': 150},
{'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 10},
{'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 30},
{'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 50},
{'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 70},
{'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 100},
{'algorithm': 'SAMME.R', 'learning_rate': 1, 'n_estimators': 150},
{'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 10},
{'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 30},
{'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 50},
{'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 70},
{'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 100},
{'algorithm': 'SAMME.R', 'learning_rate': 1.5, 'n_estimators': 150},
{'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 10},
{'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 30},
{'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 50},
{'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 70},
{'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 100},
{'algorithm': 'SAMME.R', 'learning_rate': 2, 'n_estimators': 150}]
```

[53]:
```
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
↪cv_results_['mean_test_score'])
```

[53]: <BarContainer object of 48 artists>

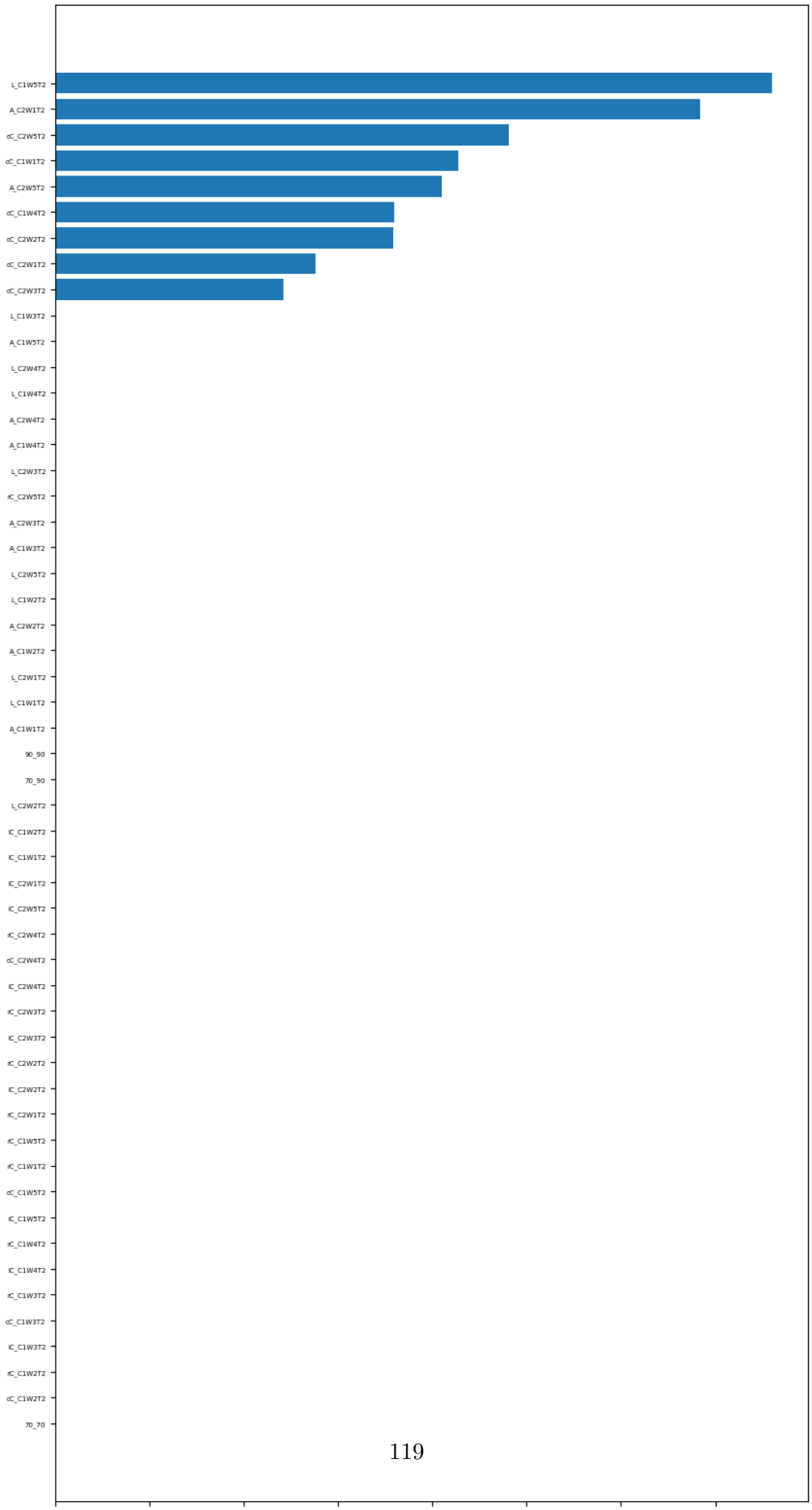


[44]:
```
model = AdaBoostClassifier(algorithm = 'SAMME', learning_rate = 1,␣
 ↪n_estimators= 10)
model.fit(X_train_T2, y_train)
y_pred = model.predict(X_test_T2)
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
# print("Accuracy: ",accuracy)
# print("f1 score: ",f1)
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T2)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T2),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_T2.columns)[indices])
```

```
Accuracy on train Dataset:  0.8835616438356164
f1 score on train Dataset:  0.880074029363915
Accuracy on test Dataset:  0.8648648648648649
f1 score on test Dataset:  0.8515783688197482
              precision    recall  f1-score   support

           0       0.50      0.25      0.33         4
           1       1.00      0.93      0.97        15
           2       0.81      0.94      0.87        18

    accuracy                           0.86        37
   macro avg       0.77      0.71      0.72        37
weighted avg       0.85      0.86      0.85        37
```


L_C1W5T2
A_C2W1T2
cC_C2W5T2
cC_C1W1T2
A_C2W5T2
cC_C1W4T2
cC_C2W2T2
cC_C2W1T2
cC_C2W3T2
L_C1W3T2
A_C1W5T2
L_C2W4T2
L_C1W4T2
A_C2W4T2
A_C1W4T2
L_C2W3T2
xC_C2W5T2
A_C2W3T2
A_C1W3T2
L_C2W5T2
L_C1W2T2
A_C2W2T2
A_C1W2T2
L_C2W1T2
L_C1W1T2
A_C1W1T2
90_90
70_90
L_C2W2T2
IC_C1W2T2
IC_C1W1T2
IC_C2W1T2
IC_C2W5T2
xC_C2W4T2
cC_C2W4T2
IC_C2W4T2
xC_C2W3T2
IC_C2W3T2
xC_C2W2T2
IC_C2W2T2
xC_C2W1T2
xC_C1W5T2
xC_C1W1T2
cC_C1W5T2
IC_C1W5T2
xC_C1W4T2
IC_C1W4T2
xC_C1W3T2
cC_C1W3T2
IC_C1W3T2
xC_C1W2T2
cC_C1W2T2
70_70
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175

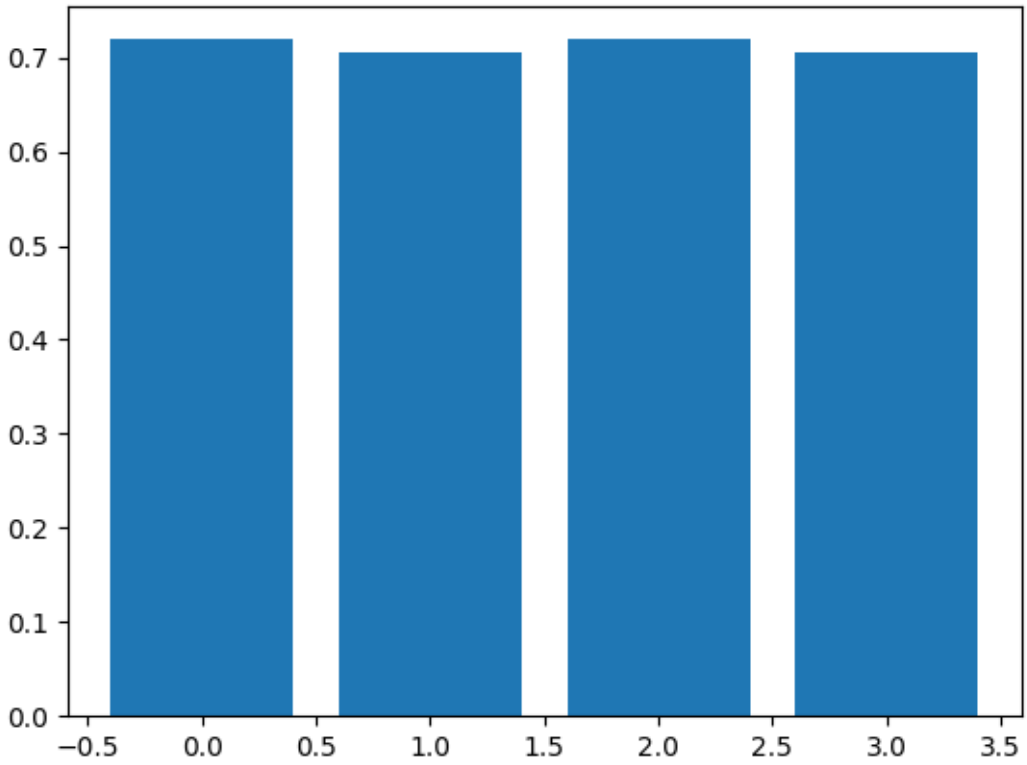
0.14 GaussianNB for T2 only

[55]:
```
grid = {
    'priors': [None,[0.34,0.33,0.33],[len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/
 ↪len(y_train),len(y_train[y_train==[2]])/
 ↪len(y_train)],[len(y_train[y_train==[2]])/
 ↪len(y_train),len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/len(y_train)]]
}
models = GridSearchCV(estimator = GaussianNB(), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_T2_scaled = scaler.fit_transform(X_train_T2)
X_test_T2_scaled = scaler.transform(X_test_T2)
models.fit(X_train_T2_scaled, y_train)
print(models.best_params_,models.best_score_)
```

```
{'priors': None} 0.7190804597701149
```

[56]:
```
print(models.cv_results_['params'])
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
 ↪cv_results_['mean_test_score'])
```

[56]:
```
<BarContainer object of 4 artists>
```



[57]:
```
#not using SMOTE
model = GaussianNB()
model.fit(X_train_T2_scaled, y_train)
y_pred = model.predict(X_test_T2_scaled)
accuracy = metrics.accuracy_score(y_pred, y_test)
f1 = metrics.f1_score(y_pred, y_test,average="weighted")
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T2_scaled)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T2_scaled),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  0.773972602739726
f1 score on train Dataset:  0.781186478126381
Accuracy on test Dataset:  0.8648648648648649
f1 score on test Dataset:  0.6879606879606879
              precision    recall  f1-score   support

           0       0.29      0.50      0.36         4
           1       0.80      0.80      0.80        15
```

```
           2       0.80      0.67      0.73        18

    accuracy                           0.70        37
   macro avg       0.63      0.66      0.63        37
weighted avg       0.74      0.70      0.72        37
```

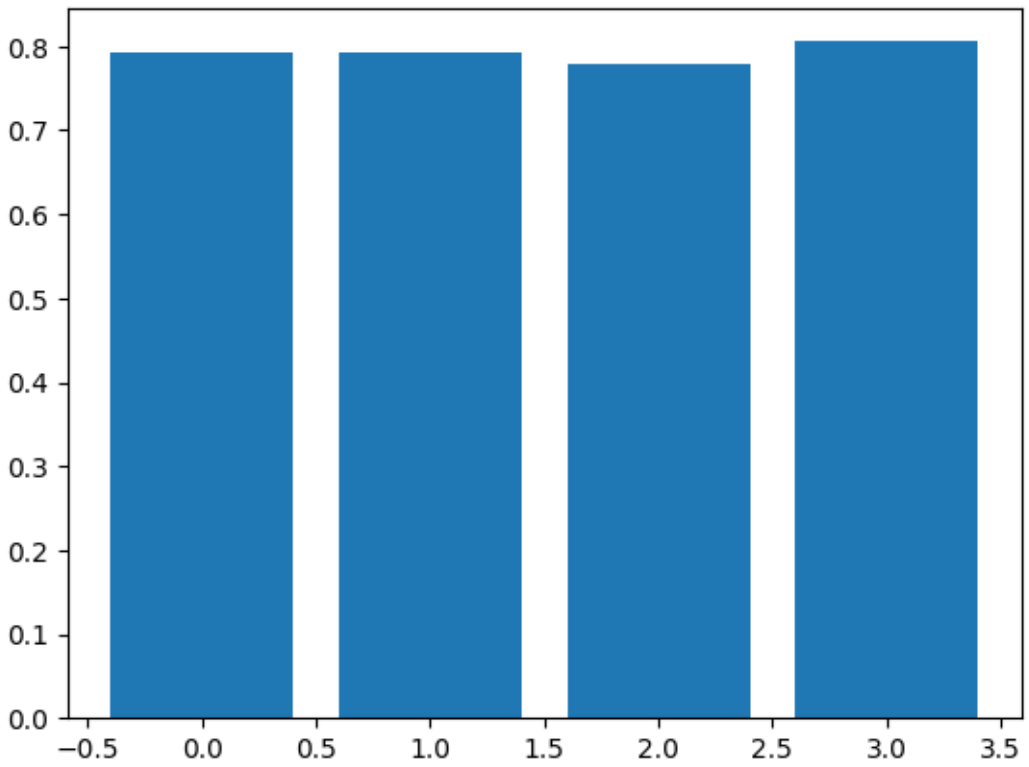
[132]:
```
#using SMOTE
grid = {
    'priors': [None,[0.34,0.33,0.33],[len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/
 ↪len(y_train),len(y_train[y_train==[2]])/
 ↪len(y_train)],[len(y_train[y_train==[2]])/
 ↪len(y_train),len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/len(y_train)]]
}
models = GridSearchCV(estimator = GaussianNB(), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_T2_scaled = scaler.fit_transform(X_train_T2)
X_test_T2_scaled = scaler.transform(X_test_T2)
oversample = SMOTE()
X, y = oversample.fit_resample(X_train_T2_scaled,y_train)
models.fit(X, y)
print(models.best_params_,models.best_score_)
```

```
{'priors': [0.4931506849315068, 0.0958904109589041, 0.410958904109589]}
0.7776955602536998
```

[60]:
```
print(models.cv_results_['params'])
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
 ↪cv_results_['mean_test_score'])
```

```
[{'priors': None}, {'priors': [0.34, 0.33, 0.33]}, {'priors':
[0.0958904109589041, 0.410958904109589, 0.4931506849315068]}, {'priors':
[0.4931506849315068, 0.0958904109589041, 0.410958904109589]}]
```

[60]:
```
<BarContainer object of 4 artists>
```



[133]:
```
model = GaussianNB(priors =  [0.4931506849315068, 0.0958904109589041, 0.
 ↪410958904109589])
model.fit(X, y)
y_pred = model.predict(X_test_T2_scaled)
accuracy = metrics.accuracy_score(y_pred, y_test)
f1 = metrics.f1_score(y_pred, y_test,average="weighted")
print("Accuracy on train Dataset: ",metrics.accuracy_score(y, model.predict(X)))
print("f1 score on train Dataset: ",metrics.f1_score(y, model.
 ↪predict(X),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  0.8194444444444444
f1 score on train Dataset:  0.8191804883569589
Accuracy on test Dataset:  0.7027027027027027
f1 score on test Dataset:  0.6879606879606879
              precision    recall  f1-score   support

           0       0.29      0.50      0.36         4
           1       0.80      0.80      0.80        15
           2       0.80      0.67      0.73        18
```

```
    accuracy                           0.70        37
   macro avg       0.63      0.66      0.63        37
weighted avg       0.74      0.70      0.72        37
```

0.15 SVM for T2 only

[63]:
```
scaler = preprocessing.StandardScaler()
X_train_T2_scaled = scaler.fit_transform(X_train_T2)
X_test_T2_scaled = scaler.transform(X_test_T2)
params_grid = [{'kernel': ['rbf'], 'gamma': [1e-4,1e-3,0.01,0.1,0.5],'C': [0.
 ↪1,1,1.5,10]},
 {'kernel': ['linear'], 'C': [0.1,1,1.5,10]}]
svm_model = GridSearchCV(svm.SVC(), params_grid, cv=kfolds)
svm_model.fit(X_train_T2_scaled, y_train)
```

[63]:
```
GridSearchCV(cv=KFold(n_splits=5, random_state=1, shuffle=True),
             estimator=SVC(),
             param_grid=[{'C': [0.1, 1, 1.5, 10],
                          'gamma': [0.0001, 0.001, 0.01, 0.1, 0.5],
                          'kernel': ['rbf']},
                         {'C': [0.1, 1, 1.5, 10], 'kernel': ['linear']}])
```

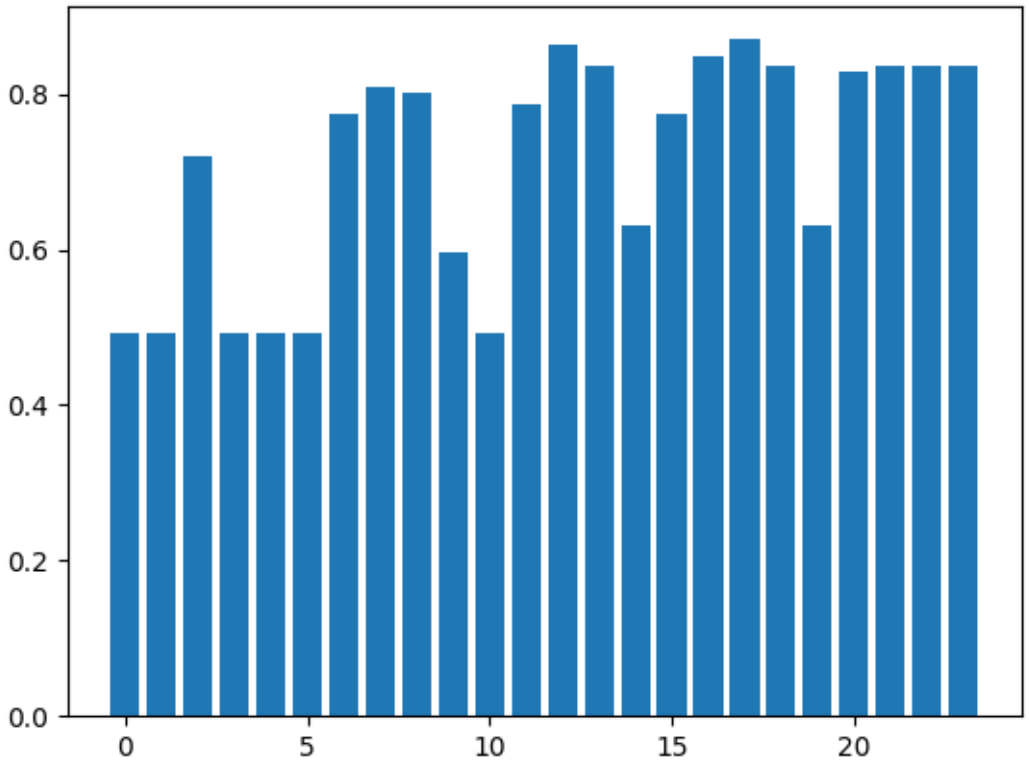
[67]:
```
svm_model.cv_results_['params']
```

[67]:
```
[{'C': 0.1, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 0.1, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 1, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 1.5, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.0001, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.001, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.01, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.1, 'kernel': 'rbf'},
 {'C': 10, 'gamma': 0.5, 'kernel': 'rbf'},
 {'C': 0.1, 'kernel': 'linear'},
```

