Title : **Image Texture Analysis using Enhanced Deep Neural Networks**

Key Words: Deep Learning, Texture analysis, Self-supervised learning, Unsupervised representation learning, Convolutional Neural Networks, Vision Transformers.

## Scientific Context of the Thesis :

In various image processing applications, texture analysis—which examines the spatial and frequential arrangement of colors or intensities—is essential for tasks such as classification, segmentation, and detecting objects or anomalies. Over the years, traditional methods based on structured or statistical approaches have been largely superseded by neural networks and deep learning techniques.

Over the past decades, numerous state-of-the-art methods have been proposed to extract texture patterns. However, effectively combining texture features with deep learning, known as deep texture, remains an open research area. In medical imaging, extensive research has demonstrated that texture analysis holds significant potential for differentiating various tissue types and pathologies [1,2]. For example, image texture can aid in the diagnosis of diseases by highlighting subtle differences in tissue structures [3-5]. Additionally, other promising application areas include precision agriculture, where texture analysis can help in detecting plant diseases or weeds [6,7], and historical heritage analysis, such as identifying patterns on ceramic shards [8,9].

Despite the progress in texture extraction methods, effectively integrating texture features with deep learning, known as deep texture, remains an open research area [12]. An ideal image texture pattern should encompass essential features, including local properties for micro-unit characterization, global properties for macro-structure representation, uniform shapes under non-uniform shape images, and invariance or robustness under common geometric transforms like rotation and scaling.

Although Vision Transformer (ViT) models have made substantial progress in various computer vision tasks, they encounter difficulties in capturing high-frequency image components, which constrains their capacity to detect local texture information in comparison to Convolutional Neural Network (CNN) models [10,11]. To tackle this challenge, this thesis seeks to create advanced models that effectively capture the intricate details of both macro and microstructures. By addressing the shortcomings of current CNN and ViT models, we aim to develop a novel approach that extracts robust texture representations encompassing both local and global features, thereby enhancing the overall performance of image texture analysis.

Traditional supervised deep learning models often encounter challenges due to their requirement for large annotated datasets, which can be time-consuming and costly to create, particularly when dealing with rare or subtle anomalies. To overcome these limitations, Self-Supervised Learning (SSL) approaches have gained popularity [13]. SSL leverages the inherent structure of data to create tasks that provide indirect supervision, thereby reducing the need for extensive labeled datasets. Consequently, SSL will play a vital role in the development of future models within the scope of this thesis.

Furthermore, taking into account certain physical properties of textures, such as periodicity, scale, and anisotropy, can be utilized to impose constraints on the structure and learning process of networks. This approach will help improve the overall performance and accuracy of the developed models in texture analysis.

In summary, this research aims to surpass current limitations and improve the accuracy, efficiency, and robustness of diagnostic tools by harnessing the power of deep learning for texture analysis. The methodological proposals can be evaluated across various application cases, including medical imaging analysis (e.g., analyzing biological tissues, wound images in collaboration with CHUO, or 3D OCT-LC stacks of the collagen matrix with LVMH Recherche), heritage analysis (e.g., detecting stone degradation, recognizing periodic patterns in ceramic shards), and precision agriculture (e.g., detecting plant diseases or weeds).

## Thesis Objectives:

This thesis aims to develop and evaluate deep learning-based methods for image texture analysis. The specific objectives include:

1. Designing and implementing deep neural network architectures for image texture analysis.

2. Developing segmentation and classification models to accurately delineate and label structures.

3. Exploring self-supervised and unsupervised learning techniques to leverage unlabeled image data.

4. Evaluating the performance of the proposed methods on benchmark imaging datasets.

5. Investigating the interpretability and applicability of the developed models for real-world applications.

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