Ph.D. in Information Technology
Thesis Defense

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Gianluca MURDACA – XXXVI Cycle

ADVANCING REMOTE SENSING: DEEP LEARNING TECHNIQUES FOR INSAR DATA PROCESSING AND ANALYSIS

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Abstract:

Synthetic Aperture Radar (SAR) represents an advanced microwave-based imaging system that operates on the principle of coherent signal processing. This system possesses a distinctive capacity for penetrating through cloud cover due to its utilization of microwave frequencies. Its active nature ensures continuous operation both during daylight and nighttime conditions. Leveraging these capabilities, the emergence of the Interferometric Synthetic Aperture Radar (InSAR) technique has revolutionized remote sensing, offering unparalleled accuracy in Earth surface monitoring. InSAR enables the precise measurement of ground movements, deformation, and topographical changes, leading to invaluable insights for various scientific and practical applications. However, despite its transformative potential, InSAR encounters several challenges due to the presence of noise and artefacts within the data, which can seriously compromise the result's accuracy and reliability. This thesis represents an in-depth investigation into InSAR data processing, employing the formidable capabilities of deep learning to forge novel methodologies. The exploration begins by addressing the phase filtering and coherence estimation task, a fundamental process crucial to exploiting the potential of the subsequent InSAR methodologies developed. In particular, we introduced an innovative model for noise reduction, pattern preservation, and artifact mitigation in filtered signals. The result's accuracy ensures the reliability of the subsequent phase unwrapping outcomes, thus enhancing the whole deformation or topographic analysis. A novel simulation strategy for generating SAR interferograms is also presented using parameters extracted from real SAR imagery, establishing the basis for a dataset that accurately mirrors real-world InSAR physical properties. Additionally, an assessment of the reliability in the filtered phase is computed, providing a comprehensive understanding of the quality linked to our phase estimations. After that, we addressed the intricate challenge of identifying phase discontinuities, a critical element in ensuring the precision of phase unwrapping. These abrupt transitions hold the key to accurate unwrapped phase values, preventing results from distortions. Within the complexities of real-world scenarios, where noise necessitates filtering and unwrapping depends on a noise-free phase, we introduced a comprehensive approach to estimating phase discontinuities starting from our filtered data. Finally, we addressed the task of change detection within open-pit mines. Recognizing the impact of mine alterations on safety, efficiency, and environmental impact, we leverage deep learning to detect changes using high-resolution SAR images accurately. In summation, this thesis delves deeply into the complexities of InSAR, harnessing deep learning methodologies to overcome challenges and unlock the technology's true potential. Our approaches leverage neural networks while intricately considering the underlying physics of the data. Indeed, we actively guide the learning process rather than passively feeding

data and relying solely on deep learning for autonomous decision-making. Through the developed methods encompassing accurate phase filtering, coherence estimation, phase discontinuity identification, and change detection, this research redefines the boundaries of InSAR's capabilities, forging a path toward more profound insights and transformative applications across diverse disciplines.

PhD Committee

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