```
 {'C': 1, 'kernel': 'linear'},
 {'C': 1.5, 'kernel': 'linear'},
 {'C': 10, 'kernel': 'linear'}]
```

[68]:
```
plt.bar(range(len(svm_model.cv_results_['mean_test_score'])),svm_model.
 ↪cv_results_['mean_test_score'])
```

[68]: <BarContainer object of 24 artists>



[64]:
```
print('Best score for training data:', svm_model.best_score_)
# View the best parameters for the model found using grid search
print('Best C:',svm_model.best_estimator_.C)
print('Best Kernel:',svm_model.best_estimator_.kernel)
print('Best Gamma:',svm_model.best_estimator_.gamma)
model = svm_model.best_estimator_
y_pred = model.predict(X_test_T2_scaled)
```

```
Best score for training data: 0.8701149425287357
Best C: 10
Best Kernel: rbf
Best Gamma: 0.01
```

[69]:
```
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test, y_pred, average='weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T2_scaled)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T2_scaled),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.8918918918918919
f1 score on test Dataset:  0.8959304131717925
              precision    recall  f1-score   support

           0       0.60      0.75      0.67         4
           1       1.00      0.93      0.97        15
           2       0.89      0.89      0.89        18

    accuracy                           0.89        37
   macro avg       0.83      0.86      0.84        37
weighted avg       0.90      0.89      0.90        37
```

0.16 Neural Network for T2 only

[70]:
```
in_dim = len(X_train_T2.columns)
oversample = SMOTE()
X, y = oversample.fit_resample(X_train_T2,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
test_features = scaler.transform(X_test_T2)
```

[71]:
```
accuracies = []
model = NNModel(50,3,'relu','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(50,3,'relu','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
```

```
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(50,3,'sigmoid','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(50,3,'sigmoid','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'relu','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'relu','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'sigmoid','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'sigmoid','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
```

```
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
```

```
being deleted with unrestored values. See the following logs for the specific
values in question. To silence these warnings, use `status.expect_partial()`.
See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor
details about the status object returned by the restore function.
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.count
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
being deleted with unrestored values. See the following logs for the specific
values in question. To silence these warnings, use `status.expect_partial()`.
See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor
details about the status object returned by the restore function.
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.count
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
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*****Model Accuracy: 88.41% (2.13%)
*****Model Accuracy: 95.82% (1.75%)
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*****Model Accuracy: 30.11% (7.96%)
*****Model Accuracy: 91.68% (1.77%)

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*****Model Accuracy: 90.75% (3.86%)

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*****Model Accuracy: 95.82% (0.95%)
*****Model Accuracy: 29.15% (5.14%)

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```

```
values in question. To silence these warnings, use `status.expect_partial()`.
See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor
details about the status object returned by the restore function.
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.count
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
being deleted with unrestored values. See the following logs for the specific
values in question. To silence these warnings, use `status.expect_partial()`.
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WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.count
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
being deleted with unrestored values. See the following logs for the specific
values in question. To silence these warnings, use `status.expect_partial()`.
See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor
details about the status object returned by the restore function.
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.count
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count
WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
being deleted with unrestored values. See the following logs for the specific
values in question. To silence these warnings, use `status.expect_partial()`.
See https://www.tensorflow.org/api_docs/python/tf/train/Checkpoint#restorefor
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WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.total
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.0.count
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.total
```

```
WARNING:tensorflow:Value in checkpoint could not be found in the restored
object: (root).keras_api.metrics.1.count

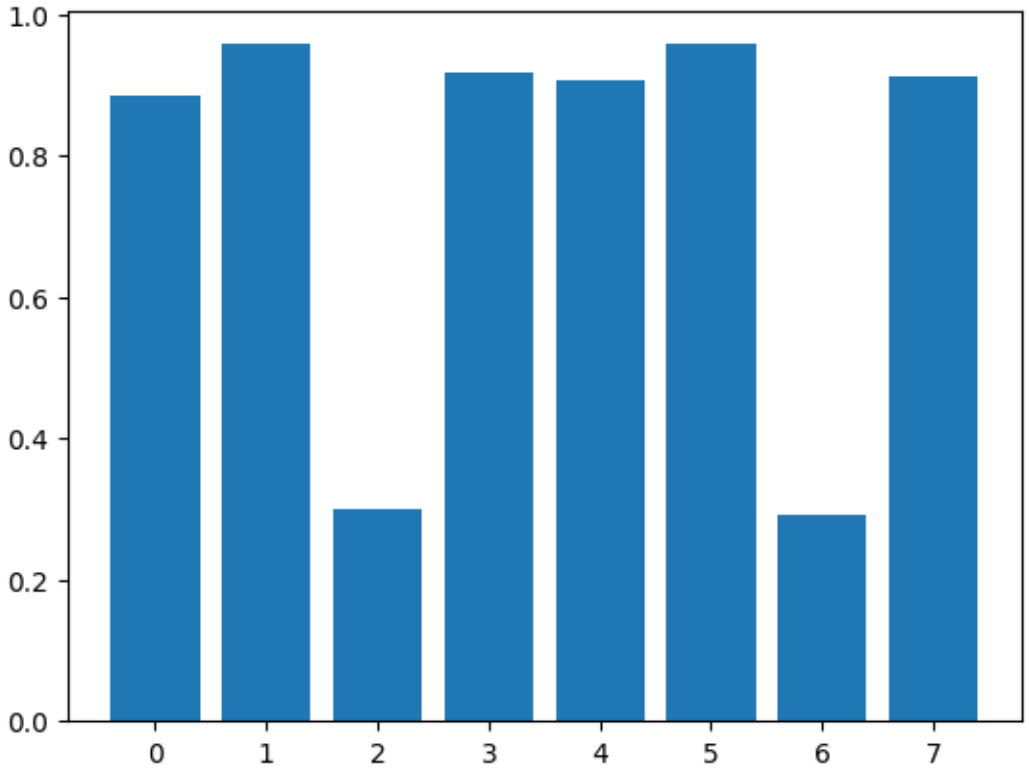
*****Model Accuracy: 91.21% (1.73%)
```

[72]:
```
print('Accuracies in order:\n',
      '50 Neurons/layer,relu,SGD\n','50 Neurons/layer,relu,Adam,\n','50 Neurons/
 ↪layer,sigmoid,SGD\n','50 Neurons/layer,sigmoid,Adam,\n','50 Neurons/
 ↪layer,relu,SGD\n','50 Neurons/layer,relu,Adam,\n','50 Neurons/
 ↪layer,sigmoid,SGD\n','50 Neurons/layer,sigmoid,Adam,\n')
```

```
Accuracies in order:
 50 Neurons/layer,relu,SGD
 50 Neurons/layer,relu,Adam,
 50 Neurons/layer,sigmoid,SGD
 50 Neurons/layer,sigmoid,Adam,
 50 Neurons/layer,relu,SGD
 50 Neurons/layer,relu,Adam,
 50 Neurons/layer,sigmoid,SGD
 50 Neurons/layer,sigmoid,Adam,
```

[73]:
```
plt.bar(range(len(accuracies)),accuracies)
```

[73]:
```
<BarContainer object of 8 artists>
```



[99]:
```
model = Sequential()
model.add(Dense(100, input_dim = in_dim, activation = 'relu'))
model.add(Dense(100, activation = 'relu'))
model.add(Dense(100, activation = 'relu'))
model.add(Dense(3, activation = 'softmax'))
model.compile(loss = 'categorical_crossentropy', optimizer = 'Adam', metrics =␣
 ↪['accuracy'])
model.fit(train_features, pd.get_dummies(y), epochs = 30, batch_size =␣
 ↪16,verbose = 2)
scores = model.evaluate(test_features, pd.get_dummies(data_add_test.iloc[:,0]))
for i, m in enumerate(model.metrics_names):
    print("\n%s: %.3f"% (m, scores[i]))
y_pred = model.predict(test_features).round()
print(metrics.f1_score(y_pred,pd.get_dummies(y_test),average = 'weighted'))
print(metrics.classification_report(pd.DataFrame(y_pred),pd.
 ↪get_dummies(y_test)))
```

```
Epoch 1/30
14/14 - 1s - loss: 0.8533 - accuracy: 0.6806 - 1s/epoch - 104ms/step
Epoch 2/30
14/14 - 0s - loss: 0.4550 - accuracy: 0.8796 - 56ms/epoch - 4ms/step
Epoch 3/30
14/14 - 0s - loss: 0.2788 - accuracy: 0.9306 - 52ms/epoch - 4ms/step
Epoch 4/30
14/14 - 0s - loss: 0.1712 - accuracy: 0.9583 - 49ms/epoch - 3ms/step
Epoch 5/30
14/14 - 0s - loss: 0.0956 - accuracy: 0.9861 - 62ms/epoch - 4ms/step
Epoch 6/30
14/14 - 0s - loss: 0.0607 - accuracy: 0.9907 - 50ms/epoch - 4ms/step
Epoch 7/30
14/14 - 0s - loss: 0.0339 - accuracy: 0.9907 - 46ms/epoch - 3ms/step
Epoch 8/30
14/14 - 0s - loss: 0.0210 - accuracy: 1.0000 - 48ms/epoch - 3ms/step
Epoch 9/30
14/14 - 0s - loss: 0.0136 - accuracy: 1.0000 - 42ms/epoch - 3ms/step
Epoch 10/30
14/14 - 0s - loss: 0.0096 - accuracy: 1.0000 - 96ms/epoch - 7ms/step
Epoch 11/30
14/14 - 0s - loss: 0.0071 - accuracy: 1.0000 - 103ms/epoch - 7ms/step
Epoch 12/30
14/14 - 0s - loss: 0.0052 - accuracy: 1.0000 - 113ms/epoch - 8ms/step
Epoch 13/30
14/14 - 0s - loss: 0.0041 - accuracy: 1.0000 - 137ms/epoch - 10ms/step
Epoch 14/30
14/14 - 0s - loss: 0.0034 - accuracy: 1.0000 - 160ms/epoch - 11ms/step
```

```
Epoch 15/30
14/14 - 0s - loss: 0.0028 - accuracy: 1.0000 - 81ms/epoch - 6ms/step
Epoch 16/30
14/14 - 0s - loss: 0.0023 - accuracy: 1.0000 - 68ms/epoch - 5ms/step
Epoch 17/30
14/14 - 0s - loss: 0.0020 - accuracy: 1.0000 - 116ms/epoch - 8ms/step
Epoch 18/30
14/14 - 0s - loss: 0.0017 - accuracy: 1.0000 - 184ms/epoch - 13ms/step
Epoch 19/30
14/14 - 0s - loss: 0.0015 - accuracy: 1.0000 - 170ms/epoch - 12ms/step
Epoch 20/30
14/14 - 0s - loss: 0.0013 - accuracy: 1.0000 - 134ms/epoch - 10ms/step
Epoch 21/30
14/14 - 0s - loss: 0.0012 - accuracy: 1.0000 - 100ms/epoch - 7ms/step
Epoch 22/30
14/14 - 0s - loss: 0.0010 - accuracy: 1.0000 - 107ms/epoch - 8ms/step
Epoch 23/30
14/14 - 0s - loss: 9.3901e-04 - accuracy: 1.0000 - 76ms/epoch - 5ms/step
Epoch 24/30
14/14 - 0s - loss: 8.4443e-04 - accuracy: 1.0000 - 128ms/epoch - 9ms/step
Epoch 25/30
14/14 - 0s - loss: 7.6670e-04 - accuracy: 1.0000 - 115ms/epoch - 8ms/step
Epoch 26/30
14/14 - 0s - loss: 7.0518e-04 - accuracy: 1.0000 - 50ms/epoch - 4ms/step
Epoch 27/30
14/14 - 0s - loss: 6.3934e-04 - accuracy: 1.0000 - 51ms/epoch - 4ms/step
Epoch 28/30
14/14 - 0s - loss: 5.8730e-04 - accuracy: 1.0000 - 84ms/epoch - 6ms/step
Epoch 29/30
14/14 - 0s - loss: 5.4074e-04 - accuracy: 1.0000 - 129ms/epoch - 9ms/step
Epoch 30/30
14/14 - 0s - loss: 5.0026e-04 - accuracy: 1.0000 - 179ms/epoch - 13ms/step

WARNING:tensorflow:5 out of the last 9 calls to <function
Model.make_test_function.<locals>.test_function at 0x7b12a5ee3400> triggered
tf.function retracing. Tracing is expensive and the excessive number of tracings
could be due to (1) creating @tf.function repeatedly in a loop, (2) passing
tensors with different shapes, (3) passing Python objects instead of tensors.
For (1), please define your @tf.function outside of the loop. For (2),
@tf.function has reduce_retracing=True option that can avoid unnecessary
retracing. For (3), please refer to
https://www.tensorflow.org/guide/function#controlling_retracing and
https://www.tensorflow.org/api_docs/python/tf/function for  more details.

2/2 [==============================] - 1s 15ms/step - loss: 0.4736 - accuracy:
0.8378

loss: 0.474
```

```
accuracy: 0.838
2/2 [==============================] - 0s 50ms/step
              precision    recall  f1-score   support

           0       0.75      0.38      0.50         8
           1       0.93      0.93      0.93        15
           2       0.78      1.00      0.88        14

   micro avg       0.84      0.84      0.84        37
   macro avg       0.82      0.77      0.77        37
weighted avg       0.83      0.84      0.82        37
 samples avg       0.84      0.84      0.84        37
```

0.17 Random Forest for T2 only

[75]:
```
grid = {
    'criterion':["squared_error","absolute_error"],
    'max_depth': [2,3,5,7,10],
    'max_features': [3,10,"sqrt"],
    'n_estimators':[50,100,150]
}
model = GridSearchCV(estimator=RandomForestRegressor(), param_grid=grid, cv=␣
 ↪kfolds)
X, y = oversample.fit_resample(X_train_T2,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
model.fit(train_features, y)
model.best_params_
```

[75]:
```
{'criterion': 'squared_error',
 'max_depth': 10,
 'max_features': 'sqrt',
 'n_estimators': 150}
```

[76]:
```
model.cv_results_['params']
```

[76]:
```
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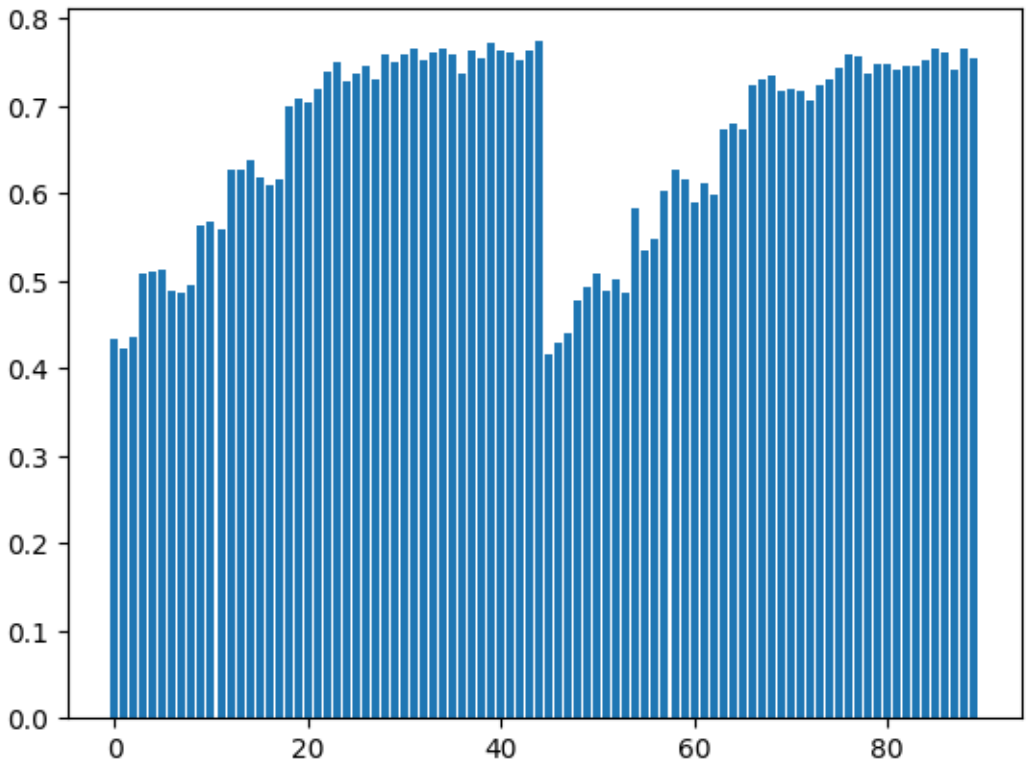
```

