Machine Learning Approach for Multipath Classification of NavIC Signals

ASHISH KUMAR SHUKLA

Indian Space Research Organization (ISRO)

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Multipath in urban and obstructed Environment

Multipath is the reception of multiple signal replicas, which might corrupt GNSS measurements.

Problem

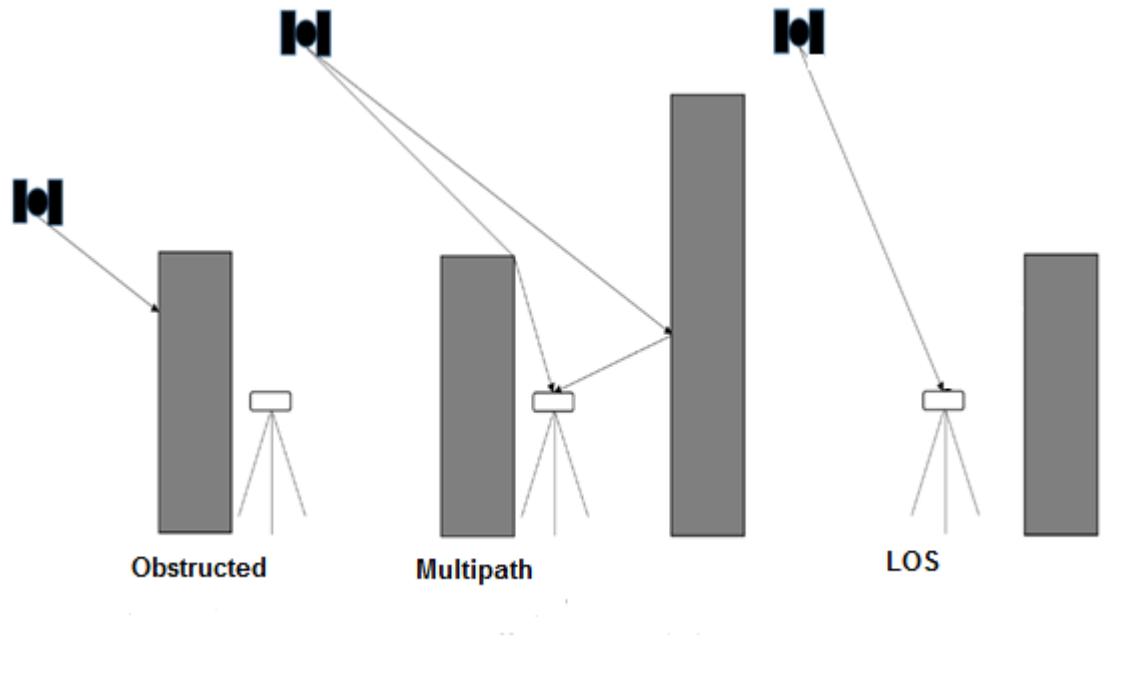
It can lead to large position errors that might create hazardous situations in Safety-of-Life and various other applications

Goal

To find a suitable technique to detect the presence of Line Of Sight (LOS), multipath and Non Line Of Sight (NLOS) signals in multipath prone environment

Motivation

Many GNSS applications need an accurate and robust position information.



LOS, Multipath and NLOS Signals

- Multipath is a major challenge experienced by GNSS receivers especially in urban environment.
- Furthermore, multipath in NavIC due to its GEO and GSO orbits is of great interest.
- Therefore, it is essential to equip GNSS receivers with algorithms that can detect and classify multipath for accurate and reliable position computation.

Machine Learning Approach

Step-1
- Generate Labels using Unsupervised Learning approach for Classification of NavIC Multipath

Step-2
- Use the generated labels in supervised learning models

Step-3
- Classification of LOS, Multipath and NLOS Signals

Step-4
- Deep Leaning models for NavIC GEO/GSO Signals as future activity

Multipath Classification Approach: Code Minus Carrier (CMC)

- Code Minus Carrier (CMC) based approach is considered for multipath classification in this work.
- Code-Phase or pseudo-range measurements are more prone to multipath which is usually in meter level.
- On the other hand, carrier-range measurements are very precise and experience very less multipath.

