

USER LOCALIZATION AND ACTIVITY RECOGNITION

EE4015

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PART 1 - ACTIVITY RECOGNITION

Data Description

[Dataset Generation](#)

[Dataset](#)

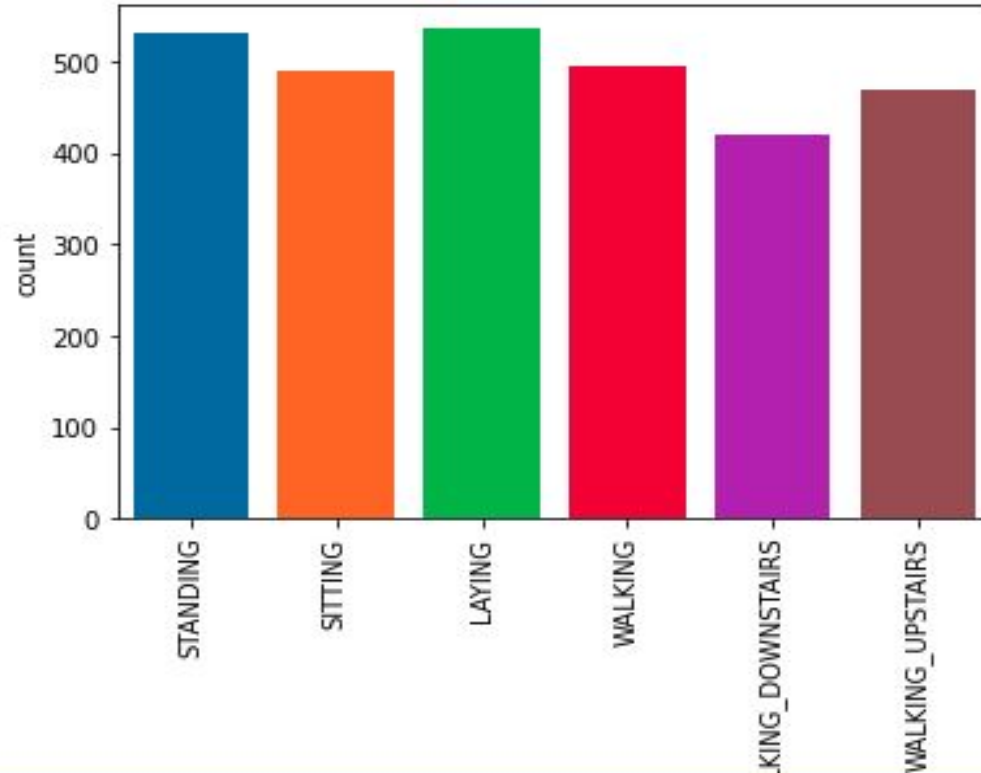
- ❖ Training data : 7352 samples, Test data: 2947 samples
- ❖ Input shape : 562 length vector mapped to 1 activity label
- ❖ Time series, multivariate data. Features come from accelerometer and gyroscope 3-axial (XYZ) raw signals.
- ❖ Time domain signals captured at 50 Hz -> filter to remove noise
- ❖ Sampled in fixed-width sliding windows of 2.56 sec and 50% overlap (128 readings/window)
- ❖ Derive acceleration values to get Jerk values.

Features extracted (for each XYZ input) in time and frequency domains

Acc
AccJerk
Gyro
GyroJerk
AccMag
AccMag
AccJerkMag
GyroMag
GyroJerkMag
mean
std

mad
max
min
energy
entropy
correlation
maxInds
meanFreq
skewness
kurtosis
bandsEnergy