[77]:
```
plt.bar(range(len(model.cv_results_['mean_test_score'])),model.
↪cv_results_['mean_test_score'])
```

[77]:
```
<BarContainer object of 90 artists>
```



[78]:
```
model = RandomForestRegressor(criterion = 'squared_error',max_depth =␣
 ↪10,max_features = "sqrt",n_estimators = 150)
X, y = oversample.fit_resample(X_train_T2,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
test_features = scaler.transform(X_test_T2)
model.fit(train_features, y)
y_pred = model.predict(test_features)
accuracy = metrics.accuracy_score(y_test, [round(i) for i in y_pred])
f1 = metrics.f1_score(y_test,[round(i) for i in y_pred], average='weighted')
print("Accuracy on Train dataset:", metrics.accuracy_score(y, [round(i) for i␣
 ↪in model.predict(train_features)]))
print("F1 on Train dataset:", metrics.f1_score(y, [round(i) for i in model.
 ↪predict(train_features)],average = 'weighted'))
print("Accuracy on Test dataset:", accuracy)
print("F1 on Test dataset:", f1)
print(metrics.classification_report(y_test,  [round(i) for i in y_pred]))
```

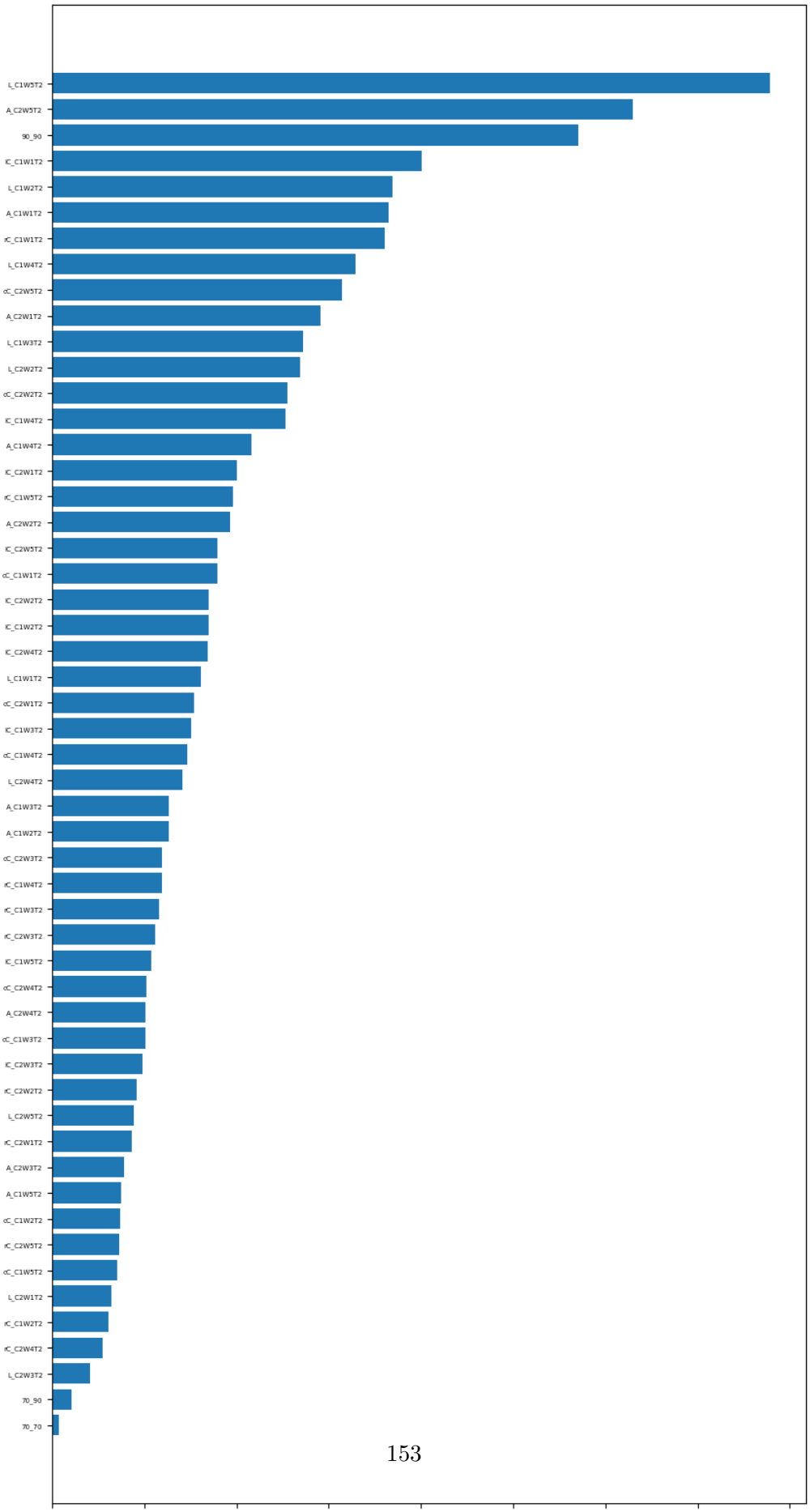
```
Accuracy on Train dataset: 0.9861111111111112
F1 on Train dataset: 0.9861050803300043
Accuracy on Test dataset: 0.7837837837837838
F1 on Test dataset: 0.7713210663974671
```

```
              precision    recall  f1-score   support

           0       1.00      0.25      0.40         4
           1       0.65      1.00      0.79        15
           2       1.00      0.72      0.84        18

    accuracy                           0.78        37
   macro avg       0.88      0.66      0.68        37
weighted avg       0.86      0.78      0.77        37
```

[79]:
```
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_T2.columns)[indices])
```


L_C1W5T2
A_C2W5T2
90_90
IC_C1W1T2
L_C1W2T2
A_C1W1T2
oC_C1W1T2
L_C1W4T2
oC_C2W5T2
A_C2W1T2
L_C1W3T2
L_C2W2T2
oC_C2W2T2
IC_C1W4T2
A_C1W4T2
IC_C2W1T2
oC_C1W5T2
A_C2W2T2
IC_C2W5T2
oC_C1W1T2
IC_C2W2T2
IC_C1W2T2
IC_C2W4T2
L_C1W1T2
oC_C2W1T2
IC_C1W3T2
oC_C1W4T2
L_C2W4T2
A_C1W3T2
A_C1W2T2
oC_C2W3T2
oC_C1W4T2
oC_C1W3T2
oC_C2W3T2
IC_C1W5T2
oC_C2W4T2
A_C2W4T2
oC_C1W3T2
IC_C2W3T2
oC_C2W2T2
L_C2W5T2
oC_C2W1T2
A_C2W3T2
A_C1W5T2
oC_C1W2T2
oC_C2W5T2
oC_C1W5T2
L_C2W1T2
oC_C1W2T2
oC_C2W4T2
L_C2W3T2
70_90
70_70
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08

0.18 Logsitic for T2 only

[45]:
```
grid = {
    'penalty': ['l1', 'l2'],
    'C':[0.5,1,1.5],
    'tol':[0.0001,0.001,0.01,0.1]
}
models = GridSearchCV(estimator=LogisticRegression(solver =␣
 ↪'liblinear',multi_class = 'ovr'), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_T2_scaled = scaler.fit_transform(X_train_T2)
X_test_T2_scaled = scaler.transform(X_test_T2)
X, y = oversample.fit_resample(X_train_T2_scaled,y_train)
models.fit(X, y)
models.best_params_
```

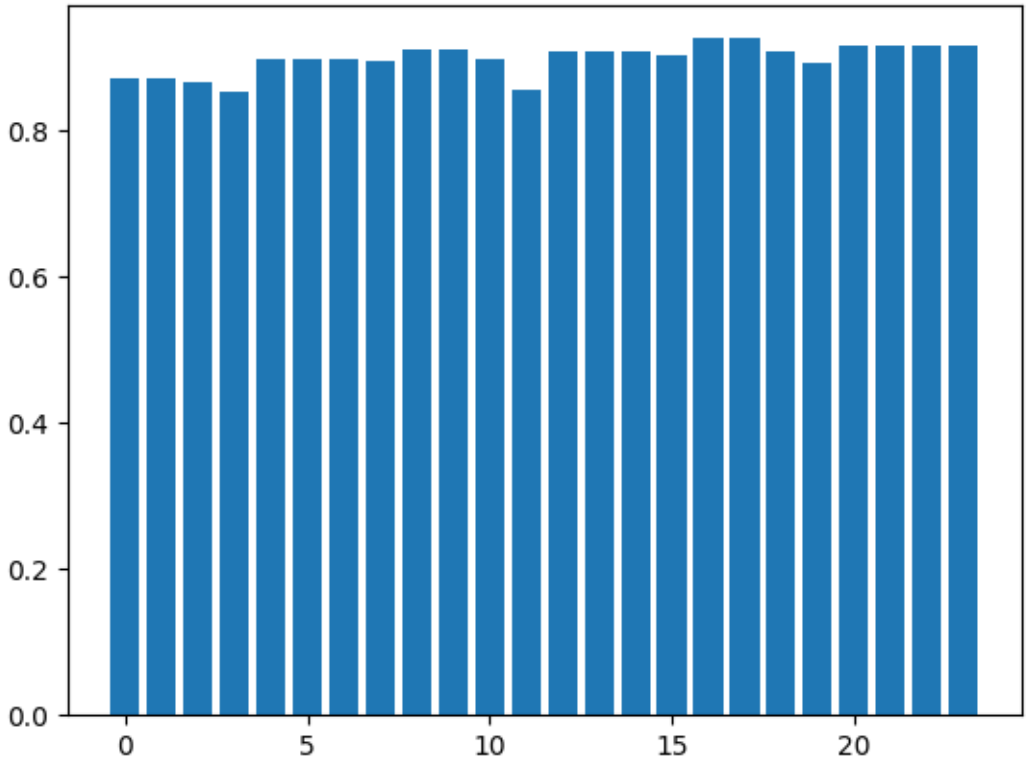
[45]:
```
{'C': 1.5, 'penalty': 'l1', 'tol': 0.0001}
```

[46]:
```
models.cv_results_['params']
```

[46]:
```
[{'C': 0.5, 'penalty': 'l1', 'tol': 0.0001},
 {'C': 0.5, 'penalty': 'l1', 'tol': 0.001},
 {'C': 0.5, 'penalty': 'l1', 'tol': 0.01},
 {'C': 0.5, 'penalty': 'l1', 'tol': 0.1},
 {'C': 0.5, 'penalty': 'l2', 'tol': 0.0001},
 {'C': 0.5, 'penalty': 'l2', 'tol': 0.001},
 {'C': 0.5, 'penalty': 'l2', 'tol': 0.01},
 {'C': 0.5, 'penalty': 'l2', 'tol': 0.1},
 {'C': 1, 'penalty': 'l1', 'tol': 0.0001},
 {'C': 1, 'penalty': 'l1', 'tol': 0.001},
 {'C': 1, 'penalty': 'l1', 'tol': 0.01},
 {'C': 1, 'penalty': 'l1', 'tol': 0.1},
 {'C': 1, 'penalty': 'l2', 'tol': 0.0001},
 {'C': 1, 'penalty': 'l2', 'tol': 0.001},
 {'C': 1, 'penalty': 'l2', 'tol': 0.01},
 {'C': 1, 'penalty': 'l2', 'tol': 0.1},
 {'C': 1.5, 'penalty': 'l1', 'tol': 0.0001},
 {'C': 1.5, 'penalty': 'l1', 'tol': 0.001},
 {'C': 1.5, 'penalty': 'l1', 'tol': 0.01},
 {'C': 1.5, 'penalty': 'l1', 'tol': 0.1},
 {'C': 1.5, 'penalty': 'l2', 'tol': 0.0001},
 {'C': 1.5, 'penalty': 'l2', 'tol': 0.001},
 {'C': 1.5, 'penalty': 'l2', 'tol': 0.01},
 {'C': 1.5, 'penalty': 'l2', 'tol': 0.1}]
```

[47]:
```
plt.bar(range(len(models.cv_results_['mean_test_score'])),models.
  ↪cv_results_['mean_test_score'])
```

[47]:
```
<BarContainer object of 24 artists>
```



[49]:
```
model = LogisticRegression(solver = 'liblinear',multi_class = 'ovr', C = 1.5,␣
  ↪penalty = 'l1', tol = 0.0001)
model.fit(X, y)
y_pred = model.predict(X_test_T2_scaled)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y, model.predict(X)))
print("f1 score on train Dataset: ",metrics.f1_score(y, model.
  ↪predict(X),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))

#plot the vairable importances

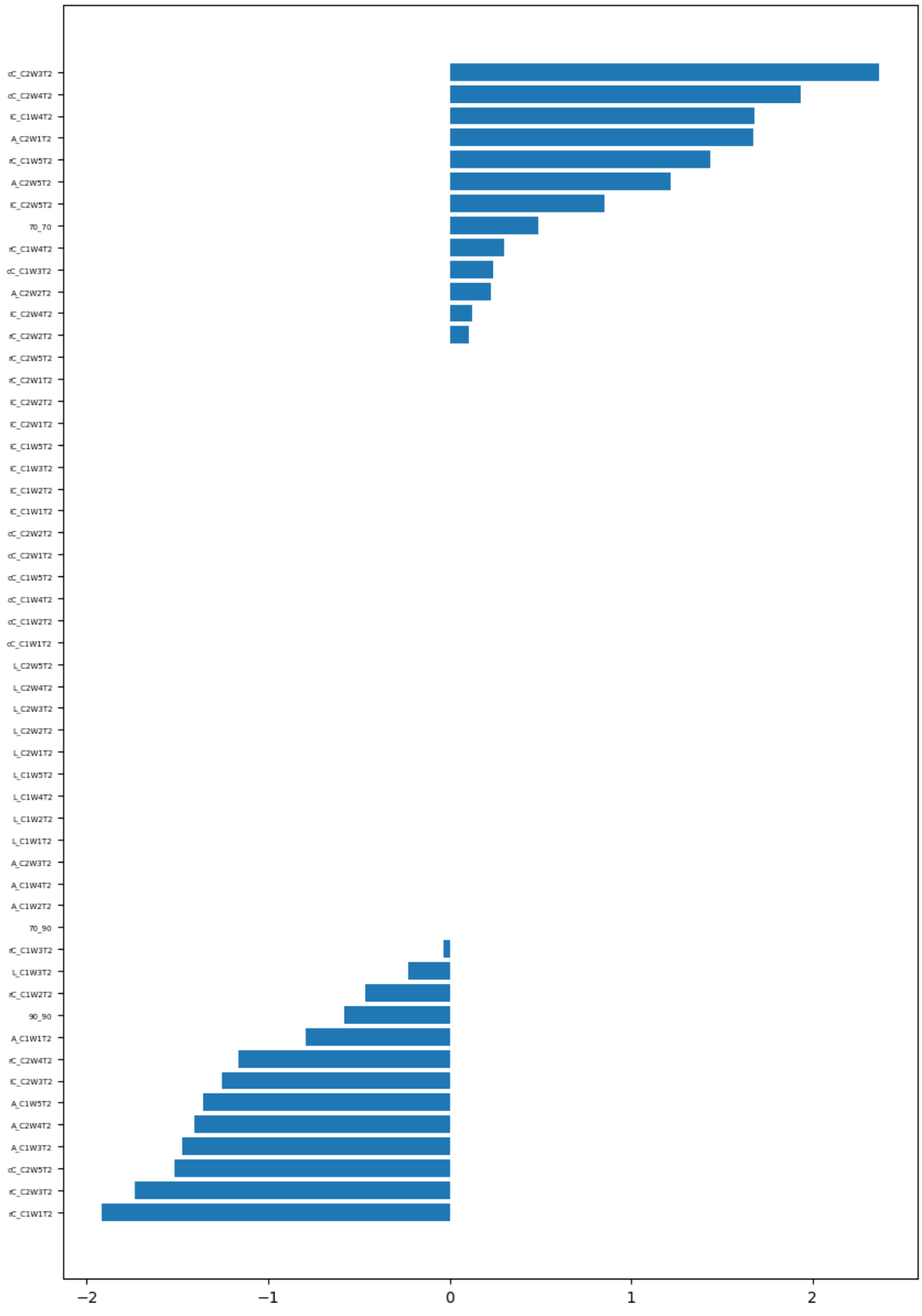
def f_importances(coef, names):
    imp = coef
```