Code Minus Carrier (CMC) Contd…

- Equations for Code ($\boldsymbol{\rho}$)and Carrier Phase (∅) observables are as follows:

$$\boldsymbol{\rho} = [\boldsymbol{r} + \boldsymbol{I} + \boldsymbol{T}] + \boldsymbol{c}(\boldsymbol{\delta t_u} - \boldsymbol{\delta t^s}) + \boldsymbol{MP} + \boldsymbol{\varepsilon_\rho}$$

$$\emptyset = \boldsymbol{\lambda^{-1}}[\boldsymbol{r} - \boldsymbol{I} + \boldsymbol{T}] + \boldsymbol{f}(\boldsymbol{\delta t_u} - \boldsymbol{\delta t^s}) + \boldsymbol{N} + \boldsymbol{MP} + \boldsymbol{\varepsilon_\emptyset}$$

$$\boldsymbol{\rho} - \emptyset = \boldsymbol{CMC} = \boldsymbol{\rho}\text{-}\emptyset = \mathbf{2I} + \mathbf{N} + \mathbf{MP} + (\boldsymbol{\varepsilon_\rho} - \boldsymbol{\varepsilon_\emptyset})$$

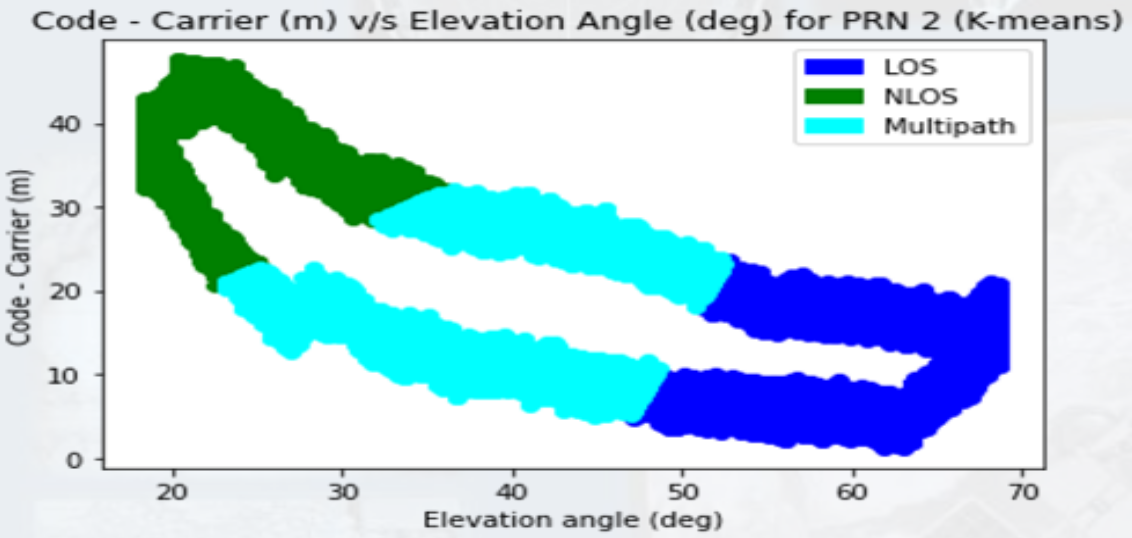
- Code Minus Carrier (CMC) after subtracting 2 times ionosphere delay is obtained as follows assuming N will remain constant throughout:

$$\boldsymbol{\rho} - \emptyset = \boldsymbol{CMC} = \boldsymbol{\rho}\text{-}\emptyset = \mathbf{MP} + (\boldsymbol{\varepsilon_\rho} - \boldsymbol{\varepsilon_\emptyset})$$

