Mapping the buildings stability at urban extent based on MT-InSAR and 3D rigid motion reconstruction method

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1. Introduction

A method to reconstruct the **3D rigid motion** of isolated buildings from a **dual-orbit set of SAR data** has been proposed [1]. Particular attention was paid to the significance assessment of the motion components. Results indicate that displacements and rotations in the order of few mm/yr and mrad/yr - with corresponding uncertainties one order of magnitude smaller - can be detected. This work combines the proposed structural investigation method with a GIS dataset to develop a methodology for assessing **building stability at an urban extent**. GIS layers were used to define the spatial relation between scatterer and building shape and to retrieve the heights of the scatterers. The 3D rigid motion analysis was conducted for all individual buildings in the municipality of Modena (Italy) with uncertainties assessment. The workflow is able to **map the potential stability issues of single buildings, at urban extent,** as starting point for further investigation.

2. 3D rigid motion reconstruction

A method for the identification of the **3D motion components** relying on the **rigid motion assumption** and on a **dual orbit** set of SAR data with the assessment of the **uncertainties associated to components** was proposed [1]. The vector collecting the motion components (θ) is estimated as:

$$\hat{\theta} = (S^T S)^{-1} S^T M$$

In which S and M are the matrices collecting the geometric parameters and the SAR displacements, respectively.

The total uncertainty results to be the sum of the **positioning** and the **measurement** uncertainty:

$$\sigma_T(\theta) = \sqrt{\sigma_{Pos}^2(\theta) + \sigma_{Meas}^2(\theta)}$$

[1] Bassoli, Vincenzi, Grassi and Mancini (2023). A multi-temporal DInSAR-based method for the assessment of the 3D rigid motion of buildings and corresponding uncertainties. *Journal of Building Engineering*, *73*, 106738. https://doi.org/10.1016/j.jobe.2023.106738

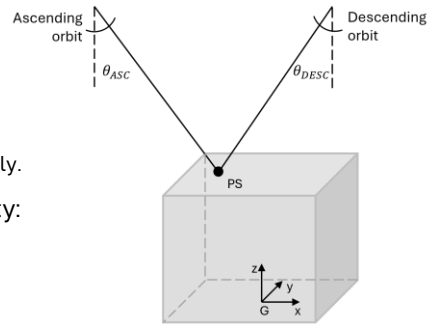


Figure 1. System used to develop the model

3. Scatterers heights validation

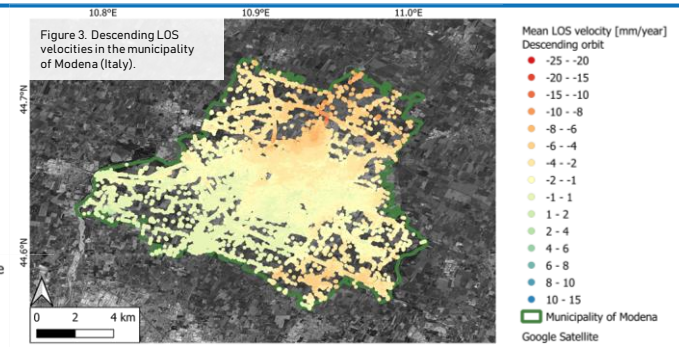
The accuracy of the targets 3D positioning must be carefully considered, as an error in their height will also affect the 2D positioning and thus the definition of the spatial relationship between the scatterer location and the buildings. To this end, a statistical analysis of the scatterer heights has been performed, calculating the difference between the mean height of the PSs and the height of the buildings with the associated uncertainty. The uncertainty of that difference has been computed from the uncertainty related to the volumetric units' height ($\pm$ 3 m) and that of the numerosity of PSs on the building, resulting in an uncertainty of $\pm$ 4.5 m.
Buildings for which the computed difference is below the uncertainty are colored in green (Figure 2).

Figure 2. Difference between targets and buildings heights.

4. Building stability at urban extent

The 3D rigid motion reconstruction method, along with a dual-orbit CSK (Figure 3) and GIS dataset, allowed to map the potential stability issues of single buildings for the municipality of Modena. The motion components for each building presenting at least 6 PSs for each orbit have been computed and the buildings for which significative results were obtained have been mapped for further investigations (Figure 4).

Figure 3. Descending LOS velocities in the municipality of Modena (Italy).



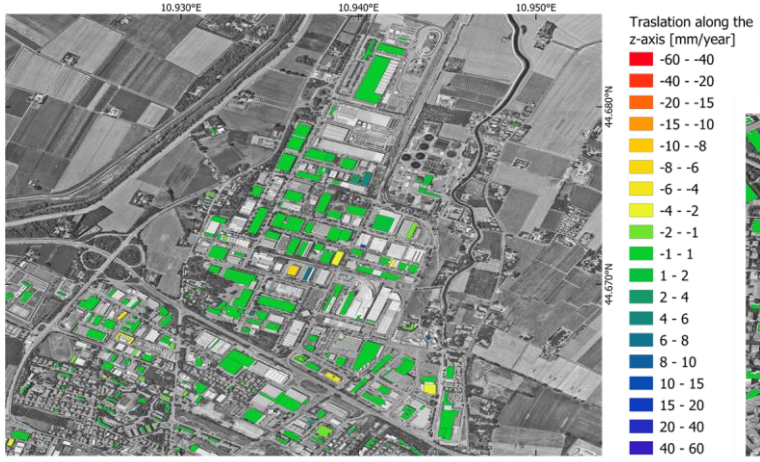


Figure 4. Vertical component for the investigated buildings (detail of the historical center and the northern part of Modena).

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