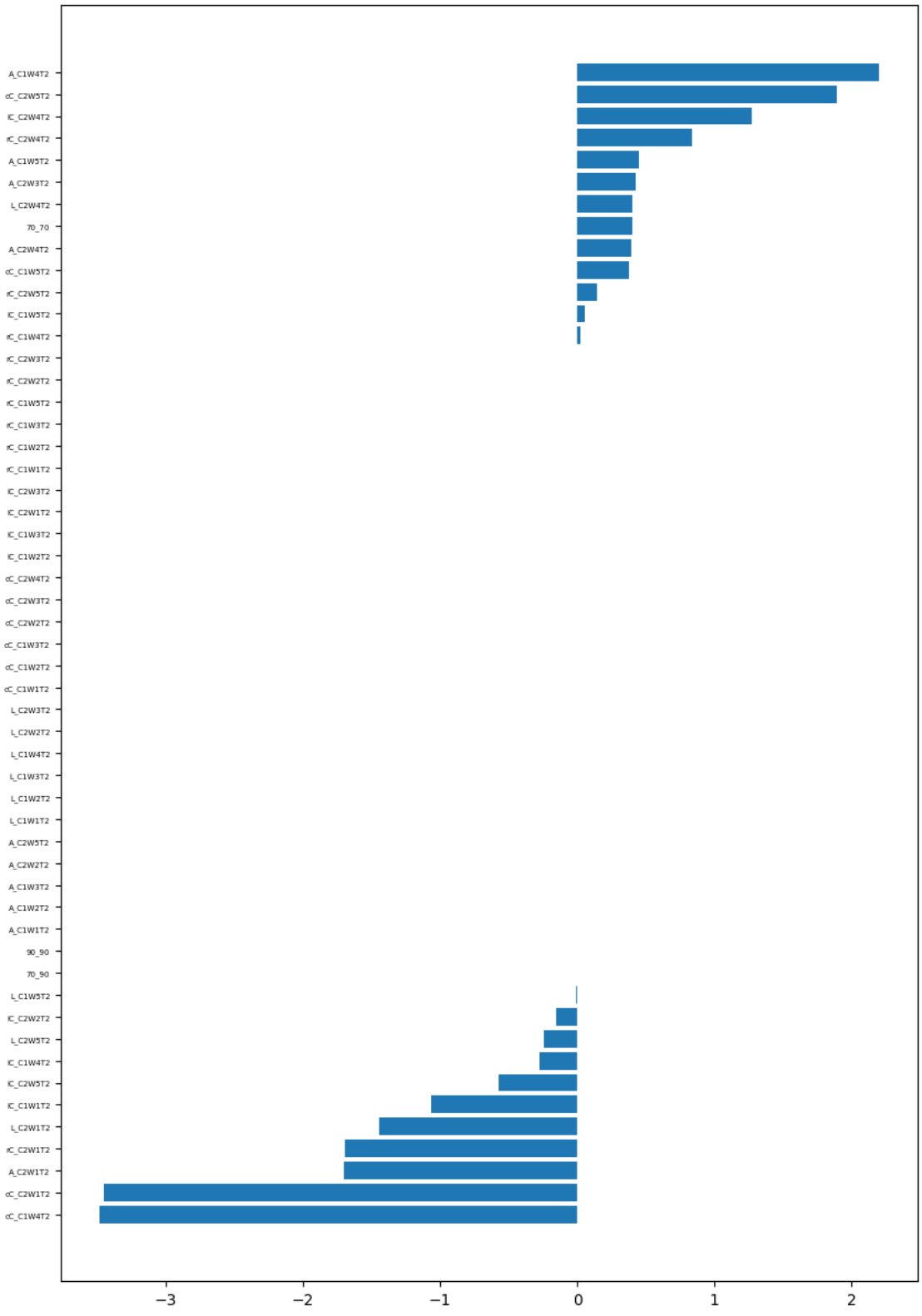
```
    imp,names = zip(*sorted(zip(imp,names)))
    plt.figure(figsize=(10,15))
    plt.barh(range(len(names)), imp, align='center')
    plt.tick_params(axis='y', labelsize=5)
    plt.yticks(range(len(names)), names)
    plt.show()
f_importances(model.coef_[0], X_train_T2.columns)
f_importances(model.coef_[1], X_train_T2.columns)
f_importances(model.coef_[2], X_train_T2.columns)
```

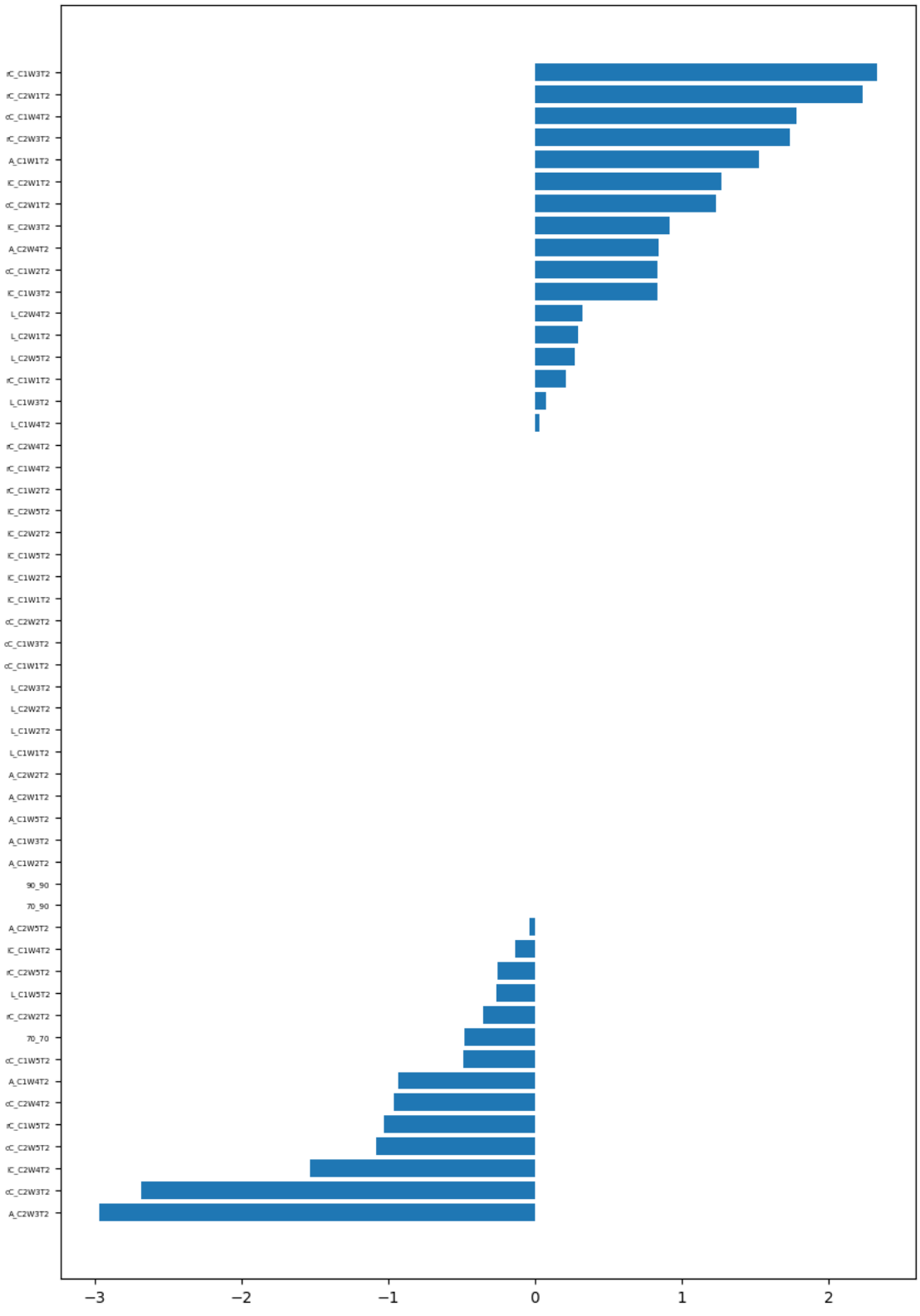
```
Accuracy on train Dataset:  0.9861111111111112
f1 score on train Dataset:  0.9860785128026507
Accuracy on test Dataset:  0.918918918918919
f1 score on test Dataset:  0.9262899262899263
              precision    recall  f1-score   support

           0       0.57      1.00      0.73         4
           1       1.00      1.00      1.00        15
           2       1.00      0.83      0.91        18

    accuracy                           0.92        37
   macro avg       0.86      0.94      0.88        37
weighted avg       0.95      0.92      0.93        37
```


dC_C2W3T2
dC_C2W4T2
IC_C1W4T2
A_C2W1T2
nC_C1W5T2
A_C2W5T2
IC_C2W5T2
70_70
nC_C1W4T2
dC_C1W3T2
A_C2W2T2
IC_C2W4T2
nC_C2W2T2
nC_C2W5T2
nC_C2W1T2
IC_C2W2T2
IC_C2W1T2
IC_C1W5T2
IC_C1W3T2
IC_C1W2T2
IC_C1W1T2
dC_C2W2T2
dC_C2W1T2
dC_C1W5T2
dC_C1W4T2
dC_C1W2T2
dC_C1W1T2
L_C2W5T2
L_C2W4T2
L_C2W3T2
L_C2W2T2
L_C2W1T2
L_C1W5T2
L_C1W4T2
L_C1W2T2
L_C1W1T2
A_C2W3T2
A_C1W4T2
A_C1W2T2
70_90
nC_C1W3T2
L_C1W3T2
nC_C1W2T2
90_90
A_C1W1T2
nC_C2W4T2
IC_C2W3T2
A_C1W5T2
A_C2W4T2
A_C1W3T2
dC_C2W5T2
nC_C2W3T2
nC_C1W1T2
−2
−1
0
1
2


A_C1W4T2
oC_C2W5T2
IC_C2W4T2
nC_C2W4T2
A_C1W5T2
A_C2W3T2
L_C2W4T2
70_70
A_C2W4T2
oC_C1W5T2
nC_C2W5T2
IC_C1W5T2
nC_C1W4T2
nC_C2W3T2
nC_C2W2T2
nC_C1W5T2
nC_C1W3T2
nC_C1W2T2
nC_C1W1T2
IC_C2W3T2
IC_C2W1T2
IC_C1W3T2
IC_C1W2T2
oC_C2W4T2
oC_C2W3T2
oC_C2W2T2
oC_C1W3T2
oC_C1W2T2
oC_C1W1T2
L_C2W3T2
L_C2W2T2
L_C1W4T2
L_C1W3T2
L_C1W2T2
L_C1W1T2
A_C2W5T2
A_C2W2T2
A_C1W3T2
A_C1W2T2
A_C1W1T2
90_90
70_90
L_C1W5T2
IC_C2W2T2
L_C2W5T2
IC_C1W4T2
IC_C2W5T2
IC_C1W1T2
L_C2W1T2
nC_C2W1T2
A_C2W1T2
oC_C2W1T2
oC_C1W4T2
−3
−2
−1
0
1
2


rC_C1W3T2
rC_C2W1T2
cC_C1W4T2
rC_C2W3T2
A_C1W1T2
lC_C2W1T2
cC_C2W1T2
lC_C2W3T2
A_C2W4T2
cC_C1W2T2
lC_C1W3T2
L_C2W4T2
L_C2W1T2
L_C2W5T2
rC_C1W1T2
L_C1W3T2
L_C1W4T2
rC_C2W4T2
rC_C1W4T2
rC_C1W2T2
lC_C2W5T2
lC_C2W2T2
lC_C1W5T2
lC_C1W2T2
lC_C1W1T2
cC_C2W2T2
cC_C1W3T2
cC_C1W1T2
L_C2W3T2
L_C2W2T2
L_C1W2T2
L_C1W1T2
A_C2W2T2
A_C2W1T2
A_C1W5T2
A_C1W3T2
A_C1W2T2
90_90
70_90
A_C2W5T2
lC_C1W4T2
rC_C2W5T2
L_C1W5T2
rC_C2W2T2
70_70
cC_C1W5T2
A_C1W4T2
cC_C2W4T2
rC_C1W5T2
cC_C2W5T2
lC_C2W4T2
cC_C2W3T2
A_C2W3T2
−3
−2
−1
0
1
2

0.19 *What happens if only using T0?*

0.20 *do the same steps/algorithms as above using T0 variables only*

[51]:
```
X_train_T0 = X_train.iloc[:,:53]
X_test_T0 = X_test.iloc[:,:53]
```

0.21 XGboost for T0 only

[126]:
```
grid = {
    'max_depth': [2,4,6,9],
    'n_estimators':[50,100,150],
    'learning_rate':[0.3,0.5,1],
    'reg_alpha':[0,0.01,0.1,0.5],
    'reg_lambda':[0,0.1,1]
}
models = GridSearchCV(estimator=XGBClassifier(), param_grid=grid, cv= kfolds)
models.fit(X_train_T0, y_train)
models.best_params_
```

[126]:
```
{'learning_rate': 1,
 'max_depth': 6,
 'n_estimators': 50,
 'reg_alpha': 0,
 'reg_lambda': 1}
```

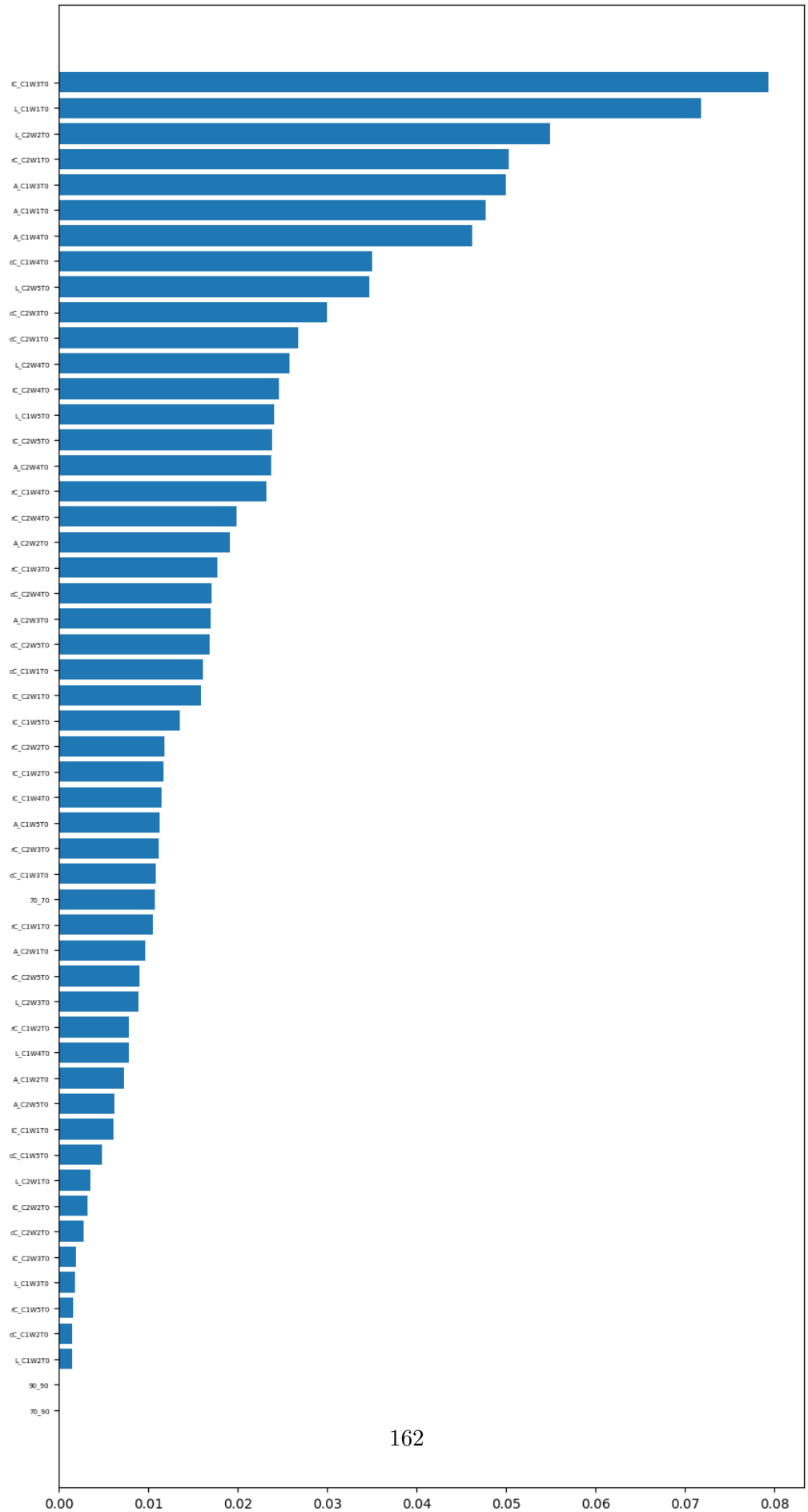
[127]:
```
model = XGBClassifier(max_depth = 6,learning_rate = 0.5, n_estimators=␣
 ↪100,reg_alpha = 0,reg_lambda = 1)
model.fit(X_train_T0, y_train)
y_pred = model.predict(X_test_T0)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T0)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T0),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_T0.columns)[indices])
```

```
Accuracy on train Dataset:  1.0
```

```
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.8378378378378378
f1 score on test Dataset:  0.8213642213642214
              precision    recall  f1-score   support

           0       0.50      0.25      0.33         4
           1       0.92      0.80      0.86        15
           2       0.82      1.00      0.90        18

    accuracy                           0.84        37
   macro avg       0.75      0.68      0.70        37
weighted avg       0.83      0.84      0.82        37
```