Data Visualisation



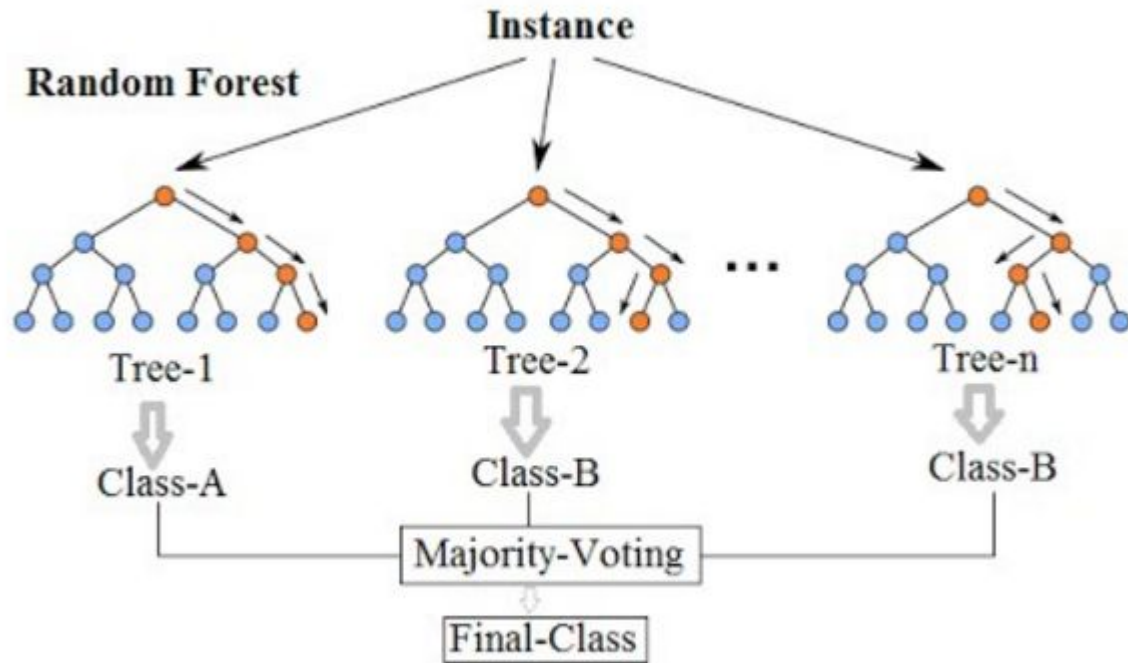
The Dataset is adequately balanced.

The problem has been solved using 3 methods using both Machine Learning and Deep Learning

1. Deep Learning - Sequential and Functional ANN
(val_acc : 94.27%)
2. Machine Learning - K Nearest Neighbours
(acc : 90.77%)
3. Machine Learning - Random Forest
(acc : 92.7%)

Particularly, this dataset is used because of its reproducibility and ease of continuing with the Indoor Localization dataset.

Random Forest



Random Forest

no.of trees:	6	accuracy:	0.8903970139124533
no.of trees:	10	accuracy:	0.9049881235154394
no.of trees:	20	accuracy:	0.9100780454699695
no.of trees:	50	accuracy:	0.9270444519850696
no.of trees:	100	accuracy:	0.9267051238547676
no.of trees:	150	accuracy:	0.9250084832032576

Confusion Matrix for 50 trees

```
print(confusion_matrix(Y_test,yhat))
```

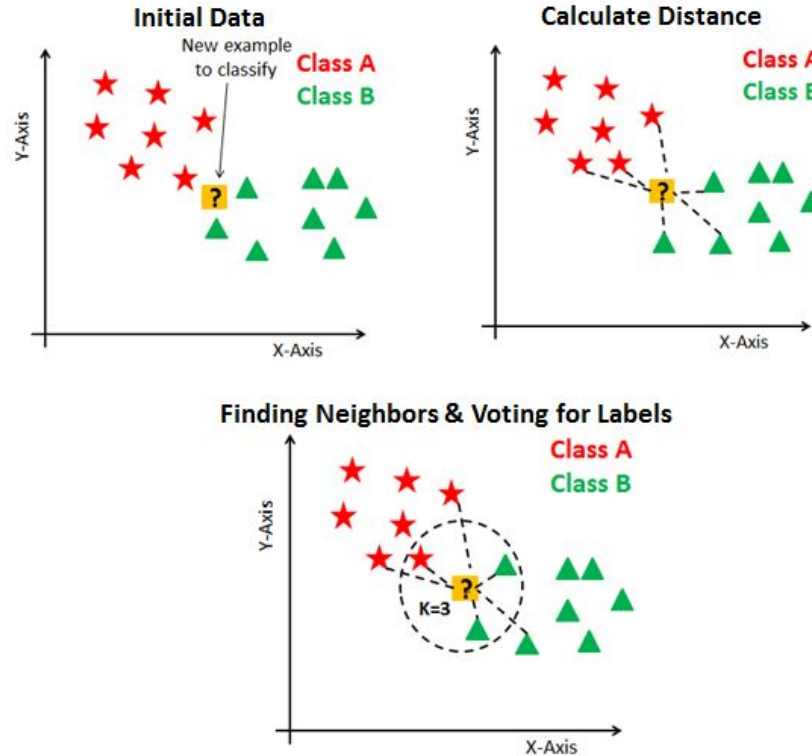
```
[[537    0    0    0    0    0]
 [   0 430   61    0    0    0]
 [   0   42 490    0    0    0]
 [   0    0    0 484    9    3]
 [   0    0    0  20 362   38]
 [   0    0    0  29    7 435]]
```

