Integration of SBAS-InSAR Time-series Data into Maintenance Prioritization of Linear Rail Infrastructure In Bangladesh

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Poster audio guide:
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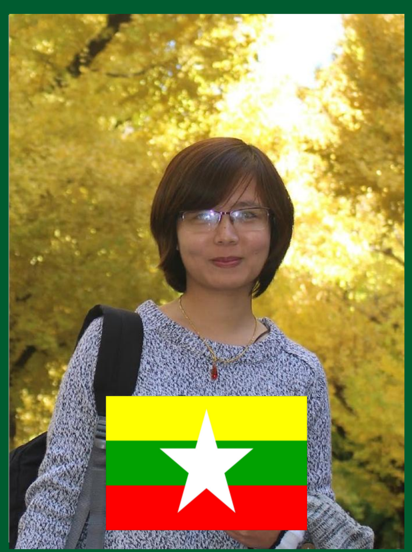
Japanese English



Abstract: Inspection and maintenance of rail infrastructure is still a challenging task for decision makers as it is resource-intensive work. It has been identified that Interferometric Synthetic Aperture Radar (InSAR) technique can detect the millimeter-level motion of the ground and this technique was regarded as one of the potential tools in structural health monitoring (SHM). Dhaka-Kasiani-Gopalganj Railway, which connects the capital city Dhaka to Gopalganj city in the southern part of Bangladesh (~150 km long), is chosen as case study. Annual instability rate along railway line was estimated by SBAS-InSAR time-series analysis with Sentinel-1A data in ascending orbit from Jan 2020 to Oct 2023. Numerical atmospheric model ERA5 was applied for tropospheric delay correction in InSAR analysis. InSAR-based instability data was integrated into existing geological background and land cover patterns to perform correlation analysis so that potential damage locations can be identified along the railway line. This study aims to help expand the application of InSAR data into engineering practices in linear rail infrastructure inspection and maintenance prioritization.

***Key Words**: railway, sentinel-1, InSAR, maintenance, geology, land cover*

I. Introduction

Previous studies have shown that InSAR can be used in structural health monitoring in combination with conventional site-based monitoring system (Chang et al., 2014; Macchiarulo et al., 2022). However, there is limited evidence of InSAR application in SHM of infrastructure network in developing countries where maintenance prioritization is a demanding topic along with quality-concerned deterioration assessment. This study aims to help expand the application of InSAR data into engineering practices in linear rail infrastructure health monitoring.

これまでの研究では、干渉SARは従来の現場ベースのモニタリングシステムと組み合わせて構造ヘルスモニタリングに使用できることが示されています(Chang et al., 2014;Macchiarulo et al., 2022)。しかし、開発途上国では、インフラ網のSHMにおける干渉SAR適用のエビデンスは限られており、品質に配慮した劣化評価とともに、メンテナンスの優先順位付けが厳しい課題となっています。　この研究は、インサルデータの応用をリニアレールインフラの健全性監視におけるエンジニアリング手法に拡大することを目的としています。