IC_C1W3T0
L_C1W1T0
L_C2W2T0
xC_C2W1T0
A_C1W3T0
A_C1W1T0
A_C1W4T0
oC_C1W4T0
L_C2W5T0
oC_C2W3T0
oC_C2W1T0
L_C2W4T0
IC_C2W4T0
L_C1W5T0
IC_C2W5T0
A_C2W4T0
xC_C1W4T0
xC_C2W4T0
A_C2W2T0
xC_C1W3T0
oC_C2W4T0
A_C2W3T0
oC_C2W5T0
oC_C1W1T0
IC_C2W1T0
IC_C1W5T0
xC_C2W2T0
IC_C1W2T0
IC_C1W4T0
A_C1W5T0
xC_C2W3T0
oC_C1W3T0
70_70
xC_C1W1T0
A_C2W1T0
xC_C2W5T0
L_C2W3T0
xC_C1W2T0
L_C1W4T0
A_C1W2T0
A_C2W5T0
IC_C1W1T0
oC_C1W5T0
L_C2W1T0
IC_C2W2T0
oC_C2W2T0
IC_C2W3T0
L_C1W3T0
xC_C1W5T0
oC_C1W2T0
L_C1W2T0
90_90
70_90
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08

0.22 Adaboost for T0 only

[109]:
```
grid = {
    'algorithm': ["SAMME","SAMME.R"],
    'n_estimators':[10,30,50,70,100,150],
    'learning_rate':[0.5,1,1.5,2]
}
models = GridSearchCV(estimator = AdaBoostClassifier(), param_grid=grid, cv=␣
 ↪kfolds)
models.fit(X_train_T0, y_train)
print(models.best_params_,models.best_score_)
```

```
{'algorithm': 'SAMME', 'learning_rate': 0.5, 'n_estimators': 100}
0.6098850574712643
```

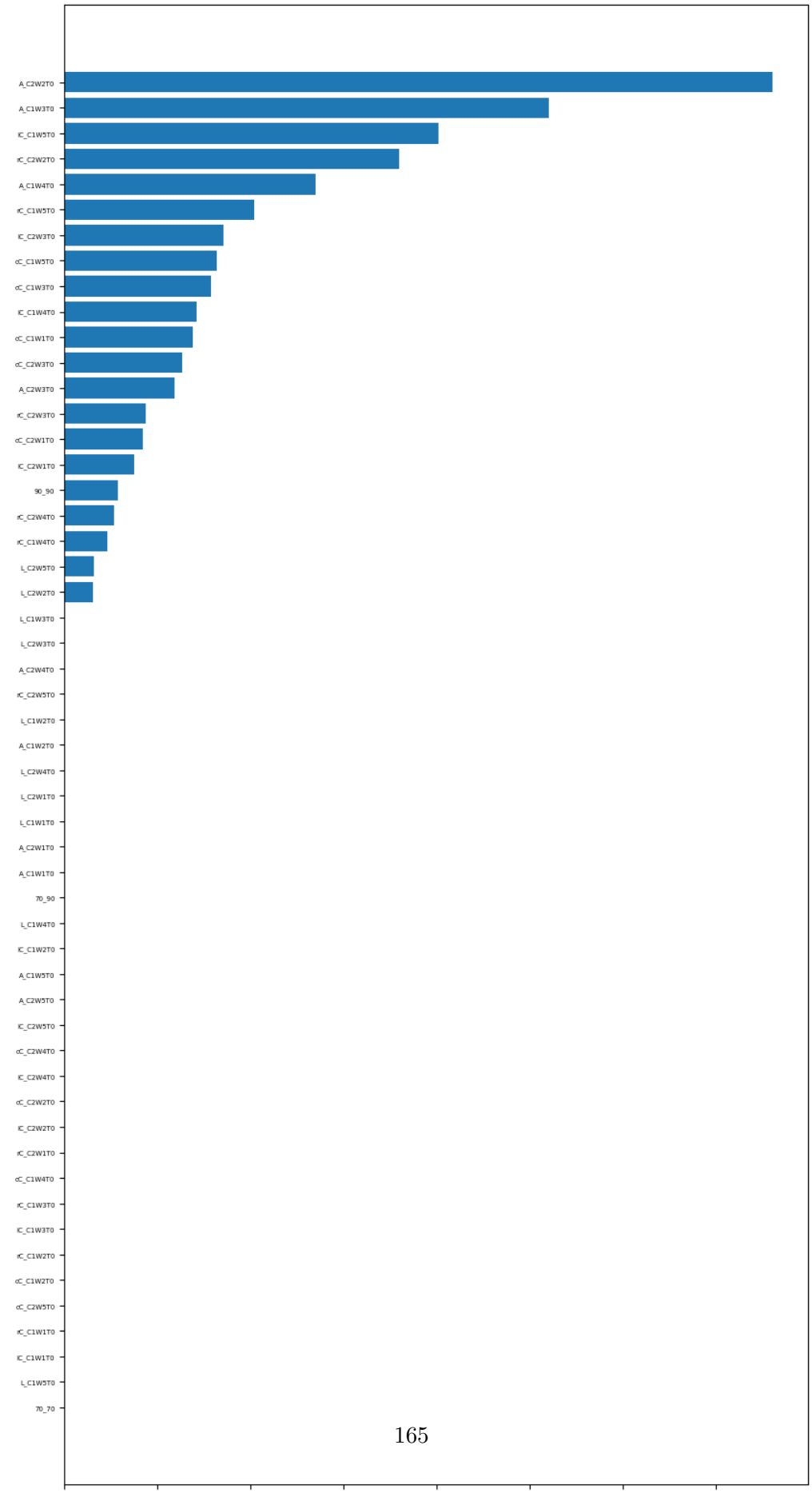
[110]:
```
model = AdaBoostClassifier(algorithm = 'SAMME', learning_rate = 0.5,␣
 ↪n_estimators= 100)
model.fit(X_train_T0, y_train)
y_pred = model.predict(X_test_T0)
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T0)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T0),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_T0.columns)[indices])
```

```
Accuracy on train Dataset:  0.8287671232876712
f1 score on train Dataset:  0.8288666462881475
Accuracy on test Dataset:  0.5945945945945946
f1 score on test Dataset:  0.5840323081702392
              precision    recall  f1-score   support

           0       0.50      0.25      0.33         4
           1       0.57      0.53      0.55        15
           2       0.62      0.72      0.67        18
```

```
              precision    recall  f1-score   support

    accuracy                       0.59        37
   macro avg       0.56      0.50      0.52        37
weighted avg       0.59      0.59      0.58        37
```


A_C2W2T0
A_C1W3T0
IC_C1W5T0
xC_C2W2T0
A_C1W4T0
xC_C1W5T0
IC_C2W3T0
oC_C1W5T0
oC_C1W3T0
IC_C1W4T0
oC_C1W1T0
oC_C2W3T0
A_C2W3T0
xC_C2W3T0
oC_C2W1T0
IC_C2W1T0
90_90
xC_C2W4T0
xC_C1W4T0
L_C2W5T0
L_C2W2T0
L_C1W3T0
L_C2W3T0
A_C2W4T0
xC_C2W5T0
L_C1W2T0
A_C1W2T0
L_C2W4T0
L_C2W1T0
L_C1W1T0
A_C2W1T0
A_C1W1T0
70_90
L_C1W4T0
IC_C1W2T0
A_C1W5T0
A_C2W5T0
IC_C2W5T0
oC_C2W4T0
IC_C2W4T0
oC_C2W2T0
IC_C2W2T0
xC_C2W1T0
oC_C1W4T0
xC_C1W3T0
IC_C1W3T0
xC_C1W2T0
oC_C1W2T0
oC_C2W5T0
xC_C1W1T0
IC_C1W1T0
L_C1W5T0
70_70
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175

0.23 Gaussian NB for T0 only

[129]:
```
#using oversampling and scaling
grid = {
    'priors': [None,[0.34,0.33,0.33],[len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/
 ↪len(y_train),len(y_train[y_train==[2]])/
 ↪len(y_train)],[len(y_train[y_train==[2]])/
 ↪len(y_train),len(y_train[y_train==[0]])/
 ↪len(y_train),len(y_train[y_train==[1]])/len(y_train)]]
}
models = GridSearchCV(estimator = GaussianNB(), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_T0_scaled = scaler.fit_transform(X_train_T0)
X_test_T0_scaled = scaler.transform(X_test_T0)
X, y = oversample.fit_resample(X_train_T0_scaled,y_train)
models.fit(X, y)
print(models.best_params_,models.best_score_)
```

```
{'priors': [0.4931506849315068, 0.0958904109589041, 0.410958904109589]}
0.6669133192389006
```

[131]:
```
model = GaussianNB(priors =  [0.4931506849315068, 0.0958904109589041, 0.
 ↪410958904109589])
model.fit(X, y)
y_pred = model.predict(X_test_T0_scaled)
accuracy = metrics.accuracy_score(y_pred, y_test)
f1 = metrics.f1_score(y_pred, y_test,average="weighted")
print("Accuracy on train Dataset: ",metrics.accuracy_score(y, model.predict(X)))
print("f1 score on train Dataset: ",metrics.f1_score(y, model.
 ↪predict(X),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  0.7175925925925926
f1 score on train Dataset:  0.7068821664402013
Accuracy on test Dataset:  0.43243243243243246
f1 score on test Dataset:  0.46159317211948797
              precision    recall  f1-score   support

           0       0.25      0.75      0.38         4
           1       0.40      0.13      0.20        15
           2       0.55      0.61      0.58        18
```

```
    accuracy                           0.43        37
   macro avg       0.40      0.50      0.38        37
weighted avg       0.46      0.43      0.40        37
```

0.24 SVM for T0 only

[113]:
```
scaler = preprocessing.StandardScaler()
X_train_T0_scaled = scaler.fit_transform(X_train_T0)
X_test_T0_scaled = scaler.transform(X_test_T0)
params_grid = [{'kernel': ['rbf'], 'gamma': [1e-4,1e-3,0.01,0.1,0.5],'C': [0.
 ↪1,1,1.5,10]},
 {'kernel': ['linear'], 'C': [0.1,1,1.5,10]}]
svm_model = GridSearchCV(svm.SVC(), params_grid, cv=kfolds)
svm_model.fit(X_train_T0_scaled, y_train)
```

[113]:
```
GridSearchCV(cv=KFold(n_splits=5, random_state=1, shuffle=True),
             estimator=SVC(),
             param_grid=[{'C': [0.1, 1, 1.5, 10],
                          'gamma': [0.0001, 0.001, 0.01, 0.1, 0.5],
                          'kernel': ['rbf']},
                         {'C': [0.1, 1, 1.5, 10], 'kernel': ['linear']}])
```

[116]:
```
print('Best score for training data:', svm_model.best_score_)
# View the best parameters for the model found using grid search
print('Best C:',svm_model.best_estimator_.C)
print('Best Kernel:',svm_model.best_estimator_.kernel)
print('Best Gamma:',svm_model.best_estimator_.gamma)
model = svm_model.best_estimator_
y_pred = model.predict(X_test_T0_scaled)
```

```
Best score for training data: 0.7537931034482759
Best C: 1.5
Best Kernel: rbf
Best Gamma: 0.1
```

[117]:
```
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test, y_pred, average='weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_T0_scaled)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_T0_scaled),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
```

```
Accuracy on test Dataset:  0.7297297297297297
f1 score on test Dataset:  0.6847826086956521
              precision    recall  f1-score   support

           0       0.00      0.00      0.00         4
           1       1.00      0.60      0.75        15
           2       0.64      1.00      0.78        18

    accuracy                           0.73        37
   macro avg       0.55      0.53      0.51        37
weighted avg       0.72      0.73      0.68        37

/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
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0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

0.25 Neural Network for T0 only

[118]:
```
in_dim = len(X_train_T0.columns)
oversample = SMOTE()
X, y = oversample.fit_resample(X_train_T0,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
test_features = scaler.transform(X_test_T0)
```

[119]:
```
accuracies = []
model = NNModel(50,3,'relu','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),
  cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
  std()*100))
accuracies.append(results.mean())
model = NNModel(50,3,'relu','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
```

```
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(50,3,'sigmoid','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
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print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
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estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'relu','SGD')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
 ↪std()*100))
accuracies.append(results.mean())
model = NNModel(100,3,'relu','Adam')
estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
 ↪cv=kfolds)
print("*****Model Accuracy: %.2f%% (%.2f%%)" % (results.mean()*100, results.
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accuracies.append(results.mean())
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estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
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estimator = KerasClassifier(model, epochs=30, batch_size=16, verbose=0)
results = cross_val_score(estimator, train_features, pd.get_dummies(y),␣
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 ↪std()*100))
```

```
accuracies.append(results.mean())
```

```
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```

```
*****Model Accuracy: 78.73% (4.80%)
*****Model Accuracy: 91.23% (3.63%)
```

```
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being deleted with unrestored values. See the following logs for the specific
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```
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*****Model Accuracy: 33.83% (11.61%)
*****Model Accuracy: 74.08% (5.74%)

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being deleted with unrestored values. See the following logs for the specific
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WARNING:tensorflow:Value in checkpoint could not be found in the restored
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object: (root).keras_api.metrics.1.count

*****Model Accuracy: 78.72% (4.65%)
*****Model Accuracy: 87.52% (3.71%)

WARNING:tensorflow:Detecting that an object or model or tf.train.Checkpoint is
being deleted with unrestored values. See the following logs for the specific
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```

```
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```

```
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```

```
*****Model Accuracy: 33.83% (12.42%)
*****Model Accuracy: 74.10% (5.61%)
```

[123]:
```
model = Sequential()
#show the prunning by change #nodes, activ function,optimizer(opt/adam)
model.add(Dense(50, input_dim = in_dim, activation = 'relu'))
model.add(Dense(50, activation = 'relu'))
model.add(Dense(50, activation = 'relu'))
model.add(Dense(3, activation = 'softmax'))
model.compile(loss = 'categorical_crossentropy', optimizer = 'Adam', metrics =␣
 ↪['accuracy'])
model.fit(train_features, pd.get_dummies(y), epochs = 30, batch_size =␣
 ↪16,verbose = 2)
scores = model.evaluate(test_features, pd.get_dummies(y_test))
for i, m in enumerate(model.metrics_names):
    print("\n%s: %.3f"% (m, scores[i]))
y_pred = model.predict(test_features).round()
metrics.f1_score(y_pred,pd.get_dummies(y_test),average = 'weighted')
print(metrics.classification_report(pd.DataFrame(y_pred),pd.
 ↪get_dummies(y_test)))
```

```
Epoch 1/30
14/14 - 1s - loss: 1.1265 - accuracy: 0.4120 - 1s/epoch - 96ms/step
Epoch 2/30
14/14 - 0s - loss: 0.8952 - accuracy: 0.6806 - 45ms/epoch - 3ms/step
Epoch 3/30
14/14 - 0s - loss: 0.7355 - accuracy: 0.7315 - 49ms/epoch - 3ms/step
Epoch 4/30
14/14 - 0s - loss: 0.5960 - accuracy: 0.7963 - 55ms/epoch - 4ms/step
Epoch 5/30
14/14 - 0s - loss: 0.4943 - accuracy: 0.8241 - 59ms/epoch - 4ms/step
Epoch 6/30
14/14 - 0s - loss: 0.4014 - accuracy: 0.8935 - 50ms/epoch - 4ms/step
Epoch 7/30
14/14 - 0s - loss: 0.3298 - accuracy: 0.8935 - 52ms/epoch - 4ms/step
Epoch 8/30
14/14 - 0s - loss: 0.2700 - accuracy: 0.9352 - 44ms/epoch - 3ms/step
Epoch 9/30
14/14 - 0s - loss: 0.2126 - accuracy: 0.9491 - 51ms/epoch - 4ms/step
Epoch 10/30
14/14 - 0s - loss: 0.1673 - accuracy: 0.9722 - 41ms/epoch - 3ms/step
Epoch 11/30
14/14 - 0s - loss: 0.1374 - accuracy: 0.9815 - 53ms/epoch - 4ms/step
Epoch 12/30
14/14 - 0s - loss: 0.1060 - accuracy: 0.9861 - 46ms/epoch - 3ms/step
Epoch 13/30
14/14 - 0s - loss: 0.0814 - accuracy: 0.9954 - 42ms/epoch - 3ms/step
Epoch 14/30
```