Classification Report for 50 trees

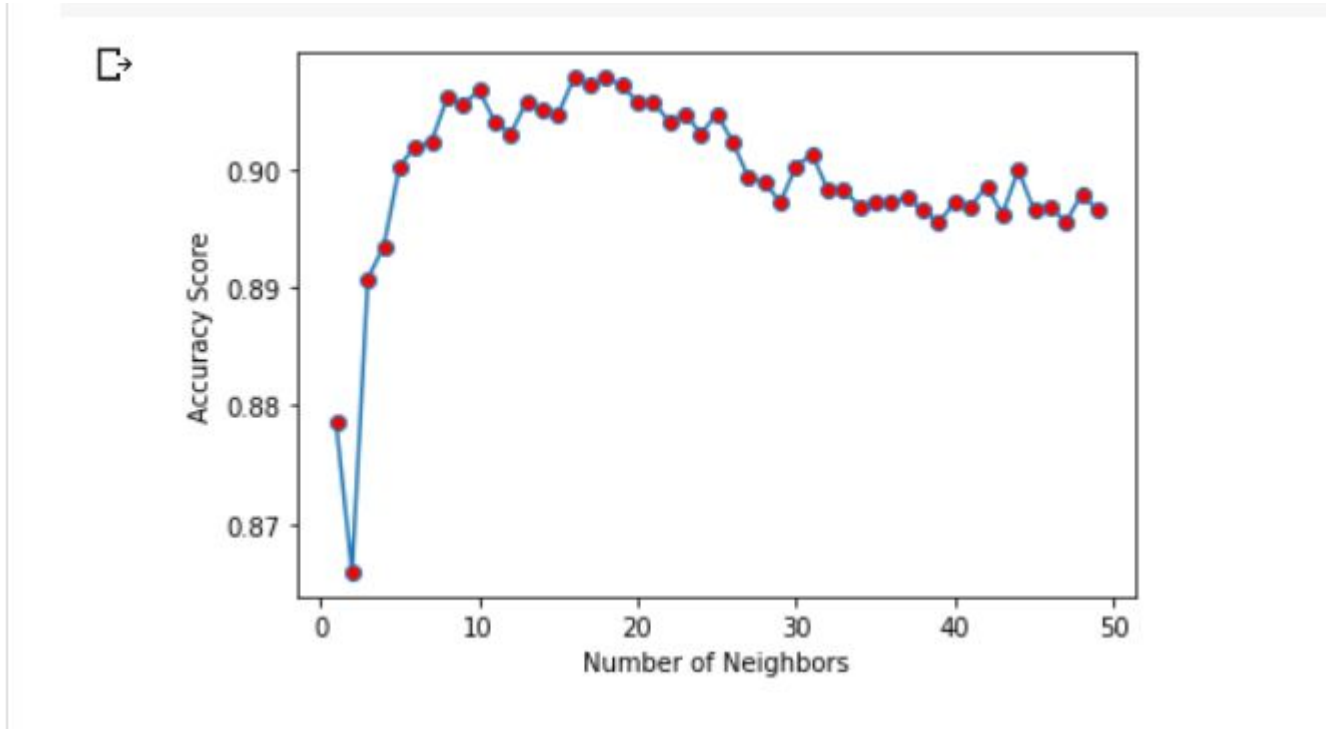
```
print(classification_report(Y_test, yhat))
```

	precision	recall	f1-score	support
0	1.00	1.00	1.00	537
1	0.91	0.88	0.89	491
2	0.89	0.92	0.90	532
3	0.91	0.98	0.94	496
4	0.96	0.86	0.91	420
5	0.91	0.92	0.92	471
accuracy			0.93	2947
macro avg	0.93	0.93	0.93	2947
weighted avg	0.93	0.93	0.93	2947

