# Project Proposal - ECE 251C

## Predicting Inpainted Images Using Wavelet-Based Features

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## Problem Statement

This project aims to replicate the DTCWT implementation proposed by Barglazan and Brad [1] and extend it by analyzing the efficacy of multiple wavelet types, to assess their impact on inpainting detection.

## Problem Description

The increasing prevalence of digital image editing tools has made it easy to manipulate images, often blurring the lines between authentic and altered visual content. Image inpainting, which is widely used for object removal or area restoration, poses a significant challenge in digital forensics as it can be difficult to detect, especially with advanced methods that mimic authentic textures and noise patterns. Current methods, although effective, lack comprehensive robustness in detecting inpainting across diverse textures, noise patterns, and wavelet transformations.

The primary problem addressed in this project is the detection of inpainting forgeries in images through a combination of wavelet-based noise analysis, segmentation, and texture analysis. The existing method leverages the Dual-Tree Complex Wavelet Transform (DTCWT) due to its robustness in handling shifts and its ability to maintain directional selectivity, which aids in identifying subtle anomalies.

However, the potential of exploring various other wavelet transforms remains underdeveloped, which may yield further insights and enhancements in detecting inpainting in different contexts. These transforms may also help overcome some known limitations of DTCWT: susceptibility to aliasing, limited frequency localization, and sensitivity to scale, rotation and noise. By implementing and comparing these wavelet techniques, we aim to establish a framework that could provide a more versatile and accurate approach to image inpainting detection.

## Related Work

While researching wavelets for inpainting detection, the Dual-Tree Complex Wavelet Transform (DTCWT), introduced by Kingsbury [2], stood out for its shift-invariance, directional selectivity, and ability to capture both magnitude and phase information. These properties enable DTCWT to highlight subtle artifacts in manipulated images [6], such as unnatural boundaries and inconsistencies in texture [5] and noise, which traditional wavelets often miss. Its multiscale representation further enhances detection by revealing discrepancies across various scales, making it a powerful tool for identifying altered regions in digital forensics.

Despite these strengths, we found limited prior work that leveraged DTCWT for image forgery detection. Gao et al. [3] demonstrated DTCWT's effectiveness in face forgery detection by leveraging its directional sensitivity to capture noise inconsistencies across multiple scales, and identifying anomalies in face manipulation techniques. Building on this foundation, Barglazan and Brad [1][4] applied DTCWT to image inpainting detection, combining wavelet-based decomposition with noise inconsistency analysis across segmented regions. Their approach capitalized on DTCWT's multi-scale and shift-invariant capabilities, successfully isolating inpainted areas by analyzing noise and texture variations within segments.

## Proposed Methodology

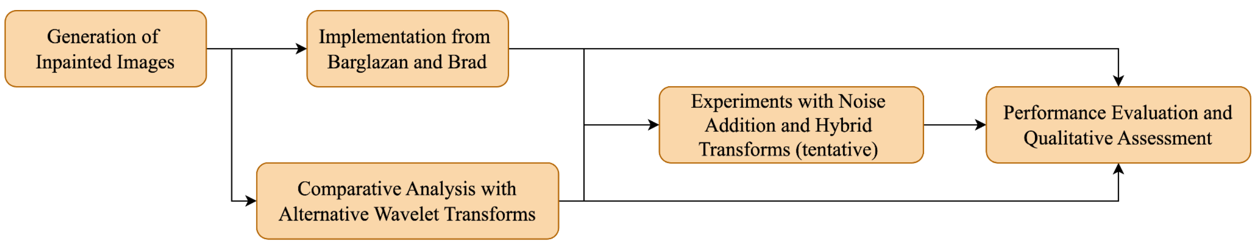


Figure 1: High-level overview of our method

As seen in Figure 1, we would like to implement the following as a part of our project:

### Generation of Inpainted Images

- We will create a dataset of inpainted images from image-object mask pairs. This may involve the use of generative AI, diffusion models, transformers etc. We will most likely use pre-existing code or frameworks for this step.

### Implementation Based on an Existing Method

- We will implement and adapt methods from Barglazan and Brad, to provide a baseline for inpainting detection. This will include using predefined filters or feature extraction techniques from the paper. Figure 2 contains our interpretation of the paper's proposed method, which we will use to guide our work in this step.