```
14/14 - 0s - loss: 0.0672 - accuracy: 0.9907 - 47ms/epoch - 3ms/step
Epoch 15/30
14/14 - 0s - loss: 0.0538 - accuracy: 0.9954 - 48ms/epoch - 3ms/step
Epoch 16/30
14/14 - 0s - loss: 0.0404 - accuracy: 0.9954 - 51ms/epoch - 4ms/step
Epoch 17/30
14/14 - 0s - loss: 0.0340 - accuracy: 0.9954 - 56ms/epoch - 4ms/step
Epoch 18/30
14/14 - 0s - loss: 0.0280 - accuracy: 0.9954 - 66ms/epoch - 5ms/step
Epoch 19/30
14/14 - 0s - loss: 0.0216 - accuracy: 1.0000 - 63ms/epoch - 5ms/step
Epoch 20/30
14/14 - 0s - loss: 0.0176 - accuracy: 1.0000 - 61ms/epoch - 4ms/step
Epoch 21/30
14/14 - 0s - loss: 0.0141 - accuracy: 1.0000 - 51ms/epoch - 4ms/step
Epoch 22/30
14/14 - 0s - loss: 0.0124 - accuracy: 1.0000 - 47ms/epoch - 3ms/step
Epoch 23/30
14/14 - 0s - loss: 0.0101 - accuracy: 1.0000 - 47ms/epoch - 3ms/step
Epoch 24/30
14/14 - 0s - loss: 0.0092 - accuracy: 1.0000 - 50ms/epoch - 4ms/step
Epoch 25/30
14/14 - 0s - loss: 0.0079 - accuracy: 1.0000 - 50ms/epoch - 4ms/step
Epoch 26/30
14/14 - 0s - loss: 0.0069 - accuracy: 1.0000 - 50ms/epoch - 4ms/step
Epoch 27/30
14/14 - 0s - loss: 0.0062 - accuracy: 1.0000 - 118ms/epoch - 8ms/step
Epoch 28/30
14/14 - 0s - loss: 0.0055 - accuracy: 1.0000 - 91ms/epoch - 6ms/step
Epoch 29/30
14/14 - 0s - loss: 0.0051 - accuracy: 1.0000 - 58ms/epoch - 4ms/step
Epoch 30/30
14/14 - 0s - loss: 0.0046 - accuracy: 1.0000 - 104ms/epoch - 7ms/step
2/2 [==============================] - 0s 10ms/step - loss: 0.7407 - accuracy:
0.7027

loss: 0.741

accuracy: 0.703
2/2 [==============================] - 0s 5ms/step
              precision    recall  f1-score   support

           0       0.50      0.25      0.33         8
           1       0.73      0.85      0.79        13
           2       0.72      0.87      0.79        15

   micro avg       0.70      0.72      0.71        36
   macro avg       0.65      0.65      0.64        36
```

```
weighted avg       0.68      0.72      0.69        36
 samples avg       0.70      0.70      0.70        36
```

```
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Recall and F-score are ill-defined and being set to 0.0
in samples with no true labels. Use `zero_division` parameter to control this
behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

0.26 Random Forest for T0 only

[124]:
```
grid = {
    'criterion':["squared_error","absolute_error"],
    'max_depth': [2,3,5,7,10],
    'max_features': [3,10,"sqrt"],
    'n_estimators':[50,100,150]
}
model = GridSearchCV(estimator=RandomForestRegressor(), param_grid=grid, cv=␣
 ↪kfolds)
X, y = oversample.fit_resample(X_train_T0,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
model.fit(train_features, y)
model.best_params_
```

[124]:
```
{'criterion': 'squared_error',
 'max_depth': 7,
 'max_features': 'sqrt',
 'n_estimators': 100}
```

[125]:
```
model = RandomForestRegressor(criterion = 'squared_error',max_depth =␣
 ↪7,max_features = "sqrt",n_estimators = 100)
X, y = oversample.fit_resample(X_train_T0,y_train)
scaler = preprocessing.StandardScaler()
train_features = scaler.fit_transform(X)
test_features = scaler.transform(X_test_T0)
model.fit(train_features, y)
y_pred = model.predict(test_features)
accuracy = metrics.accuracy_score(y_test, [round(i) for i in y_pred])
f1 = metrics.f1_score(y_test,[round(i) for i in y_pred], average='weighted')
print("Accuracy on Train dataset:", metrics.accuracy_score(y, [round(i) for i␣
 ↪in model.predict(train_features)]))
print("F1 on Train dataset:", metrics.f1_score(y, [round(i) for i in model.
 ↪predict(train_features)],average = 'weighted'))
print("Accuracy on Test dataset:", accuracy)
print("F1 on Test dataset:", f1)
print(metrics.classification_report(y_test,  [round(i) for i in y_pred]))
```

```
Accuracy on Train dataset: 0.9861111111111112
F1 on Train dataset: 0.9861104412828551
Accuracy on Test dataset: 0.7567567567567568
F1 on Test dataset: 0.7198712360002683
              precision    recall  f1-score   support

           0       0.00      0.00      0.00         4
           1       0.62      1.00      0.77        15
           2       1.00      0.72      0.84        18

    accuracy                           0.76        37
   macro avg       0.54      0.57      0.54        37
weighted avg       0.74      0.76      0.72        37

/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
/usr/local/lib/python3.10/dist-packages/sklearn/metrics/_classification.py:1344:
UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
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control this behavior.
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UndefinedMetricWarning: Precision and F-score are ill-defined and being set to
0.0 in labels with no predicted samples. Use `zero_division` parameter to
control this behavior.
  _warn_prf(average, modifier, msg_start, len(result))
```

0.27 Logistic for T0 only

[52]:
```
grid = {
    'penalty': ['l1', 'l2'],
    'C':[0.5,1,1.5],
    'tol':[0.0001,0.001,0.01,0.1]
}
models = GridSearchCV(estimator=LogisticRegression(solver =
 ↪'liblinear',multi_class = 'ovr'), param_grid=grid, cv= kfolds)
scaler = preprocessing.StandardScaler()
X_train_T0_scaled = scaler.fit_transform(X_train_T0)
X_test_T0_scaled = scaler.transform(X_test_T0)
X, y = oversample.fit_resample(X_train_T0_scaled,y_train)
models.fit(X, y)
models.best_params_
```

[52]:
```
{'C': 1, 'penalty': 'l2', 'tol': 0.0001}
```

[53]:
```
model = LogisticRegression(solver = 'liblinear',multi_class = 'ovr', C = 1,␣
 ↪penalty = 'l2', tol = 0.0001)
model.fit(X, y)
y_pred = model.predict(X_test_T0_scaled)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y, model.predict(X)))
print("f1 score on train Dataset: ",metrics.f1_score(y, model.
 ↪predict(X),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))

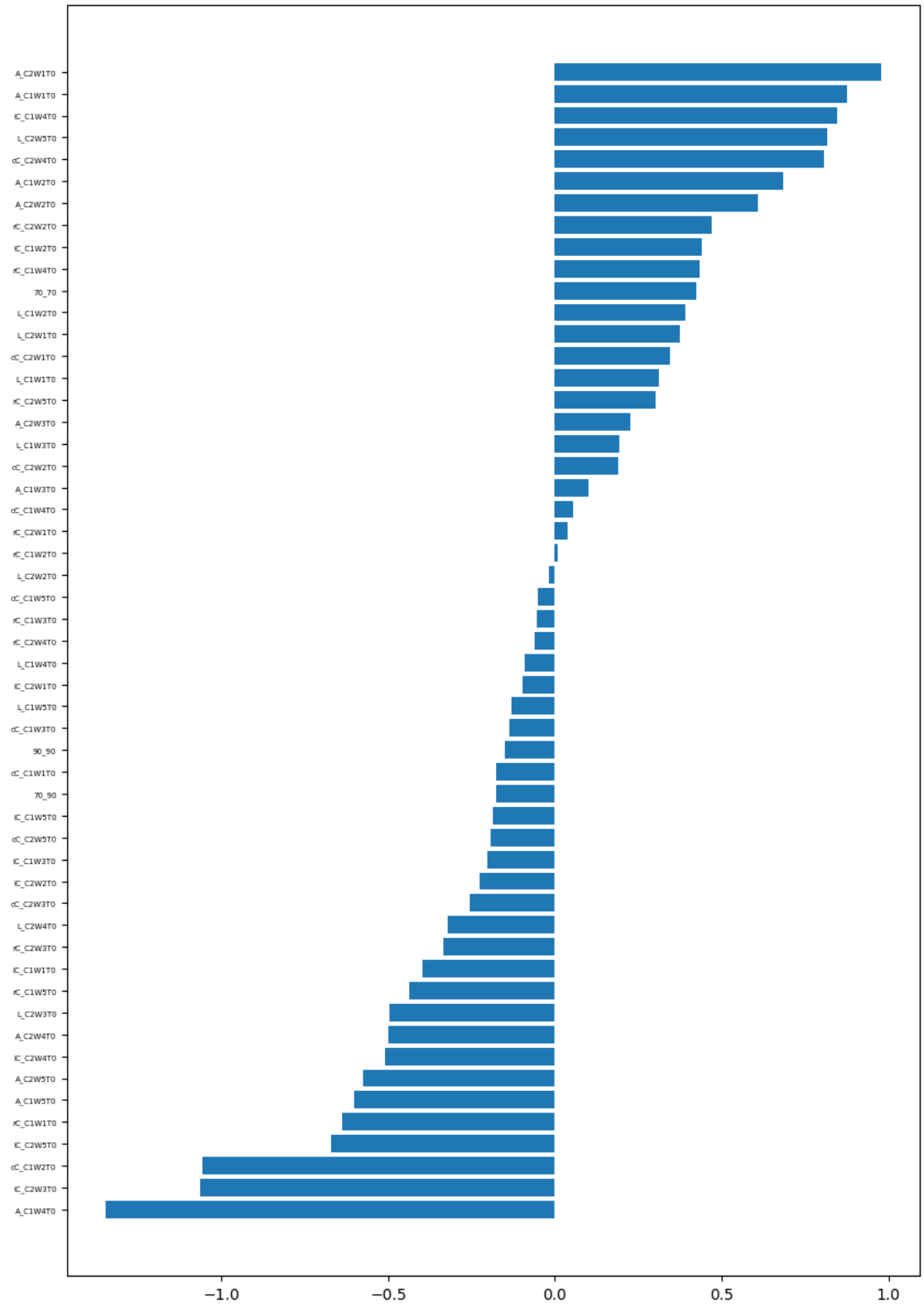
#plot the variable importances

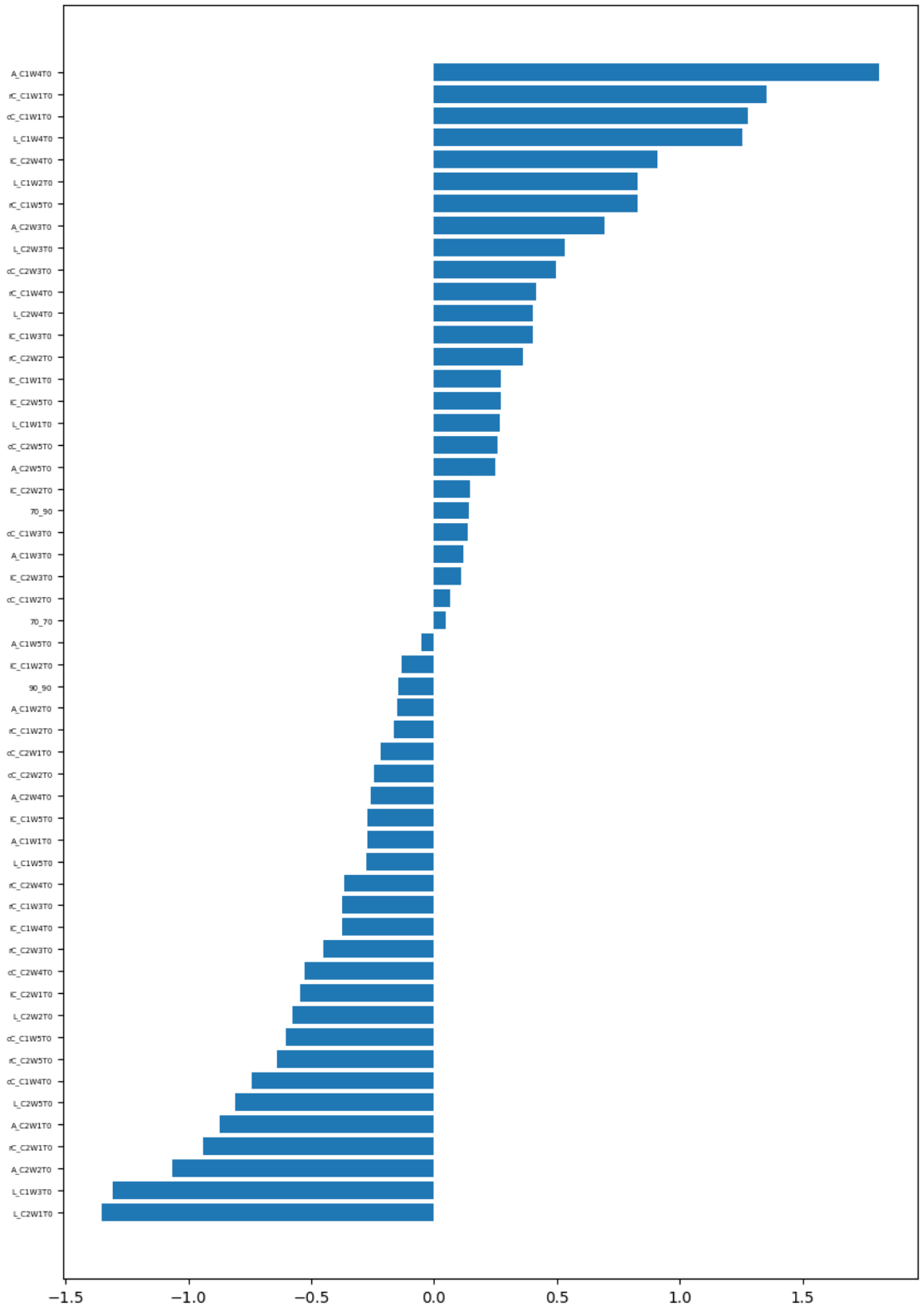
def f_importances(coef, names):
    imp = coef
    imp,names = zip(*sorted(zip(imp,names)))
    # fig, ax = plt.subplots(figsize=(10,15))
    # ax.barh(range(len(names)), imp,align = 'center')
    # ax.tick_params(axis='y', labelsize=8)
    # _ = ax.set_yticklabels(names)
    plt.figure(figsize=(10,15))
    plt.barh(range(len(names)), imp, align='center')
    plt.tick_params(axis='y', labelsize=5)
    plt.yticks(range(len(names)), names)
    plt.show()
f_importances(model.coef_[0], X_train_T0.columns)
f_importances(model.coef_[1], X_train_T0.columns)
f_importances(model.coef_[2], X_train_T0.columns)
```

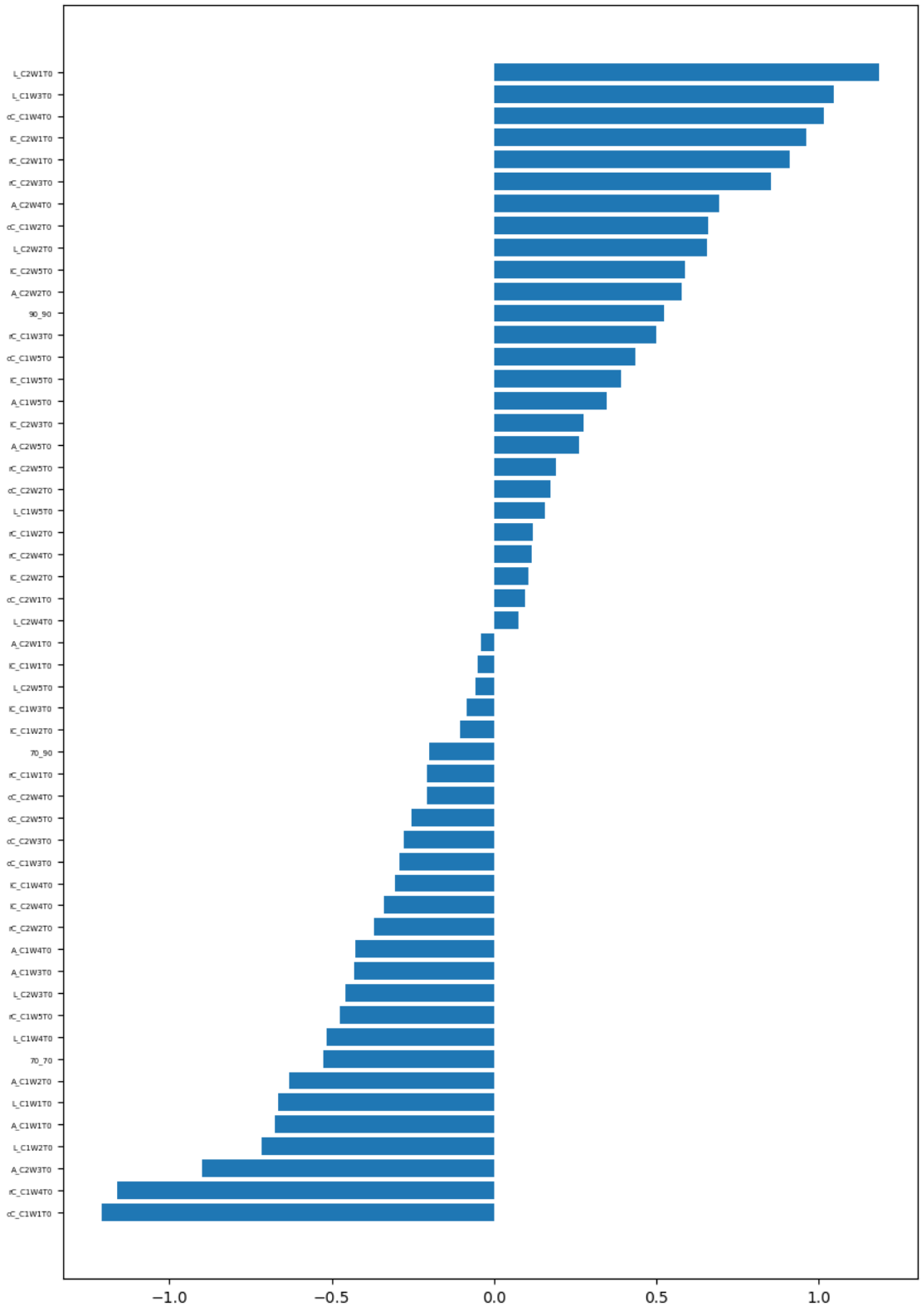
```
Accuracy on train Dataset:  0.8888888888888888
f1 score on train Dataset:  0.8876664195813133
Accuracy on test Dataset:  0.6756756756756757
f1 score on test Dataset:  0.6797082797082797
              precision    recall  f1-score   support

           0       0.40      0.50      0.44         4
           1       0.67      0.67      0.67        15
           2       0.76      0.72      0.74        18

    accuracy                           0.68        37
   macro avg       0.61      0.63      0.62        37
weighted avg       0.69      0.68      0.68        37
```