K-Nearest Neighbors algorithm



Number of neighbours(k) vs Accuracy attained



Confusion Matrix for k = 16

```
▶ print(confusion_matrix(y_test,ypred))
```

```
↳ [[535   1   1   0   0   0]
    [  0 373 114   0   0   4]
    [  0  32 500   0   0   0]
    [  0   0   0 490   6   0]
    [  0   0   0  63 315  42]
    [  0   0   0  40   2 429]]
```

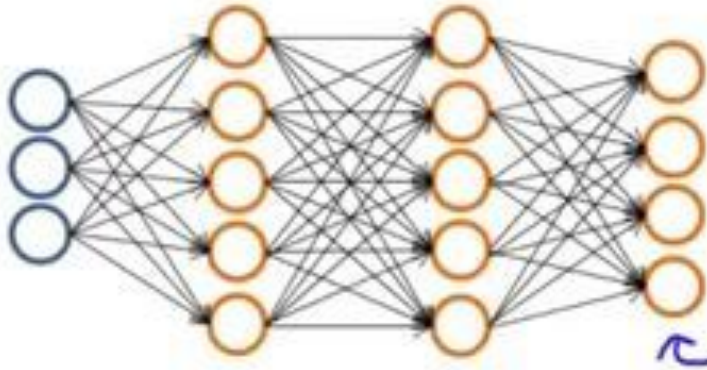
Classification Report for k = 16

```
print(classification_report(y_test,ypred))
```



	precision	recall	f1-score	support
LAYING	1.00	1.00	1.00	537
SITTING	0.92	0.76	0.83	491
STANDING	0.81	0.94	0.87	532
WALKING	0.83	0.99	0.90	496
WALKING_DOWNSTAIRS	0.98	0.75	0.85	420
WALKING_UPSTAIRS	0.90	0.91	0.91	471
accuracy			0.90	2947
macro avg	0.91	0.89	0.89	2947
weighted avg	0.90	0.90	0.90	2947

Using Deep Learning



Input Dimensions : (562,)

Output : 6 nodes (Number of output classes)

3 Hidden layers

SEQUENTIAL API

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 128)	72064
dense_1 (Dense)	(None, 64)	8256
dense_2 (Dense)	(None, 32)	2080
dropout (Dropout)	(None, 32)	0
dense_3 (Dense)	(None, 6)	198
Total params: 82,598		
Trainable params: 82,598		
Non-trainable params: 0		

```
[[1406      0      0      0      1      0]
 [      0 1188      98      0      0      0]
 [      0     12 1362      0      0      0]
 [      0      0      0 1223      3      0]
 [      0      0      0      0  986      0]
 [      0      0      3      2     34 1034]]
```

CONFUSION MATRIX

	precision	recall	f1-score	support
0	1.00	1.00	1.00	1407
1	0.99	0.92	0.96	1286
2	0.93	0.99	0.96	1374
3	1.00	1.00	1.00	1226
4	0.96	1.00	0.98	986
5	1.00	0.96	0.98	1073
accuracy			0.98	7352
macro avg	0.98	0.98	0.98	7352
weighted avg	0.98	0.98	0.98	7352