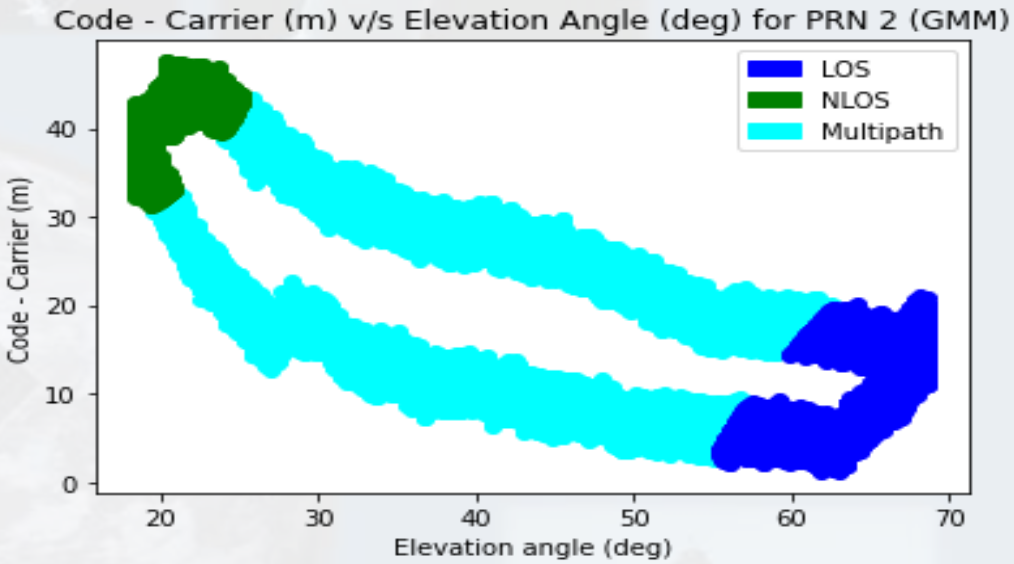
Unsupervised Machine Learning: Clustering Algorithms

- In the absence of label data for machine learning, unsupervised machine learning was a natural choice since it can do classification purely on the basis of raw data using clustering algorithms.
- Therefore, we implemented here various unsupervised machine learning algorithm and compared their results using '**Silhouette Score**' as a metric.
- Following clustering algorithms were considered in this work:
  - ✓K-Means Clustering
  - ✓Gaussian Mixture Model
  - ✓Balanced Iterative Reducing and Clustering Using Hierarchies (BIRCH)
  - ✓Mini Batch K-Means

Results of Multipath Classification using candidate Algorithms for NavIC PRN 2



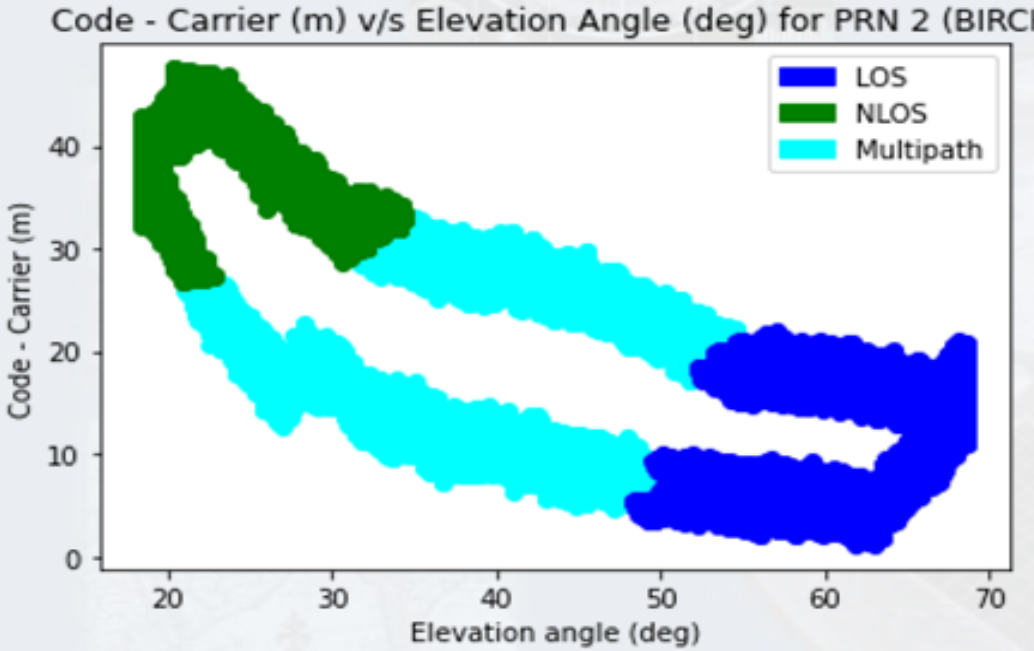
Clustering using K-Means for NavIC PRN 2



