Land cover classification with reflected GNSS signals and machine learning

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1 Introduction

GNSS reflectometry (GNSS-R) technology has shown its potential in monitoring the land surfaces, such as vegetation growth, soil moisture, glacier and land hydrology. Signal-to-Noise Ratio (SNR) contains information of the interference between the direct and reflected signals, making it possible to be applied in land cover classification.

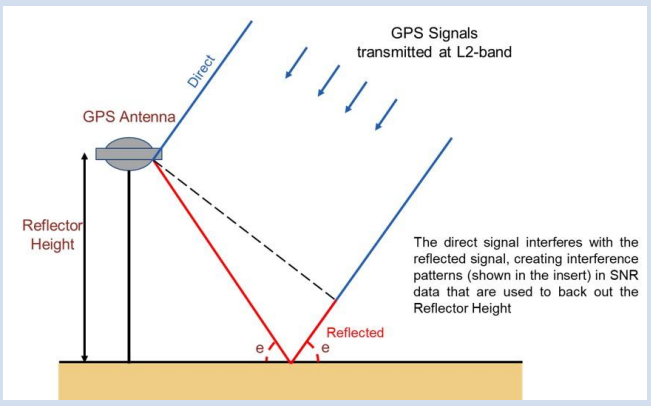

Figure 1: Diagram of GNSS-R signal reflection mechanism

2 Data Preprocessing

- 30-second Daily Observation data from IGS
  Time: 2015-2019, day of year 180-210 (summer)
  Region: Europe
- Copernicus Land Cover Dataset
- Based on particle swarm optimization (PSO) algorithm[1], select the optimal arc with best data quality

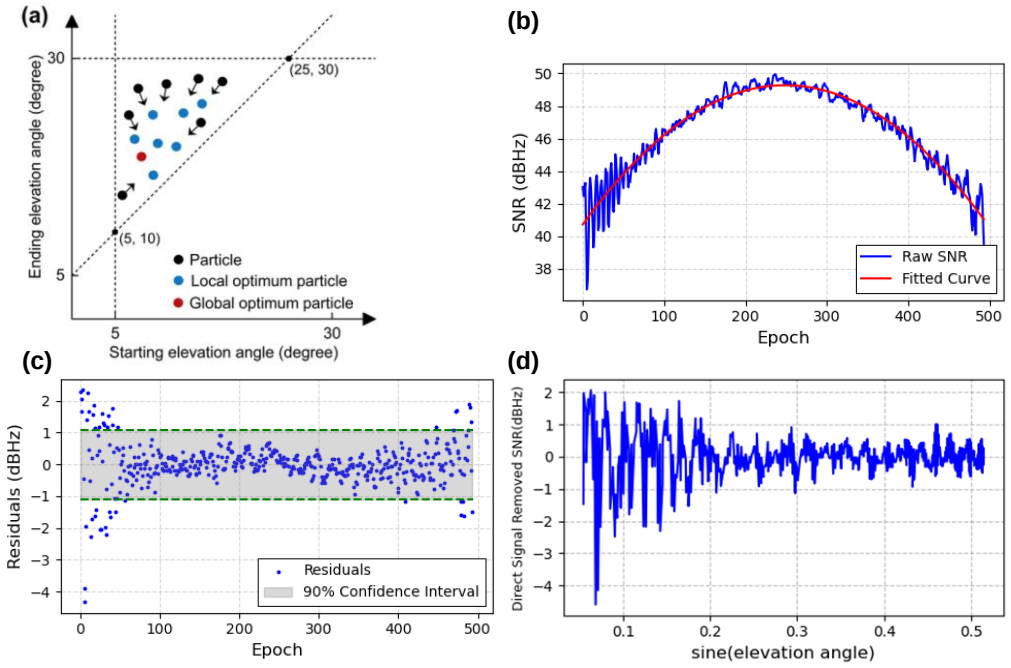

Figure 3: Preprocess the raw SNR to obtain the detrend optimal arc with best data quality

3 Methods

- Fresnel reflection zone grouped by azimuth/elevation angle
- Use the same land cover classification system as Copernicus Land Cover Dataset