CLASSIFICATION REPORT

TRAINING SNAPSHOT - 20 EPOCHS

```
7352/7352 [=====] - 1s 128us/sample - loss: 0.0808 - acc: 0.9709 - val_loss: 0.1862 -  
val_acc: 0.9464  
Epoch 12/20  
7352/7352 [=====] - 1s 113us/sample - loss: 0.0729 - acc: 0.9761 - val_loss: 0.1574 -  
val_acc: 0.9508  
Epoch 13/20  
7352/7352 [=====] - 1s 118us/sample - loss: 0.0722 - acc: 0.9743 - val_loss: 0.1587 -  
val_acc: 0.9505  
Epoch 14/20  
7352/7352 [=====] - 1s 132us/sample - loss: 0.0659 - acc: 0.9761 - val_loss: 0.2634 -  
val_acc: 0.9301  
Epoch 15/20  
7352/7352 [=====] - 1s 134us/sample - loss: 0.0680 - acc: 0.9728 - val_loss: 0.1748 -  
val_acc: 0.9477  
Epoch 16/20  
7352/7352 [=====] - 1s 120us/sample - loss: 0.0780 - acc: 0.9716 - val_loss: 0.3395 -  
val_acc: 0.9152  
Epoch 17/20  
7352/7352 [=====] - 1s 121us/sample - loss: 0.0509 - acc: 0.9820 - val_loss: 0.1475 -  
val_acc: 0.9545  
Epoch 18/20  
7352/7352 [=====] - 1s 125us/sample - loss: 0.0718 - acc: 0.9748 - val_loss: 0.1919 -  
val_acc: 0.9464  
Epoch 19/20  
7352/7352 [=====] - 1s 121us/sample - loss: 0.0495 - acc: 0.9841 - val_loss: 0.2981 -  
val_acc: 0.9308  
Epoch 20/20  
7352/7352 [=====] - 1s 125us/sample - loss: 0.0574 - acc: 0.9770 - val_loss: 0.2558 -  
val_acc: 0.9427
```

FUNCTIONAL API

Model: "model"

Layer (type)	Output Shape	Param #
input_2 (InputLayer)	[(None, 562)]	0
dense_4 (Dense)	(None, 128)	72064
dense_5 (Dense)	(None, 64)	8256
dense_6 (Dense)	(None, 32)	2080
dense_7 (Dense)	(None, 6)	198

Total params: 82,598
Trainable params: 82,598
Non-trainable params: 0

```
[[537    0    0    0    0    0]
 [   0 438   51    0    0    2]
 [   0   14 518    0    0    0]
 [   0    0    0 482    6    8]
 [   0    0    0   6 382   32]
 [   0    0    0  10    1 460]]
```

CONFUSION MATRIX

	precision	recall	f1-score	support
0	1.00	1.00	1.00	537
1	0.97	0.89	0.93	491
2	0.91	0.97	0.94	532
3	0.97	0.97	0.97	496
4	0.98	0.91	0.94	420
5	0.92	0.98	0.95	471
accuracy			0.96	2947
macro avg	0.96	0.95	0.95	2947
weighted avg	0.96	0.96	0.96	2947

CLASSIFICATION REPORT

PART 2 - INDOOR LOCALIZATION

INDOOR LOCALIZATION

[Dataset](#)

Columns 1-520 : Received Signal Strength Indicator of 520 WiFi sources : 0 to -104 (increasing order of strength) : 100 for no signal

Longitude : Longitude of position

Latitude : Latitude of position

Floor : Indicative values 0 to 4. Each building has different number of floors.

Building ID : Indicative values 0 to 2. 3 buildings in total

Space ID : Relative Position

User ID, Phone ID, Timestamp

	WAP001	WAP002	WAP003	WAP004	WAP005	WAP006	WAP007	WAP008	WAP009	WAP010	...	WAP520
0	100	100	100	100	100	100	100	100	100	100	...	100
1	100	100	100	100	100	100	100	100	100	100	...	100
2	100	100	100	100	100	100	100	-97	100	100	...	100
3	100	100	100	100	100	100	100	100	100	100	...	100
4	100	100	100	100	100	100	100	100	100	100	...	100
...
19932	100	100	100	100	100	100	100	100	100	100	...	100
19933	100	100	100	100	100	100	100	100	100	100	...	100
19934	100	100	100	100	100	100	100	100	100	100	...	100
19935	100	100	100	100	100	100	100	100	100	100	...	100
19936	100	100	100	100	100	100	100	100	100	100	...	100