A_C2W1T0
A_C1W1T0
IC_C1W4T0
L_C2W5T0
dC_C2W4T0
A_C1W2T0
A_C2W2T0
nC_C2W2T0
IC_C1W2T0
nC_C1W4T0
70_70
L_C1W2T0
L_C2W1T0
dC_C2W1T0
L_C1W1T0
nC_C2W5T0
A_C2W3T0
L_C1W3T0
dC_C2W2T0
A_C1W3T0
dC_C1W4T0
nC_C2W1T0
nC_C1W2T0
L_C2W2T0
dC_C1W5T0
nC_C1W3T0
nC_C2W4T0
L_C1W4T0
IC_C2W1T0
L_C1W5T0
dC_C1W3T0
90_90
dC_C1W1T0
70_90
IC_C1W5T0
dC_C2W5T0
IC_C1W3T0
IC_C2W2T0
dC_C2W3T0
L_C2W4T0
nC_C2W3T0
IC_C1W1T0
nC_C1W5T0
L_C2W3T0
A_C2W4T0
IC_C2W4T0
A_C2W5T0
A_C1W5T0
nC_C1W1T0
IC_C2W5T0
dC_C1W2T0
IC_C2W3T0
A_C1W4T0
−1.0
−0.5
0.0
0.5
1.0


A_C1W4T0
nC_C1W1T0
cC_C1W1T0
L_C1W4T0
IC_C2W4T0
L_C1W2T0
nC_C1W5T0
A_C2W3T0
L_C2W3T0
cC_C2W3T0
nC_C1W4T0
L_C2W4T0
IC_C1W3T0
nC_C2W2T0
IC_C1W1T0
IC_C2W5T0
L_C1W1T0
cC_C2W5T0
A_C2W5T0
IC_C2W2T0
70_90
cC_C1W3T0
A_C1W3T0
IC_C2W3T0
cC_C1W2T0
70_70
A_C1W5T0
IC_C1W2T0
90_90
A_C1W2T0
nC_C1W2T0
cC_C2W1T0
cC_C2W2T0
A_C2W4T0
IC_C1W5T0
A_C1W1T0
L_C1W5T0
nC_C2W4T0
nC_C1W3T0
IC_C1W4T0
nC_C2W3T0
cC_C2W4T0
IC_C2W1T0
L_C2W2T0
cC_C1W5T0
nC_C2W5T0
cC_C1W4T0
L_C2W5T0
A_C2W1T0
nC_C2W1T0
A_C2W2T0
L_C1W3T0
L_C2W1T0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5


L_C2W1T0
L_C1W3T0
dC_C1W4T0
lC_C2W1T0
rC_C2W1T0
rC_C2W3T0
A_C2W4T0
dC_C1W2T0
L_C2W2T0
lC_C2W5T0
A_C2W2T0
90_90
rC_C1W3T0
dC_C1W5T0
lC_C1W5T0
A_C1W5T0
lC_C2W3T0
A_C2W5T0
rC_C2W5T0
dC_C2W2T0
L_C1W5T0
rC_C1W2T0
rC_C2W4T0
lC_C2W2T0
dC_C2W1T0
L_C2W4T0
A_C2W1T0
lC_C1W1T0
L_C2W5T0
lC_C1W3T0
lC_C1W2T0
70_90
rC_C1W1T0
dC_C2W4T0
dC_C2W5T0
dC_C2W3T0
dC_C1W3T0
lC_C1W4T0
lC_C2W4T0
rC_C2W2T0
A_C1W4T0
A_C1W3T0
L_C2W3T0
rC_C1W5T0
L_C1W4T0
70_70
A_C1W2T0
L_C1W1T0
A_C1W1T0
L_C1W2T0
A_C2W3T0
rC_C1W4T0
dC_C1W1T0
−1.0
−0.5
0.0
0.5
1.0

1 *What happens to scramble/oob some important variables shown in the previous plot?*

2 *Scramble and OOB A__C2W1T2 and compare results for XGBoost and Adaboost*

[156]:
```
X_train_scramble = pd.concat([pd.DataFrame(X_train.iloc[:,:54]).
 ↪reset_index(drop=True),pd.DataFrame(X_train['A_C2W1T2'].sample(frac=1)).
 ↪reset_index(drop=True),pd.DataFrame(X_train.iloc[:,55:]).
 ↪reset_index(drop=True)],axis=1)
X_train_oob = X_train.loc[:, X_train.columns != 'A_C2W1T2']
X_test_oob = X_test.loc[:, X_test.columns != 'A_C2W1T2']
```

2.1 XGboost for Scramble(using all other variables)

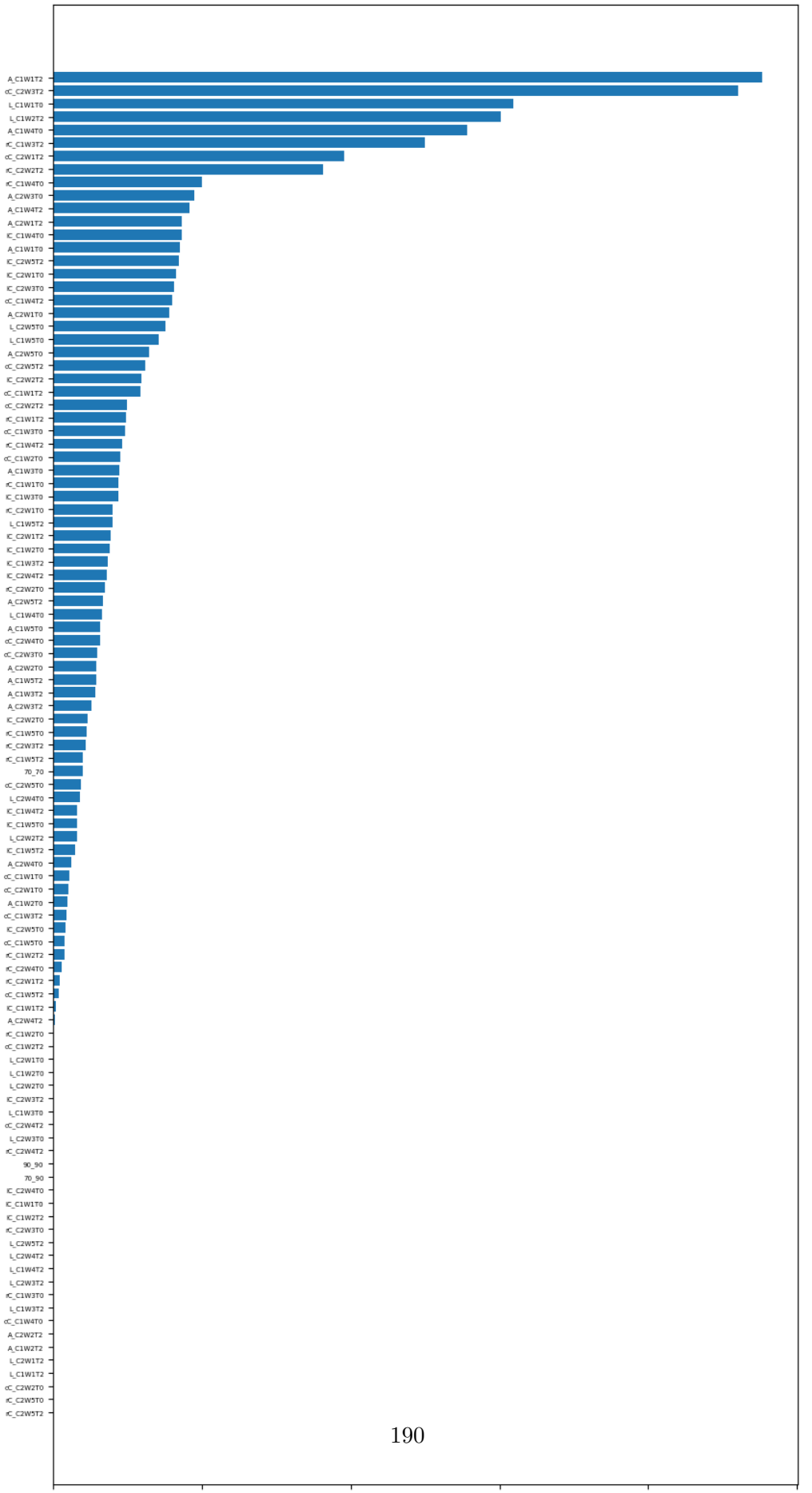
[158]:
```
model = XGBClassifier()
model.fit(X_train_scramble, y_train)
y_pred = model.predict(X_test)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_scramble)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_scramble),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_scramble.columns)[indices])
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.8918918918918919
f1 score on test Dataset:  0.8845720720720722
              precision    recall  f1-score   support

           0       1.00      0.50      0.67         4
           1       0.88      1.00      0.94        15
           2       0.89      0.89      0.89        18

    accuracy                           0.89        37
   macro avg       0.92      0.80      0.83        37
```

```
weighted avg       0.90      0.89      0.88        37
```


A_C1W1T2
dC_C2W3T2
L_C1W1T0
L_C1W2T2
A_C1W4T0
dC_C1W3T2
dC_C2W1T2
dC_C2W2T2
dC_C1W4T0
A_C2W3T0
A_C1W4T2
A_C2W1T2
IC_C1W4T0
A_C1W1T0
IC_C2W5T2
IC_C2W1T0
IC_C2W3T0
dC_C1W4T2
A_C2W1T0
L_C2W5T0
L_C1W5T0
A_C2W5T0
dC_C2W5T2
IC_C2W2T2
dC_C1W1T2
dC_C2W2T2
dC_C1W1T2
dC_C1W3T0
dC_C1W4T2
dC_C1W2T0
A_C1W3T0
dC_C1W1T0
IC_C1W3T0
dC_C2W1T0
L_C1W5T2
IC_C2W1T2
IC_C1W2T0
IC_C1W3T2
IC_C2W4T2
dC_C2W2T0
A_C2W5T2
L_C1W4T0
A_C1W5T0
dC_C2W4T0
dC_C2W3T0
A_C2W2T0
A_C1W5T2
A_C1W3T2
A_C2W3T2
IC_C2W2T0
dC_C1W5T0
dC_C2W3T2
dC_C1W5T2
70_70
dC_C2W5T0
L_C2W4T0
IC_C1W4T2
IC_C1W5T0
L_C2W2T2
IC_C1W5T2
A_C2W4T0
dC_C1W1T0
dC_C2W1T0
A_C1W2T0
dC_C1W3T2
IC_C2W5T0
dC_C1W5T0
dC_C1W2T2
dC_C2W4T0
dC_C2W1T2
dC_C1W5T2
IC_C1W1T2
A_C2W4T2
dC_C1W2T0
dC_C1W2T2
L_C2W1T0
L_C1W2T0
L_C2W2T0
IC_C2W3T2
L_C1W3T0
dC_C2W4T2
L_C2W3T0
dC_C2W4T2
90_90
70_90
IC_C2W4T0
IC_C1W1T0
IC_C1W2T2
dC_C2W3T0
L_C2W5T2
L_C2W4T2
L_C1W4T2
L_C2W3T2
dC_C1W3T0
L_C1W3T2
dC_C1W4T0
A_C2W2T2
A_C1W2T2
L_C2W1T2
L_C1W1T2
dC_C2W2T0
dC_C2W5T0
dC_C2W5T2
0.00
0.02
0.04
0.06
0.08
0.10

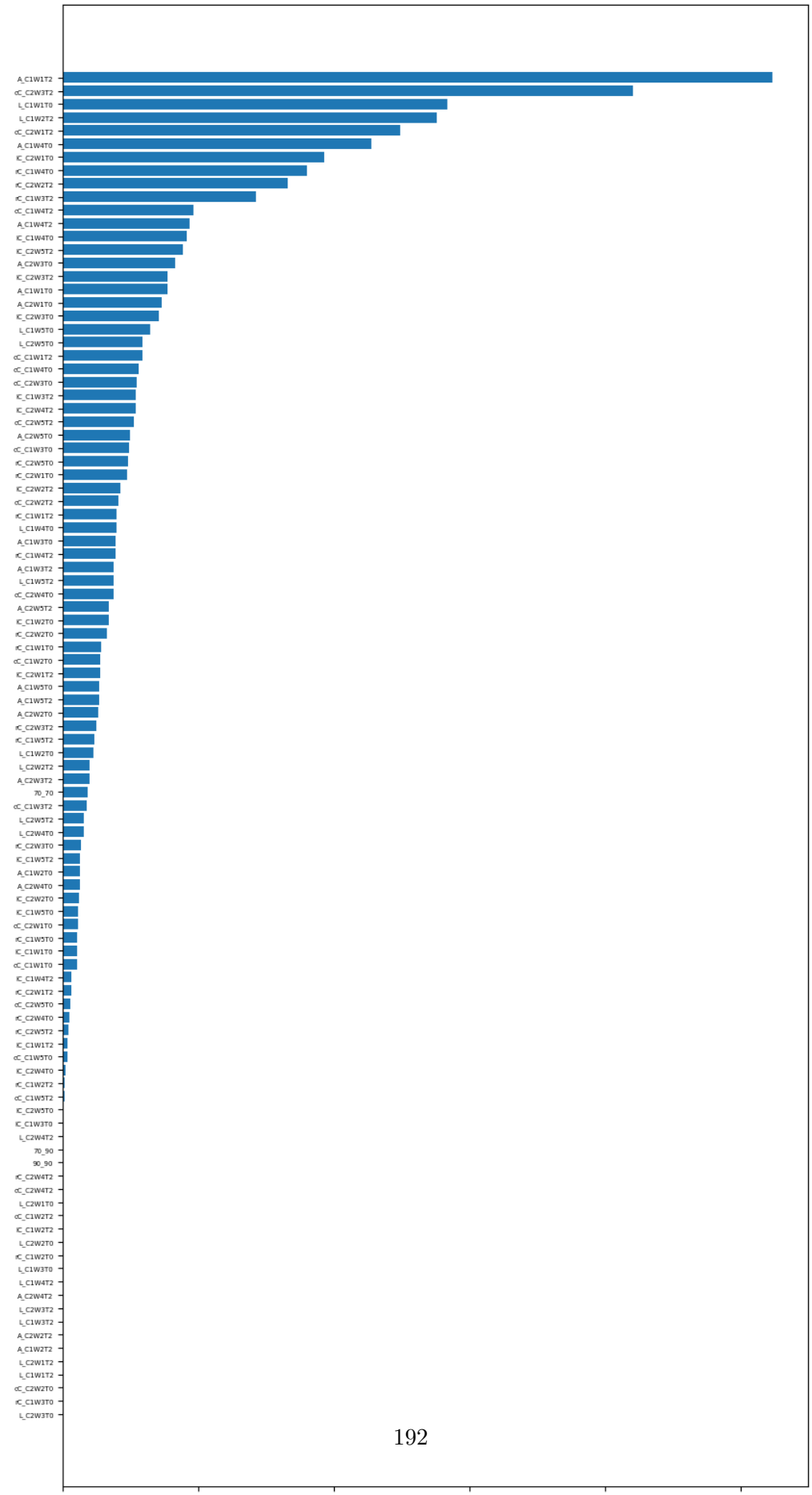
2.2 XGboost for OOB(using all other variables)

[159]:
```
model = XGBClassifier()
model.fit(X_train_oob, y_train)
y_pred = model.predict(X_test_oob)
accuracy  = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_oob)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_oob),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_oob.columns)[indices])
```

```
Accuracy on train Dataset:  1.0
f1 score on train Dataset:  1.0
Accuracy on test Dataset:  0.8918918918918919
f1 score on test Dataset:  0.8845720720720722
              precision    recall  f1-score   support

           0       1.00      0.50      0.67         4
           1       0.88      1.00      0.94        15
           2       0.89      0.89      0.89        18

    accuracy                           0.89        37
   macro avg       0.92      0.80      0.83        37
weighted avg       0.90      0.89      0.88        37
```


