

## ABSTRACT

This research presents the Two-Phase Adaptive Pattern Frequency Replacement (PFR) method, an innovative approach designed to enhance embedding capacity in reversible data hiding (RDH) for binary images. The method addresses the limitations of the Adaptive Pattern Substitution (PS) method by utilizing a two-phase embedding process, leveraging the second least frequent pattern (PFR) to significantly increase the capacity for embedding secret data while attempting to minimize distortion.

However, experimental results reveal that while the Two-Phase Adaptive PFR method successfully increases embedding capacity, it does not achieve the same level of performance in terms of distortion metrics such as Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM). In particular, the method introduces increased distortion due to disruptions in pattern structures caused by the flip mirroring process used during the second embedding phase. This issue becomes especially evident when the images are subjected to noise, such as salt & pepper or physical damage like scratches, where the previous Adaptive PS method outperforms the proposed method in terms of image quality.

Despite these limitations, the Two-Phase Adaptive PFR method offers a significant improvement in data embedding capacity, making it suitable for applications where high-capacity data hiding is prioritized over minimal distortion, such as military maps or sensitive governmental documentation. Future research should focus on optimizing the flip mirroring process to reduce distortion and enhance the robustness of the method in noise-prone environments.

**Keywords: Reversible Data Hiding, Binary Images, Two-Phase Adaptive Pattern Frequency Replacement (PFR), Embedding Capacity, Distortion, Flip Mirroring.**