19937 rows × 529 columns

WAP009	WAP010	...	WAP520	LONGITUDE	LATITUDE	FLOOR	BUILDINGID	SPACEID	RELATIVEPOSITION	USERID	PHONEID	TIMESTAMP
100	100	...	100	-7541.2643	4.864921e+06	2	1	106	2	2	23	1371713733
100	100	...	100	-7536.6212	4.864934e+06	2	1	106	2	2	23	1371713691
100	100	...	100	-7519.1524	4.864950e+06	2	1	103	2	2	23	1371714095
100	100	...	100	-7524.5704	4.864934e+06	2	1	102	2	2	23	1371713807
100	100	...	100	-7632.1436	4.864982e+06	0	0	122	2	11	13	1369909710
...
100	100	...	100	-7485.4686	4.864875e+06	3	1	1	2	18	10	1371710683
100	100	...	100	-7390.6206	4.864836e+06	1	2	140	2	18	10	1371710402
100	100	...	100	-7516.8415	4.864889e+06	3	1	13	2	18	10	1371710921
100	100	...	100	-7537.3219	4.864896e+06	3	1	113	2	18	10	1371711049
100	100	...	100	-7536.1658	4.864898e+06	3	1	112	2	18	10	1371711025

USING DEEP LEARNING

1. The problem is a case of Multi-Label Classification.
2. Solution : Identify Building ID, Floor ID, Longitude and Latitude as separate labels or together
3. Can be identified individually/ together as a unique position.

Data Preprocessing -

Scaling RSSI values from **-104 to 0 TO 0 to 105**

Normalising Scaled values for columns 1-520

};

AP008	WAP009	WAP010	...	LONGITUDE	LATITUDE	FLOOR	BUILDINGID	SPACEID	RELATIVEPOSITION	USERID	PHONEID	TIMESTAMP	NEWID
.00000	0.0	0.0	...	-7541.2643	4.864921e+06	2	1	106	2	2	23	1371713733	1151
.00000	0.0	0.0	...	-7536.6212	4.864934e+06	2	1	106	2	2	23	1371713691	1126
.07619	0.0	0.0	...	-7519.1524	4.864950e+06	2	1	103	2	2	23	1371714095	1036
.00000	0.0	0.0	...	-7524.5704	4.864934e+06	2	1	102	2	2	23	1371713807	1067
.00000	0.0	0.0	...	-7632.1436	4.864982e+06	0	0	122	2	11	13	1369909710	1445
...
.00000	0.0	0.0	...	-7485.4686	4.864875e+06	3	1	1	2	18	10	1371710683	915
.00000	0.0	0.0	...	-7390.6206	4.864836e+06	1	2	140	2	18	10	1371710402	550
.00000	0.0	0.0	...	-7516.8415	4.864889e+06	3	1	13	2	18	10	1371710921	1027
.00000	0.0	0.0	...	-7537.3219	4.864896e+06	3	1	113	2	18	10	1371711049	1134
.00000	0.0	0.0	...	-7536.1658	4.864898e+06	3	1	112	2	18	10	1371711025	1118

1996 unique locations were obtained

RESULTS

Hyperparameters :

Hidden layers - 3

Epochs - 150

Dropout - 0.2

Batch size - 6

Output Neurons - 1996 (No of NEWIDs)

Results :