II. Methodology

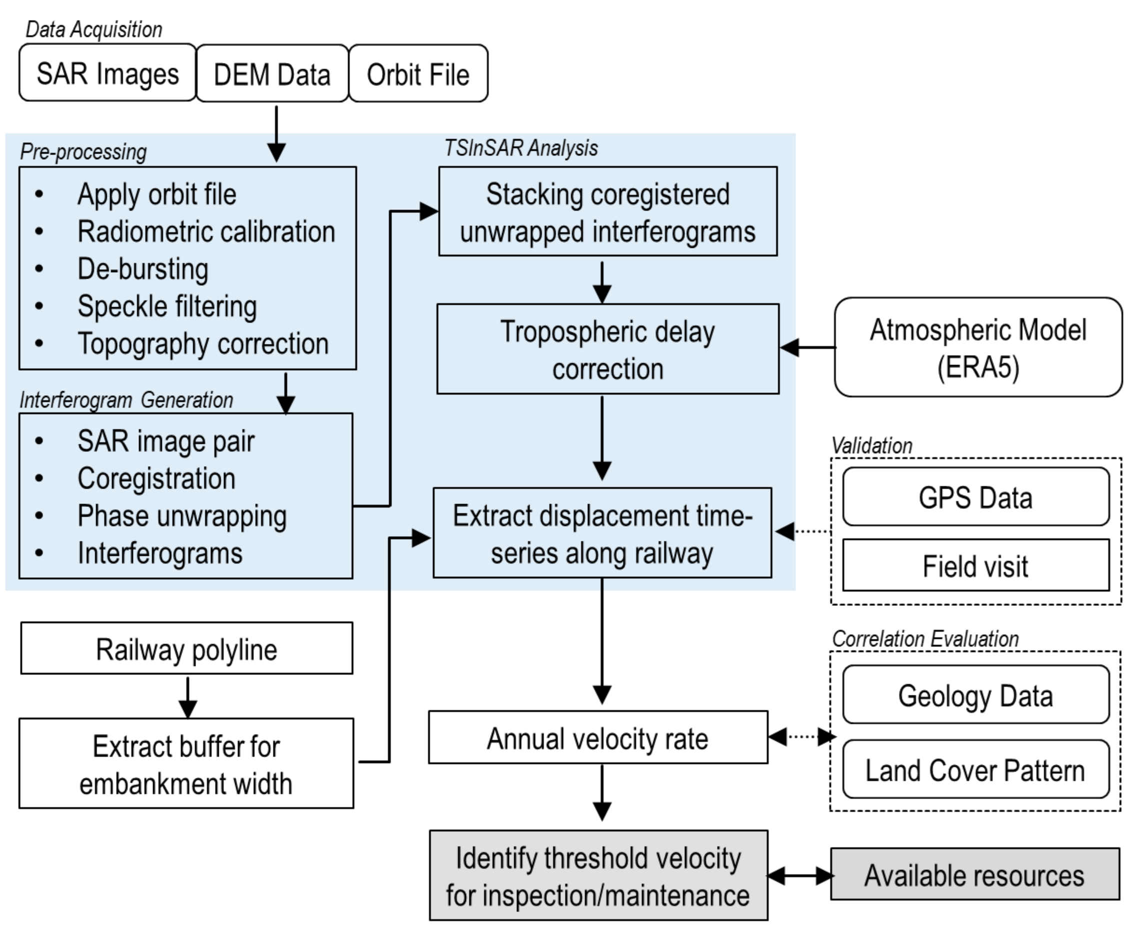


Fig 1. Research Framework.

Table1. Data used in SBAS TSInSAR analysis

Dataset	Characteristics	Value
Sentinel-1 SAR images	Flight direction	Ascending
	Wavelength	5.6 cm
	Beam mode	IW
	Revisit time	12 days
	Path number	114
	Temporal span	Jan 2020~Oct 2023
Copernicus DEM	Resolution	30 m
ERA5	Temporal resolution	1 hr
	Horizontal resolution	31 km (approx. 80 km from surface)
LULC Map	Impact Observatory, Microsoft, and ESRI (Karra et al., 2021)	
	Resolution	10 m
Geology Map	Produced by Geological Survey of Bangladesh in 1990	

Fig 2. Embankment constructions (google street view).

III. Results and Discussion

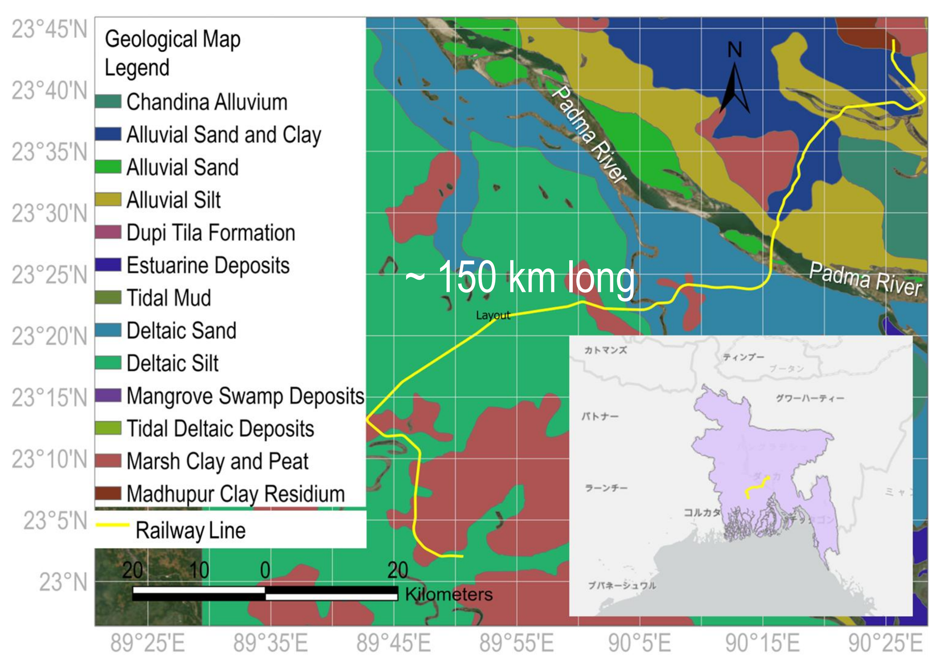


Fig 3. Railway line superimposed on geology map.