A_C1W1T2
cC_C2W3T2
L_C1W1T0
L_C1W2T2
cC_C2W1T2
A_C1W4T0
IC_C2W1T0
xC_C1W4T0
xC_C2W2T2
xC_C1W3T2
cC_C1W4T2
A_C1W4T2
IC_C1W4T0
IC_C2W5T2
A_C2W3T0
IC_C2W3T2
A_C1W1T0
A_C2W1T0
IC_C2W3T0
L_C1W5T0
L_C2W5T0
cC_C1W1T2
cC_C1W4T0
cC_C2W3T0
IC_C1W3T2
IC_C2W4T2
cC_C2W5T2
A_C2W5T0
cC_C1W3T0
xC_C2W5T0
xC_C2W1T0
IC_C2W2T2
cC_C2W2T2
xC_C1W1T2
L_C1W4T0
A_C1W3T0
xC_C1W4T2
A_C1W3T2
L_C1W5T2
cC_C2W4T0
A_C2W5T2
IC_C1W2T0
xC_C2W2T0
xC_C1W1T0
cC_C1W2T0
IC_C2W1T2
A_C1W5T0
A_C1W5T2
A_C2W2T0
xC_C2W3T2
xC_C1W5T2
L_C1W2T0
L_C2W2T2
A_C2W3T2
70_70
cC_C1W3T2
L_C2W5T2
L_C2W4T0
xC_C2W3T0
IC_C1W5T2
A_C1W2T0
A_C2W4T0
IC_C2W2T0
IC_C1W5T0
cC_C2W1T0
IC_C1W5T0
IC_C1W1T0
cC_C1W1T0
IC_C1W4T2
xC_C2W1T2
cC_C2W5T0
xC_C2W4T0
xC_C2W5T2
IC_C1W1T2
cC_C1W5T0
IC_C2W4T0
xC_C1W2T2
cC_C1W5T2
IC_C2W5T0
IC_C1W3T0
L_C2W4T2
70_90
90_90
xC_C2W4T2
cC_C2W4T2
L_C2W1T0
cC_C1W2T2
IC_C1W2T2
L_C2W2T0
xC_C1W2T0
L_C1W3T0
L_C1W4T2
A_C2W4T2
L_C2W3T2
L_C1W3T2
A_C2W2T2
A_C1W2T2
L_C2W1T2
L_C1W1T2
cC_C2W2T0
xC_C1W3T0
L_C2W3T0
0.00
0.02
0.04
0.06
0.08
0.10

2.3 Adaboost for Scramble(using all other variables)

[161]:
```
grid = {
    'algorithm': ["SAMME","SAMME.R"],
    'n_estimators':[10,30,50,70,100,150],
    'learning_rate':[0.5,1,1.5,2]
}
models = GridSearchCV(estimator = AdaBoostClassifier(), param_grid=grid, cv=␣
 ↪kfolds)
models.fit(X_train_scramble, y_train)
print(models.best_params_,models.best_score_)
```

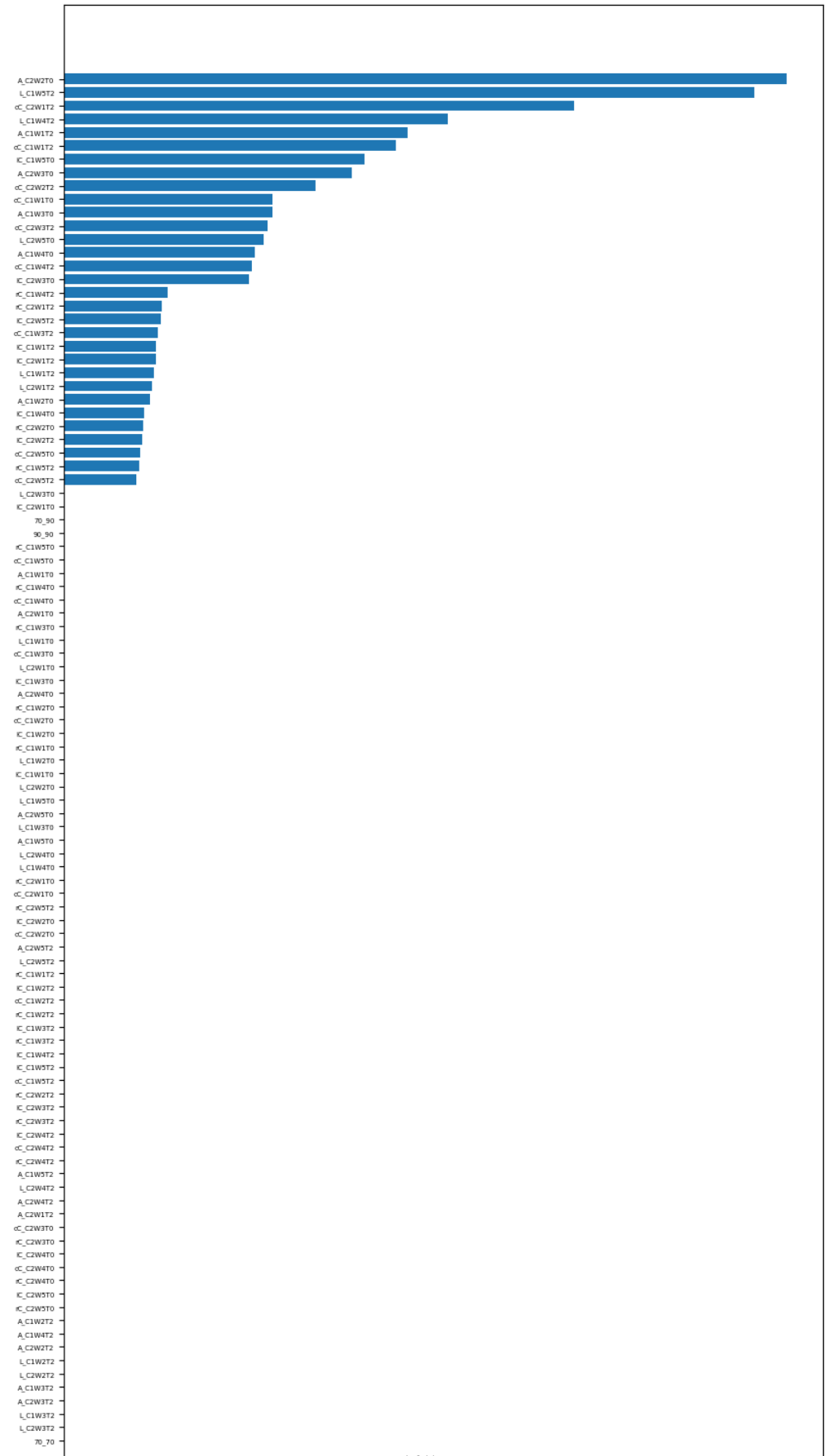
```
{'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 70}
0.8427586206896553
```

[162]:
```
model = AdaBoostClassifier(algorithm = 'SAMME', learning_rate = 1,␣
 ↪n_estimators= 70)
model.fit(X_train_scramble, y_train)
y_pred = model.predict(X_test)
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_scramble)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_scramble),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_scramble.columns)[indices])
```

```
Accuracy on train Dataset:  0.9931506849315068
f1 score on train Dataset:  0.9931550392322497
Accuracy on test Dataset:  0.9459459459459459
f1 score on test Dataset:  0.9444513638062025
              precision    recall  f1-score   support

           0       1.00      0.75      0.86         4
           1       0.94      1.00      0.97        15
           2       0.94      0.94      0.94        18
```

```
    accuracy                           0.95        37
   macro avg       0.96      0.90      0.92        37
weighted avg       0.95      0.95      0.94        37
```


A_C2W2T0
I_C1W5T2
cC_C2W1T2
I_C1W4T2
A_C1W1T2
cC_C1W1T2
IC_C1W5T0
A_C2W3T0
cC_C2W2T2
cC_C1W1T0
A_C1W3T0
cC_C2W3T2
I_C2W5T0
A_C1W4T0
cC_C1W4T2
IC_C2W3T0
iC_C1W4T2
iC_C2W1T2
IC_C2W5T2
cC_C1W3T2
IC_C1W1T2
IC_C2W1T2
I_C1W1T2
I_C2W1T2
A_C1W2T0
IC_C1W4T0
iC_C2W2T0
IC_C2W2T2
cC_C2W5T0
iC_C1W5T2
cC_C2W5T2
I_C2W3T0
IC_C2W1T0
70_90
90_90
iC_C1W5T0
cC_C1W5T0
A_C1W1T0
iC_C1W4T0
cC_C1W4T0
A_C2W1T0
iC_C1W3T0
I_C1W1T0
cC_C1W3T0
I_C2W1T0
IC_C1W3T0
A_C2W4T0
iC_C1W2T0
cC_C1W2T0
IC_C1W2T0
iC_C1W1T0
I_C1W2T0
IC_C1W1T0
I_C2W2T0
I_C1W5T0
A_C2W5T0
I_C1W3T0
A_C1W5T0
I_C2W4T0
I_C1W4T0
iC_C2W1T0
cC_C2W1T0
iC_C2W5T2
IC_C2W2T0
cC_C2W2T0
A_C2W5T2
I_C2W5T2
iC_C1W1T2
IC_C1W2T2
cC_C1W2T2
iC_C1W2T2
IC_C1W3T2
iC_C1W3T2
IC_C1W4T2
IC_C1W5T2
cC_C1W5T2
iC_C2W2T2
IC_C2W3T2
iC_C2W3T2
IC_C2W4T2
cC_C2W4T2
IC_C2W4T2
A_C1W5T2
I_C2W4T2
A_C2W4T2
A_C2W1T2
cC_C2W3T0
iC_C2W3T0
IC_C2W4T0
cC_C2W4T0
iC_C2W4T0
IC_C2W5T0
iC_C2W5T0
A_C1W2T2
A_C1W4T2
A_C2W2T2
I_C1W2T2
I_C2W2T2
A_C1W3T2
A_C2W3T2
I_C1W3T2
I_C2W3T2
70_70
0.00
0.02
0.04
0.06
0.08
0.10

2.4 Adaboost for OOB(using all other variables)

[163]:
```
grid = {
    'algorithm': ["SAMME","SAMME.R"],
    'n_estimators':[10,30,50,70,100,150],
    'learning_rate':[0.5,1,1.5,2]
}
models = GridSearchCV(estimator = AdaBoostClassifier(), param_grid=grid, cv=␣
 ↪kfolds)
models.fit(X_train_oob, y_train)
print(models.best_params_,models.best_score_)
```

```
{'algorithm': 'SAMME', 'learning_rate': 1, 'n_estimators': 70}
0.8427586206896553
```

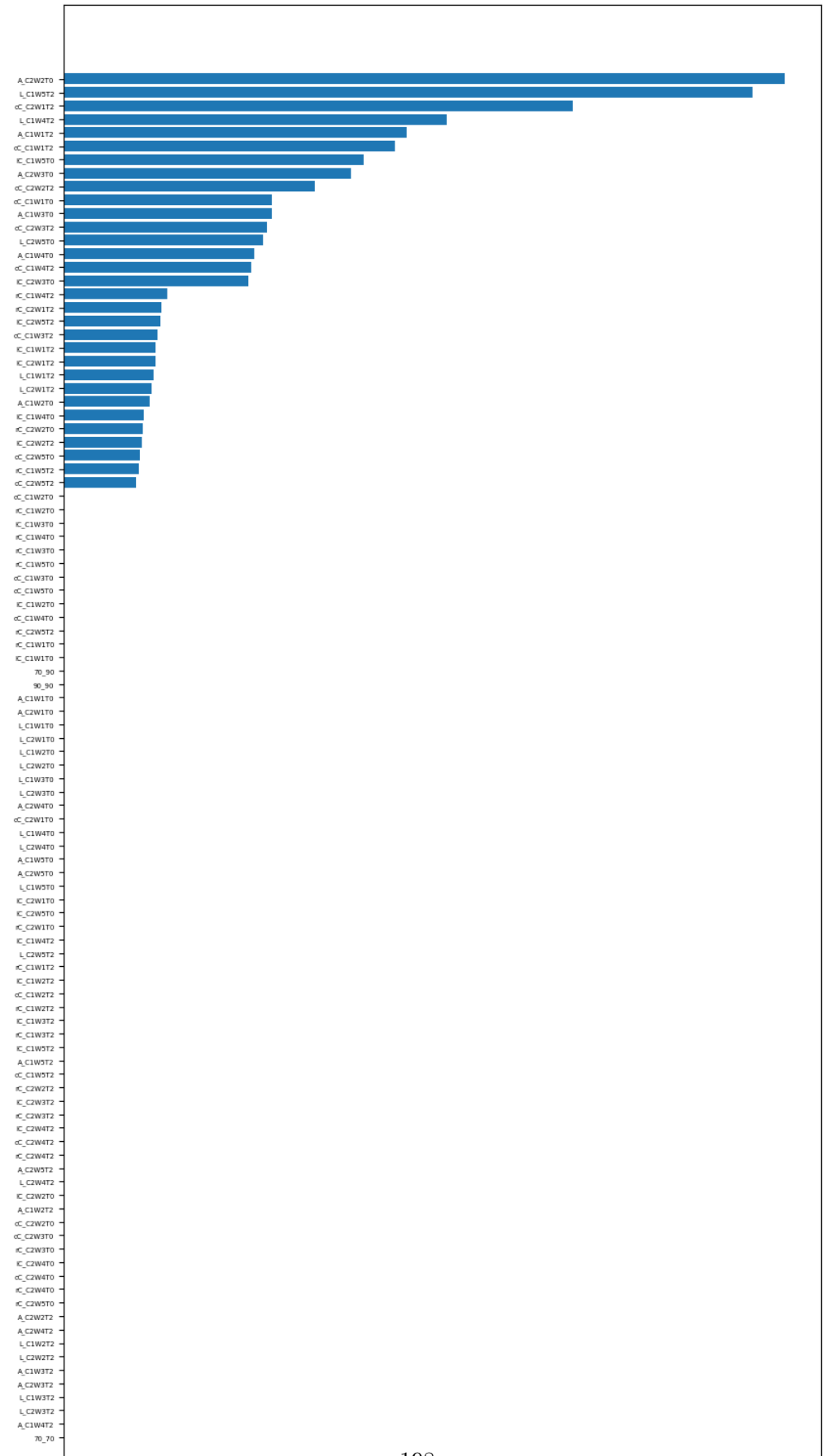
[164]:
```
model = AdaBoostClassifier(algorithm = 'SAMME', learning_rate = 1,␣
 ↪n_estimators= 70)
model.fit(X_train_oob, y_train)
y_pred = model.predict(X_test_oob)
accuracy = metrics.accuracy_score(y_test, y_pred)
f1 = metrics.f1_score(y_test,y_pred,average = 'weighted')
print("Accuracy on train Dataset: ",metrics.accuracy_score(y_train, model.
 ↪predict(X_train_oob)))
print("f1 score on train Dataset: ",metrics.f1_score(y_train, model.
 ↪predict(X_train_oob),average = 'weighted'))
print("Accuracy on test Dataset: ",accuracy)
print("f1 score on test Dataset: ",f1)
print(metrics.classification_report(y_test,y_pred))
importances = model.feature_importances_
indices = np.argsort(importances)
fig, ax = plt.subplots(figsize=(10,20))
ax.barh(range(len(importances)), importances[indices])
ax.set_yticks(range(len(importances)))
ax.tick_params(axis='y', labelsize=5)
_ = ax.set_yticklabels(np.array(X_train_oob.columns)[indices])
```

```
Accuracy on train Dataset:  0.9931506849315068
f1 score on train Dataset:  0.9931550392322497
Accuracy on test Dataset:  0.9459459459459459
f1 score on test Dataset:  0.9444513638062025
              precision    recall  f1-score   support

           0       1.00      0.75      0.86         4
           1       0.94      1.00      0.97        15
           2       0.94      0.94      0.94        18
```

```
              precision    recall  f1-score   support

    accuracy                       0.95        37
   macro avg       0.96      0.90      0.92        37
weighted avg       0.95      0.95      0.94        37
```


A_C2W2T0
L_C1W5T2
cC_C2W1T2
L_C1W4T2
A_C1W1T2
cC_C1W1T2
IC_C1W5T0
A_C2W3T0
cC_C2W2T2
cC_C1W1T0
A_C1W3T0
cC_C2W3T2
L_C2W5T0
A_C1W4T0
cC_C1W4T2
IC_C2W3T0
xC_C1W4T2
xC_C2W1T2
IC_C2W5T2
cC_C1W3T2
IC_C1W1T2
IC_C2W1T2
L_C1W1T2
L_C2W1T2
A_C1W2T0
IC_C1W4T0
xC_C2W2T0
IC_C2W2T2
cC_C2W5T0
xC_C1W5T2
cC_C2W5T2
cC_C1W2T0
xC_C1W2T0
IC_C1W3T0
xC_C1W4T0
xC_C1W3T0
xC_C1W5T0
cC_C1W3T0
cC_C1W5T0
IC_C1W2T0
cC_C1W4T0
xC_C2W5T2
xC_C1W1T0
IC_C1W1T0
70_90
90_90
A_C1W1T0
A_C2W1T0
L_C1W1T0
L_C2W1T0
L_C1W2T0
L_C2W2T0
L_C1W3T0
L_C2W3T0
A_C2W4T0
cC_C2W1T0
L_C1W4T0
L_C2W4T0
A_C1W5T0
A_C2W5T0
L_C1W5T0
IC_C2W1T0
IC_C2W5T0
xC_C2W1T0
IC_C1W4T2
L_C2W5T2
xC_C1W1T2
IC_C1W2T2
cC_C1W2T2
xC_C1W2T2
IC_C1W3T2
xC_C1W3T2
IC_C1W5T2
A_C1W5T2
cC_C1W5T2
xC_C2W2T2
IC_C2W3T2
xC_C2W3T2
IC_C2W4T2
cC_C2W4T2
xC_C2W4T2
A_C2W5T2
L_C2W4T2
IC_C2W2T0
A_C1W2T2
cC_C2W2T0
cC_C2W3T0
xC_C2W3T0
IC_C2W4T0
cC_C2W4T0
xC_C2W4T0
xC_C2W5T0
A_C2W2T2
A_C2W4T2
L_C1W2T2
L_C2W2T2
A_C1W3T2
A_C2W3T2
L_C1W3T2
L_C2W3T2
A_C1W4T2
70_70
0.00
0.02
0.04
0.06
0.08
0.10