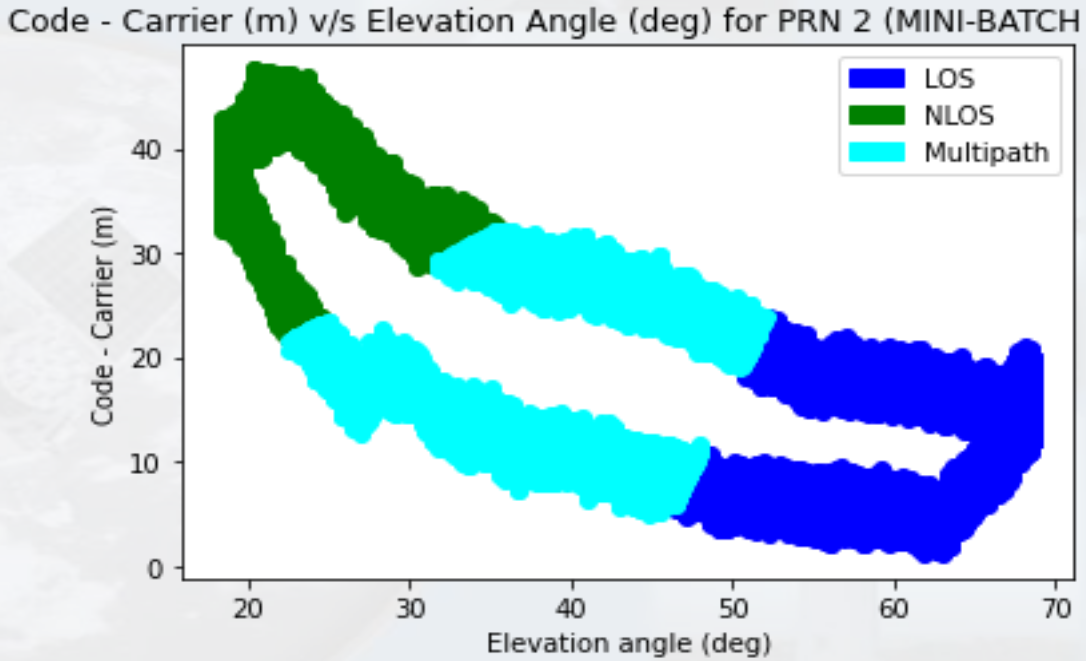
Clustering using GMM for NavIC PRN 2

The cluster formed on the left most side (shown in green) where the angle of elevation is low is NLOS signal, the cluster formed in the middle is multipath signal and the cluster on the right most side (shown in dark blue) of the graph is the LOS signal.

Results of Multipath Classification ….contd.



Clustering using BIRCH for NavIC PRN 2



Clustering using Mini Batch K-Means for NavIC PRN 2

Results of Unsupervised Machine Learning Approach

Conclusion

- Code Minus Carrier and Elevation angle are more consistent metrics for NavIC multipath classification.
- Out of the all the candidate algorithms, Mini Batch K-Means gives the best performance based on Silthouete score.

Supervised machine learning algorithms has also been attempted for NavIC multipath classification using labels generated from unsupervised learning.