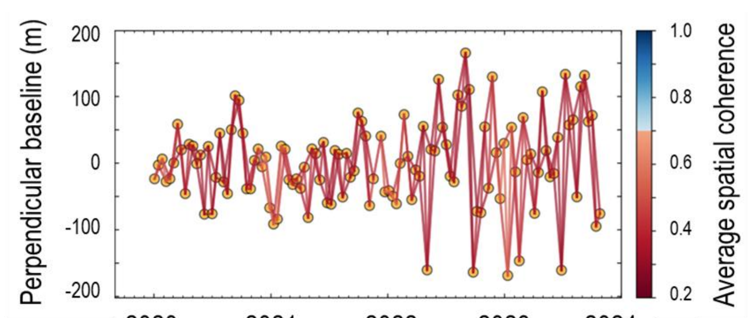


Fig 4. Interferogram Network (from ISCE).

Fig 5. Field visit to Kasiani and Chapta Station.

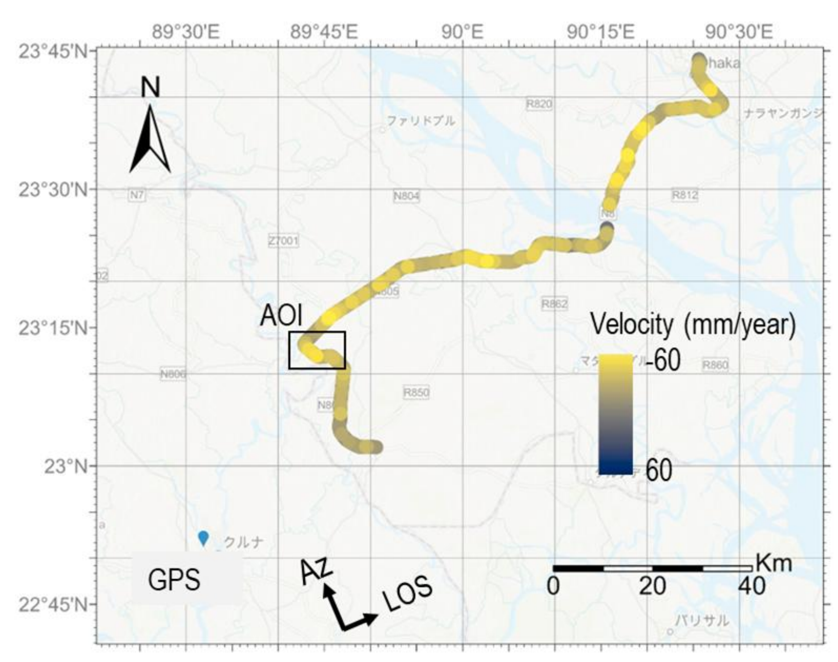
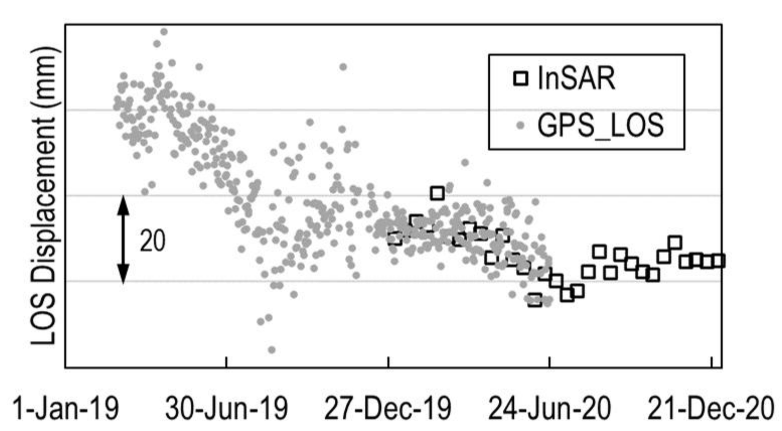


Fig 6. LOS velocity rate from SBAS-InSAR.



Wright et.al. (2004)

$$v_{los} = (-sin\theta cos\alpha \ sin\theta sin\alpha \ cos\theta)\begin{pmatrix} v_E \\ v_N \\ v_V \end{pmatrix}$$

Fig 7. Validation with GPS data.