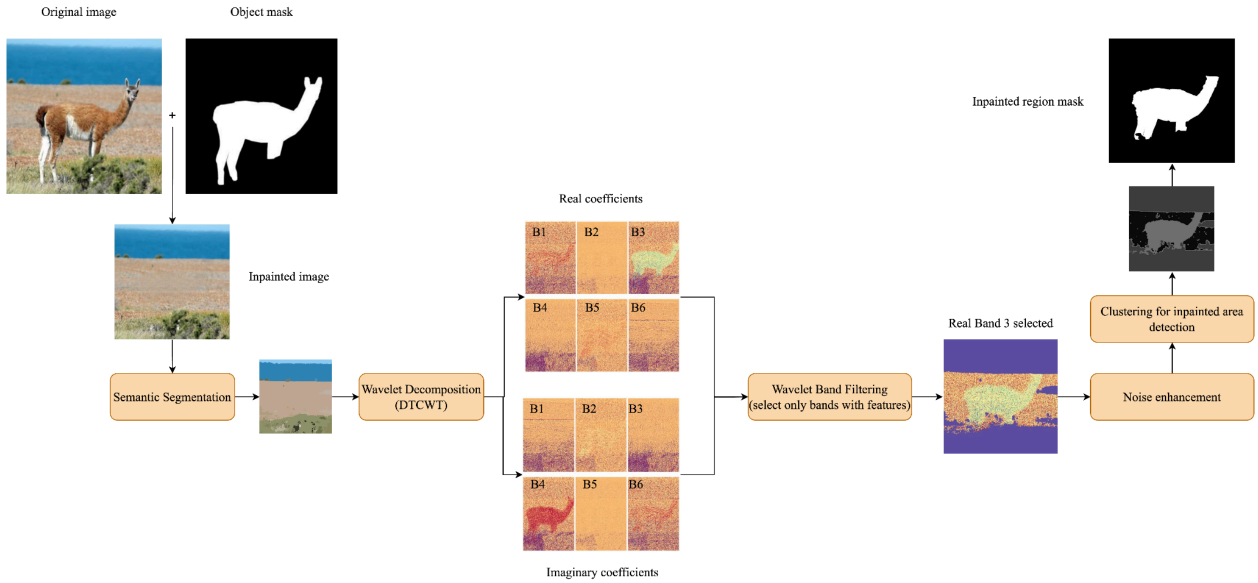


Figure 2: Pipeline for inpainted region detection from [1]

### Comparative Analysis with Alternative Wavelet Transforms

- We will compare the performance of different wavelet transforms for inconsistency extraction from inpainted images to identify the most effective transform(s) for capturing inpainting artifacts.

### Experiments with Inpainted Image Filtering and Hybrid Transforms (Tentative)

- We will conduct experiments on adding noise to/blurring the inpainted image to assess the robustness of the inpainting detection pipeline. We may also implement some hybrid transforms that combine different wavelet types.

### Performance Evaluation and Qualitative Assessment

- We will evaluate the effectiveness of the proposed methodology by comparing the generated inpainted region mask with the object mask as a ground truth. Metrics used may include Intersection-over-Union (IoU), Dice similarity coefficient, pixel-wise accuracy and F1 score, and boundary-based distance metrics like the Hausdorff distance.

## References

[1] Barglazan, Adrian-Alin, and Remus Brad. “Wavelet based inpainting detection.” *Advances in Artificial Intelligence and Machine Learning*, vol. 04, no. 03, (2024), pp. 2783–2809

[2] Kingsbury, Nick. "Image processing with complex wavelets." *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences* 357.1760 (1999): 2543-2560.

[3] Gao, Shichao, Ming Xia, and Gaobo Yang. "Dual‐Tree Complex Wavelet Transform‐Based Direction Correlation for Face Forgery Detection." *Security and Communication Networks* 2021.1 (2021): 8661083.

[4] Adrian-Alin, Barglazan, and Brad Remus. "Enhanced Wavelet Scattering Network for image inpainting detection." arXiv preprint arXiv:2409.17023 (2024).

[5] Sun, Huixian, Yuhua Zhang, and Zhaorui Li. "Texture Defect Detection Using Dual-Tree Complex Wavelet Reconstruction." 2014 IEEE 17th International Conference on Computational Science and Engineering. IEEE, (2014).

[6] Wolter, Moritz, et al. "Wavelet-packets for deepfake image analysis and detection." *Machine Learning* 111.11 (2022): 4295-4327.