Silhouette Score for all algorithms

Satellite Number	2	3	4	5	6	7
K-Means	0.5379	0.5712	0.6407	0.5735	0.5679	0.6228
GMM	0.3568	0.3272	0.5232	0.5378	0.3130	0.3890
BIRCH	0.4575	0.5621	0.6382	0.5632	0.5199	0.6122
Mini Batch K-Means	0.5382	0.5713	0.6390	0.5770	0.5703	0.6300

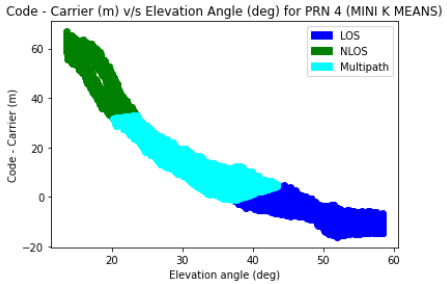
Silhouette Score = (a-b)/max(a,b)

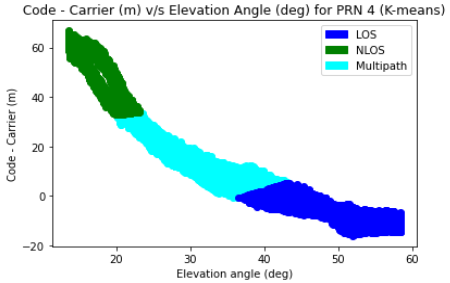
Where a = intra cluster distance i.e the average distance between each point within a cluster.

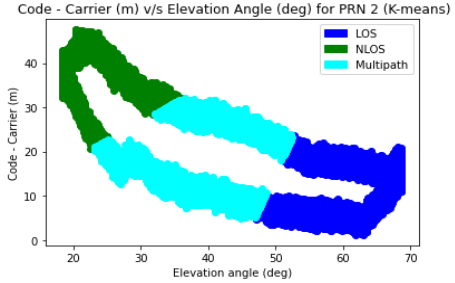
And b = inter cluster distance i.e the average distance between all clusters.

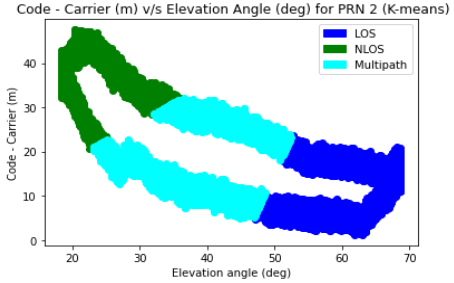
Approach & Results of Supervised Machine Learning

Acquisition of data from L5 frequency receiver for GSO AND GEO Satellites → Data preprocessing and feature selection → Prinicpal Component Analysis (PCA) for dimensionality reduction in GSO Satellites → Clustering in Elevation angle v/s Code minus carrier plot for obtaining LOS, NLOS, mulipath lables → Training of supervised learning and Deep learning models on the obtained labels









PRN-2 Supervised Learning Models

MODELS TRAINED ON KMEANS LABELS		MODELS TRAINED ON MINI BATCH KMEANS LABELS	
Model	Testing Accuracy (%)	Model	Testing Accuracy (%)
SVM	99.98	SVM	99.97
DT	99.83	DT	99.89
RF	99.91	RF	99.93

PRN-4 Supervised Learning Models

MODELS TRAINED ON KMEANS LABELS		MODELS TRAINED ON MINI BATCH KMEANS LABELS	
Model	Testing Accuracy (%)	Model	Testing Accuracy (%)
SVM	99.98	SVM	99.97
DT	99.90	DT	99.91
RF	99.94	RF	99.95

Conclusion & Future Work

- An unsupervised Machine Learning approach was implemented on NavIC signals for classification of multipath signals in the absence of labeled data.
- This reduces dependency on computationally heavy techniques such as ray tracing, building models, 3D mapping aided with positioning etc.
- Using the labels derived from the unsupervised leaning approach, supervised learning was attempted.
- The next step for this work is that to attempt Deep Learning approach for NavIC multipath classification.

Thank You