Introduction to Computer Vision

Lab 2: Frequency Domain Filtering & Hybrid Images

ESIN, UIR — Spring 2026

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1 Introduction

In the previous lab, we studied 1D convolution and computed it by hand. In this lab, we move to **2D images** and ask a fundamental question:

Is there a faster way to compute convolution than sliding a kernel over every pixel?

The answer is **yes** — and it comes from a remarkable mathematical result called the **Convolution Theorem**. This theorem connects two seemingly different operations: convolution in the *spatial domain* and multiplication in the *frequency domain*.

By the end of this lab, you will be able to:

- State and apply the 2D Convolution Theorem.
- Explain the computational advantage of FFT-based filtering.
- Design and apply ideal and Gaussian low-pass and high-pass filters.
- Explain the Gibbs Phenomenon and why Gaussian filters avoid it.
- Create hybrid images by combining frequency components of two images.

2 Lab Instructions

2.1 .ipynb Notebook

Open the provided notebook (better on Colab or Kaggle). It is organized into three parts:

1. **Part 1 — Convolution Theorem in Practice**
   You will benchmark spatial convolution vs. FFT-based convolution using `scipy.signal` and observe the computational difference.

2. **Part 2 — Frequency Domain Filtering**
   You will use provided functions to apply ideal and Gaussian low-pass and high-pass filters to images, visualize the spectrum overlays, and compare the ringing artifacts.

3. **Part 3 — Hybrid Images**
   Complete the provided code to implement the hybrid images pipeline yourself, namely the (`hybrid_image_color`) function.

2.2 Deliverables

Submit a single merged PDF file on Connect UIR before the deadline, containing the following two documents **in this order**:

1. **Completed notebook** exported as a `.pdf` with all cells executed and outputs visible, including your implementation of hybrid images in color.
2. **Short report** (`.docx` exported as PDF, maximum 2 pages) containing:
   - Your name, Group, and Student ID
   - Answers to all report questions
   - A screenshot of your best hybrid image (your own image pair)

2.3 How to Prepare Your Submission

Follow these two steps in order:

1. **Export your notebook to PDF**
   Run all cells (`Runtime` → `Run all`), then download your notebook (`File` → `Download` → `Download .ipynb`) and convert it using:

   https://www.vertopal.com/en/convert/ipynb-to-pdf

2. **Merge both PDFs into one file**
   Go to the following website, upload your notebook PDF first and your report PDF second, then download the merged file:

   https://www.ilovepdf.com/merge_pdf

Submission Rules

- Submit **one single merged PDF** — not two separate files.
- Make sure all notebook cells have visible outputs before exporting.
- **Do not send your submission by email. (I won't correct it)**