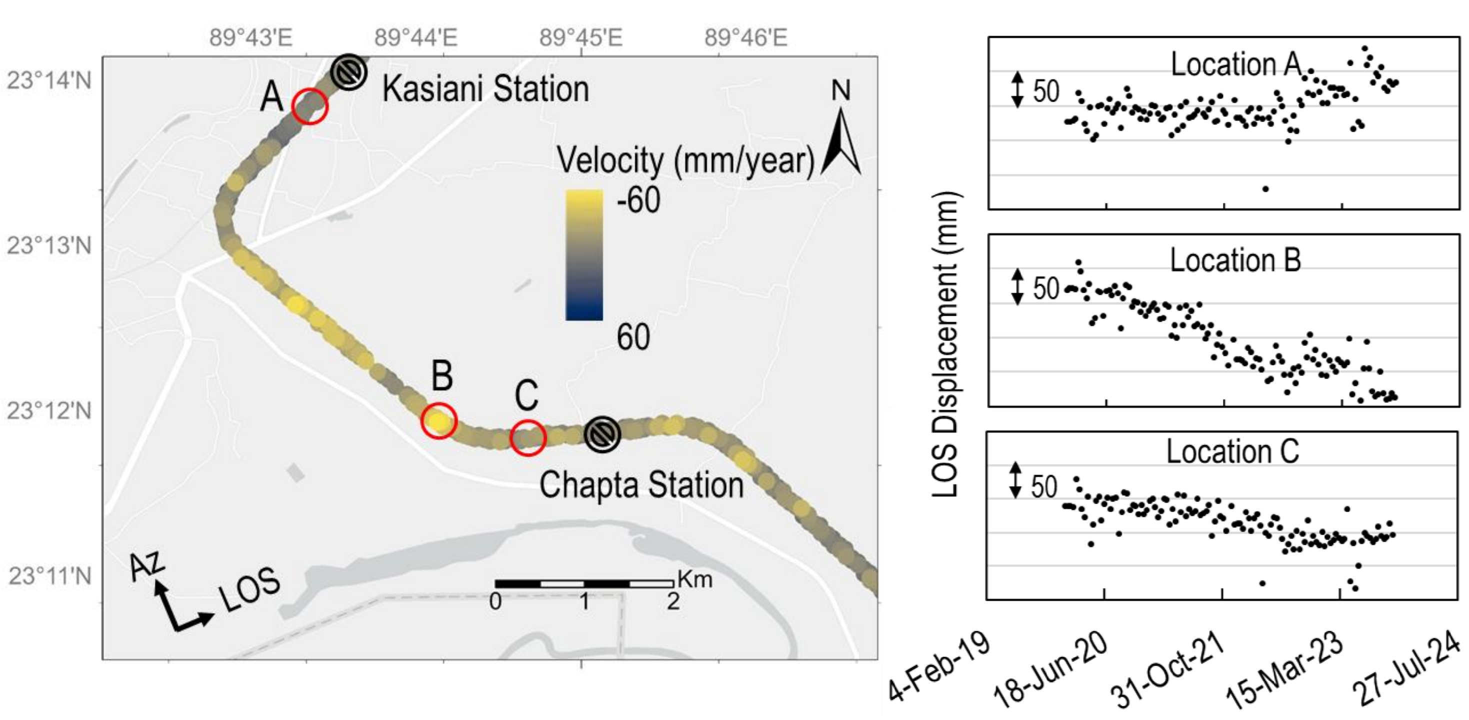


Fig 8. Time-series displacement plot for location A, B and C.

