Ph.D. in Information Technology
Thesis Defense

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At 10:00 a.m.
Room Aula BIO 1 - Building 21

Giovanni COSTA – XXXVIII Cycle

CHANGE DETECTION FOR PHASE ESTIMATION IN LARGE INSAR DATASETS

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Abstract:

Synthetic Aperture Radar (SAR) and SAR Interferometry (InSAR) have proven effective for monitoring surface deformation and infrastructure health. However, a key challenge for existing algorithms is their difficulty in handling temporal changes, which jeopardizes the analysis of partially stable targets. The development of SAR-based change detection methods is therefore paramount for applications like hazard prevention, as they can provide change information well before target motion estimation, thereby complementing standard InSAR analysis and aiding in the interpretation of time series. SAR-based change detection approaches can be classified as time-series based (TS-CD), which works downstream of deformation analyses, as amplitude-based (ACD) or coherence-based (CCD), which work upstream, making them the most effective for enhanced InSAR analysis. Many traditional ACD and CCD methods suffer from significant limitations. The statistical based ones often rely on strong theoretical assumptions that limit their applicability when these assumptions are not met, and they may require calibration data under steady-state conditions (i.e., datasets where the targets are known to be stable). Deep Learning (DL)- based methods face two challenges: a lack of large, reliable labeled datasets for robust training, and a general difficulty in interpreting their outputs in a classical statistical sense. Furthermore, most existing algorithms rely on a single information source, either amplitude or coherence. These sources are generally considered orthogonal in this field due to their different resolutions, and the potential of mixing them for a comprehensive understanding of a change phenomenon is neglected. To address these limitations, this research aims to provide upstream change detection algorithms for a change-conscious InSAR framework. Initially, an interferometric interpretation and formalization of changes is discussed, distinguishing between Definitive, or abrupt, Change (DC), and Temporary Change (TC) based on their unique signature in the coherence matrix. The work then presents two CCD algorithms: the Permutational Change Detection (PCD), a first step toward a fully non-parametric CCD specialized for DC detection, and the Band-limited Uncalibrated Detector (BUD). BUD advances the development of a fully non-parametric CCD by inferring changes, regardless of their nature, through directly testing the multi-temporal evolution of the observed coherence samples. Additionally, BUD proposes a novel way of interpreting change detection results, moving from traditional binary maps to more quantitative information for in-depth analysis. Furthermore, it also proposes a multi-frequency/multi-geometry analysis that can serve as a cross-validation of the detected changes. The goal of inferring not only a change but also its nature is achieved through DANINET (Deep Analysis for Non-stable InSAR targets Network). DANI-NET represents the first effective method to infer a change's nature and spatio-temporal location. It uniquely unifies amplitude and coherence information, proposing the first such unified approach for SAR-based change detection. Furthermore, DANI-NET follows a fully

synthetic-based training and testing strategy. This synthetic dataset models the effects of changes on coherence and amplitude and, at the same time, satisfies the need for a transparent, interpretable, and explainable DL-based method, revealing interesting insights into its decision-making process. Synthetic analyses demonstrate the robustness and competitiveness of PCD, BUD, and DANI-NET against a diverse set of state-of-the-art methods. The frameworks are validated across multiple real-world applications, ranging from mostly rural to urban scenarios, to demonstrate their wider applicability and flexibility.

PhD Committee

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