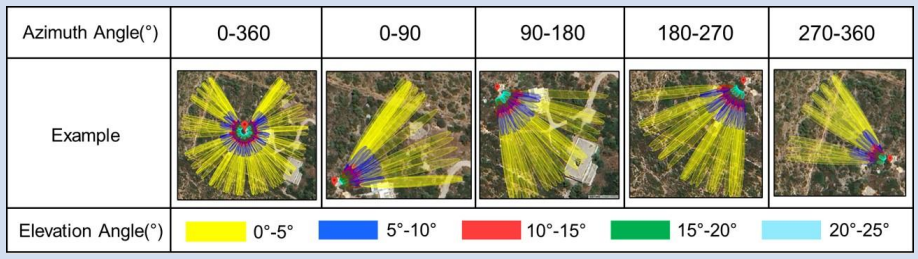

Figure 4: Fresnel Reflection Zones surrounding an IGS station, group by azimuth angle

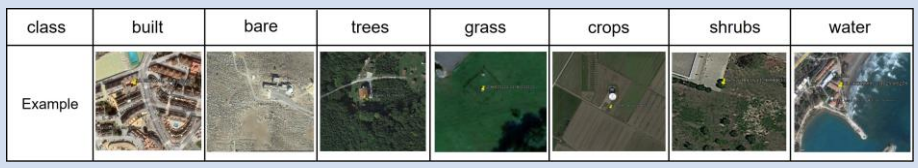

Figure 5: Land cover classification samples of IGS stations

- Features

(1) Statistical features: min, max, mean, standard deviation

(2) Dielectric constant for soil: Fresnel semi-empirical formula

$$\epsilon_s = \left(\frac{(1+\sqrt{SNR})\sin(\theta)}{(1-\sqrt{SNR})\sin(\theta)}\right)^2 \quad (1)$$

→ distinguish among built, bare, and water

(3) Lomb-Scargle Periodogram: Tree/Snow height is highly related to the phase and periodicity of the reflected signal[2]

$$SNR = A(e)\sin\left(\frac{4\pi h}{\lambda}\sin(e) + \emptyset\right) \quad (2)$$

→ distinguish among trees, grass, crops and shrubs

- Machine learning model: Random Forest Model

4 Results

Table 1: Scores of evaluation metrics for each class

class	precision	recall	f1-score
bare	0.71	0.45	0.56
built	0.59	0.92	0.72
crops	0.89	0.23	0.36
grass	0.46	0.3	0.36
shrubs	0.56	0.27	0.37
trees	0.67	0.4	0.5
water	/	/	/

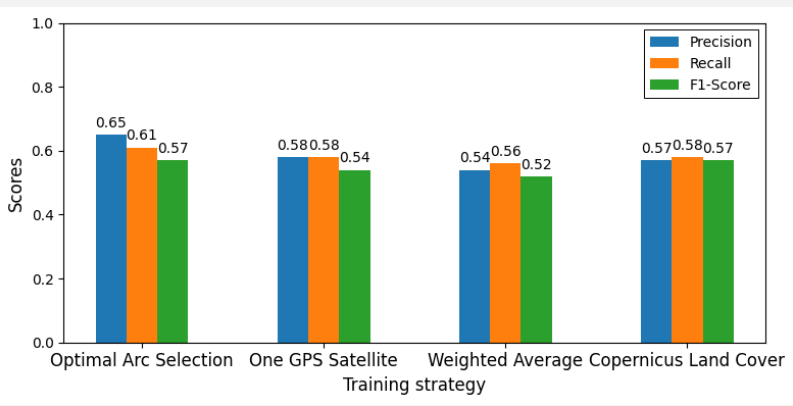

Figure 6: Land cover classification results of different satellite selection strategies

5 References

[1] He J, Zheng N, Ding R. Soil moisture retrieval using GNSS signal-to-noise ratio data based on an improved optimal arc selection method[J]. 2024.

[2] BilichA L K M. Mapping the GPS Multipath Environment Using the Signal-to-Noise[J]. Radio Science, 2007, 42.