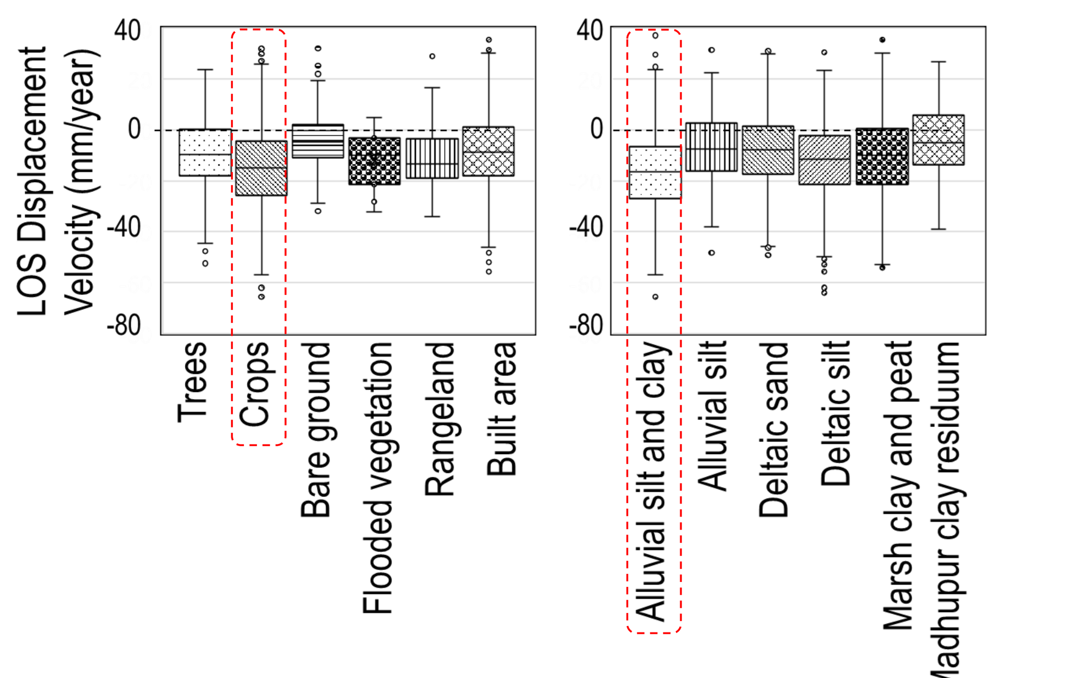


Fig 9. Correlation evaluation between InSAR, land cover and geology.

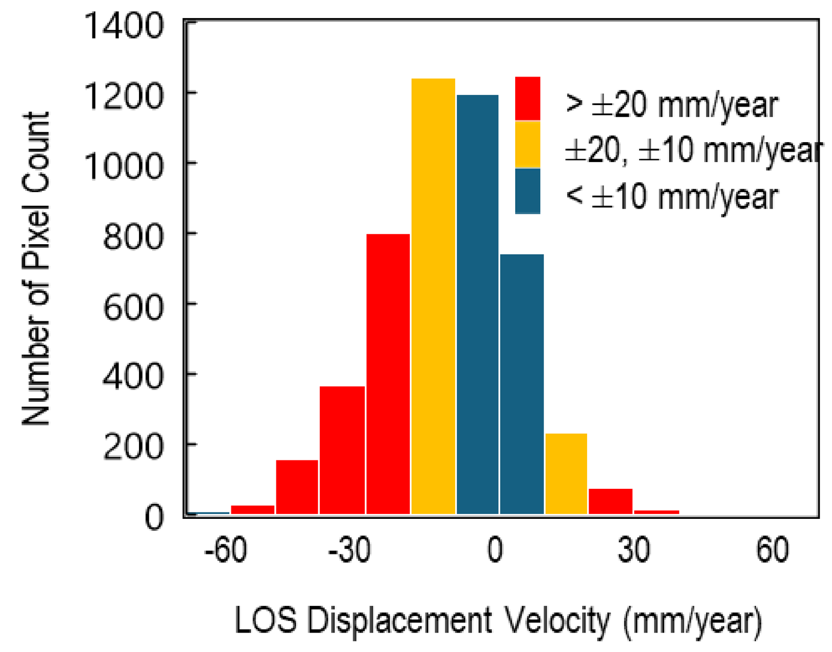


Fig 10. Pixel count for different LOS displacement.

- SBAS-InSAR result shows an agreement with LOS-projected GPS data (Fig-7) and field visit (Fig-5 & Fig-8).
  Location A (Kasiani Station Fig-5 left, built area, no elevated embankment) → LOS velocity ~ +10 mm/yr (Fig-8)
  Location B&C (near Chapta Station Fig-5 right, crop land, ~10m elevated embankment) → LOS velocity >-20 mm/yr.
- InSAR exhibits LOS displacement rate ranging from -60 to +20 mm/yr along railway line (Fig-6 & Fig-8).
- InSAR result indicates that railway line passing paddy field area has a high potential of instability (Fig-9 left).
  "Crops" land cover type ~ -20 mm/yr.
- High rate of LOS displacement rate reported on "Alluvial silt and clay" soil type, followed by "Deltaic silt" and "Marsh clay and peat" type (Fig-7 right).
- Application of InSAR results in SHM
  Threshold velocity Fig-10 (prioritization → resources)
  > ±20 mm/yr, (red) (~ 30% of total pixel count)
  between ±10 and ±20mm/yr (orange)
  < ±10 mm/yr (blue)
- Multi-looked ~ 30x30m resolution for InSAR result.
- Future work → detailed analysis on current damage condition in correlation with InSAR result.

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