Training accuracy - 95.8%

Validation accuracy - 79.5%

TRAINING SET - 80% of train data set

VALIDATION SET - 20% of train data set

TEST SET - Test data set

TRAINING SNAPSHOT - 150 EPOCHS

⬆	⬇	▶ Run	■	↺	▶▶	Code	⌵	⌵
Epoch 136/150	15949/15949	[=====]	-	3s 214us/step	-	loss: 0.1852	-	categorical_accuracy: 0.9530
Epoch 137/150	15949/15949	[=====]	-	4s 221us/step	-	loss: 0.1862	-	categorical_accuracy: 0.9503
Epoch 138/150	15949/15949	[=====]	-	4s 243us/step	-	loss: 0.1841	-	categorical_accuracy: 0.9513
Epoch 139/150	15949/15949	[=====]	-	4s 221us/step	-	loss: 0.1823	-	categorical_accuracy: 0.9528
Epoch 140/150	15949/15949	[=====]	-	4s 222us/step	-	loss: 0.1819	-	categorical_accuracy: 0.9525
Epoch 141/150	15949/15949	[=====]	-	4s 243us/step	-	loss: 0.1796	-	categorical_accuracy: 0.9522
Epoch 142/150	15949/15949	[=====]	-	4s 253us/step	-	loss: 0.1813	-	categorical_accuracy: 0.9523
Epoch 143/150	15949/15949	[=====]	-	4s 253us/step	-	loss: 0.1784	-	categorical_accuracy: 0.9525
Epoch 144/150	15949/15949	[=====]	-	4s 244us/step	-	loss: 0.1776	-	categorical_accuracy: 0.9539
Epoch 145/150	15949/15949	[=====]	-	4s 223us/step	-	loss: 0.1773	-	categorical_accuracy: 0.9529
Epoch 146/150	15949/15949	[=====]	-	3s 217us/step	-	loss: 0.1773	-	categorical_accuracy: 0.9527
Epoch 147/150	15949/15949	[=====]	-	3s 217us/step	-	loss: 0.1743	-	categorical_accuracy: 0.9544
Epoch 148/150	15949/15949	[=====]	-	3s 214us/step	-	loss: 0.1751	-	categorical_accuracy: 0.9532
Epoch 149/150	15949/15949	[=====]	-	3s 218us/step	-	loss: 0.1738	-	categorical_accuracy: 0.9539
Epoch 150/150	15949/15949	[=====]	-	4s 223us/step	-	loss: 0.1722	-	categorical_accuracy: 0.9535
	15949/15949	[=====]	-	3s 203us/step				
3988/3988	[=====]	-	2s 592us/step					

Random Forest Regressor

Preprocessing: Values to start from 0 - subtract minimum value from all

Before: min:-7632.143599998206 ; max: -7300.818990092725

After : min: 0.0 ;max: 331.32460990548134

Results

===== LONGITUDE =====

MAE: 1.641792703790993

===== LATITUDE =====

MAE: 1.240997795678485

Random Forest Classifier

===== FLOOR =====				
	precision	recall	f1-score	support
-99.0	1.00	1.00	1.00	5002
-98.0	1.00	1.00	1.00	4416
-97.0	0.99	1.00	1.00	5048
-96.0	1.00	1.00	1.00	1102
105.0	1.00	0.99	1.00	4369
accuracy			1.00	19937
macro avg	1.00	1.00	1.00	19937
weighted avg	1.00	1.00	1.00	19937

```
[[5001  0  1  0  0]
 [  0 4415  1  0  0]
 [  0  0 5048  0  0]
 [  0  0  0 1102  0]
 [  0  0  37  0 4332]]
Accuracy: 0.9980438380899834
```

===== BUILDINGID =====				
	precision	recall	f1-score	support
-99.0	1.00	0.99	1.00	5196
-98.0	1.00	1.00	1.00	9492
105.0	1.00	1.00	1.00	5249
accuracy			1.00	19937
macro avg	1.00	1.00	1.00	19937
weighted avg	1.00	1.00	1.00	19937

```
[[5159  37  0]
 [  0 9492  0]
 [  0  1 5248]]
Accuracy: 0.9980939960876761
```

Random Forest Classifier

```

===== SPACEID =====
      precision    recall  f1-score   support

154.0          1.00      1.00      1.00         10

   accuracy
 macro avg          0.97      0.96      0.96    19937
weighted avg          0.98      0.97      0.98    19937

[[65  0  0 ...  0  0  0]
 [ 0 80  0 ...  0  0  0]
 [ 1  0 82 ...  0  0  0]
 ...
 [ 0  0  0 ... 20  0  0]
 [ 0  0  0 ...  0 20  0]
 [ 0  0  0 ...  0  0 10]]
Accuracy: 0.9695540954005116

===== RELATIVEPOSITION =====
      precision    recall  f1-score   support

-99.0          1.00      0.99      0.99     3329
-98.0          1.00      1.00      1.00    16608

   accuracy
 macro avg          1.00      0.99      1.00    19937
weighted avg          1.00      1.00      1.00    19937

[[ 3283    46]
 [    2 16606]]
Accuracy: 0.9975924161107489

```

K Nearest Neighbors Regression

```
↳ ===== LONGITUDE =====  
Score 0.9963894264614553  
===== LATITUDE =====  
Score 0.9939766852066294
```

K-Nearest Neighbors

```

===== FLOOR =====
precision  recall  f1-score  support

-99.0      1.00    1.00    1.00    5002
-98.0      1.00    1.00    1.00    4416
-97.0      1.00    0.99    1.00    5048
-96.0      1.00    1.00    1.00    1102
105.0      0.99    1.00    1.00    4369

accuracy                    1.00    19937
macro avg      1.00    1.00    1.00    19937
weighted avg   1.00    1.00    1.00    19937

```

```

[[5001  0  0  0  1]
 [  0 4415  0  0  1]
 [  0  0 5011  0 37]
 [  0  0  0 1102  0]
 [  0  0  0  0 4369]]
Accuracy: 0.9980438380899834

```

```

===== BUILDINGID =====
precision  recall  f1-score  support

-99.0      1.00    0.99    1.00    5196
-98.0      1.00    1.00    1.00    9492
105.0      1.00    1.00    1.00    5249

accuracy                    1.00    19937
macro avg      1.00    1.00    1.00    19937
weighted avg   1.00    1.00    1.00    19937

```

```

[[5159 37  0]
 [  0 9492  0]
 [  0  1 5248]]
Accuracy: 0.9980939960876761

```

```

===== SPACEID =====
      precision    recall  f1-score   support

   -99.0         0.98        1.00        0.99         65
   -98.0         1.00        1.00        1.00         80
    153.0         1.00        1.00        1.00         20
    154.0         1.00        1.00        1.00         10

 accuracy          0.97          0.97          0.97        19937
 macro avg         0.97          0.95          0.95        19937
 weighted avg      0.98          0.97          0.97        19937

```

```

[[65  0  0 ...  0  0  0]
 [ 0 80  0 ...  0  0  0]
 [ 1  0 80 ...  0  0  0]
 ...
 [ 0  0  0 ... 20  0  0]
 [ 0  0  0 ...  0 20  0]
 [ 0  0  0 ...  0  0 10]]

```

Accuracy: 0.9681998294628078

```

/usr/local/lib/python3.6/dist-packages/sklearn/metrics/_classification.py:1272
_warn_prf(average, modifier, msg_start, len(result))

```

```

===== RELATIVEPOSITION =====
      precision    recall  f1-score   support

   -99.0         0.99        0.99        0.99        3329
   -98.0         1.00        1.00        1.00       16608

 accuracy          1.00          1.00          1.00        19937
 macro avg         0.99          0.99          0.99        19937
 weighted avg      1.00          1.00          1.00        19937

```

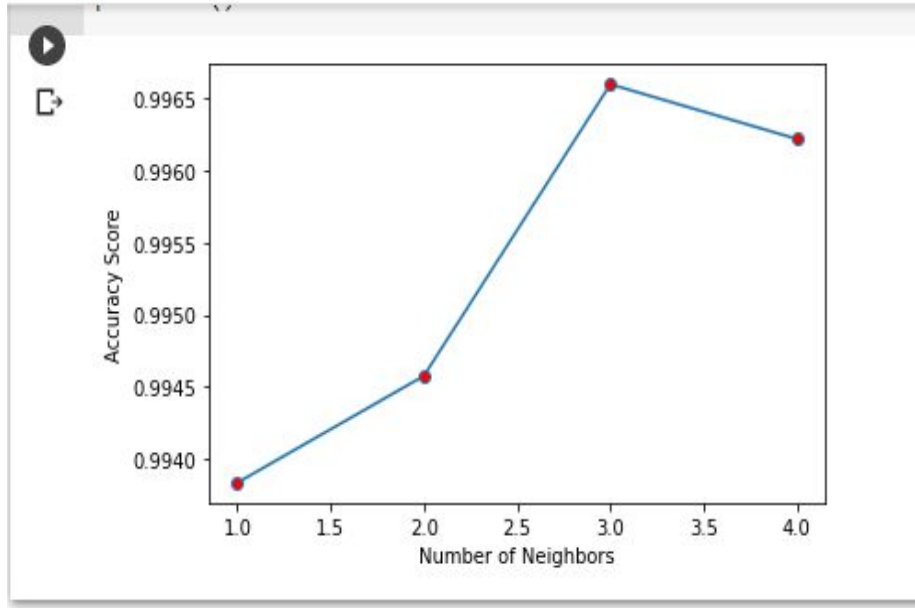
```

[[ 3294   35]
 [   41 16567]]
Accuracy: 0.9961879921753524

```


Number of neighbours(k) vs Accuracy attained

For Regression:



THANK YOU