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Tugas 2 PCVK: FFT dan perbaikan citra dalam domain frekuensi

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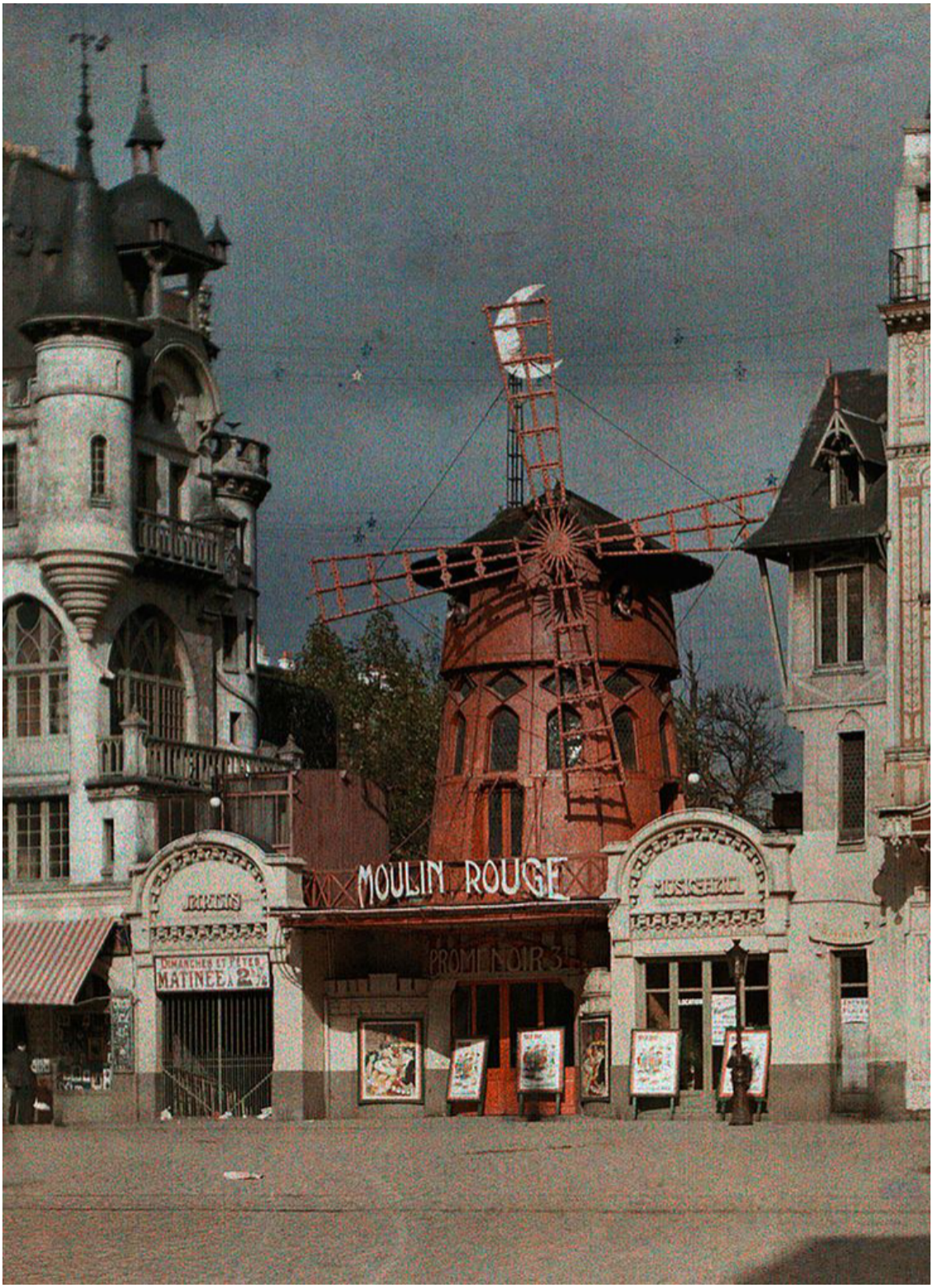
1 Library

[1]:
```
from IPython.display import Image, display, Image as IPImage
import cv2
import numpy as np
import matplotlib.pyplot as plt
from scipy.fftpack import fft2, ifft2, fftshift, dct, idct
import os
import cv2
import io
```

2 Filtering

[2]:
```
Image(filename='image/d (1).png')
```

[2]: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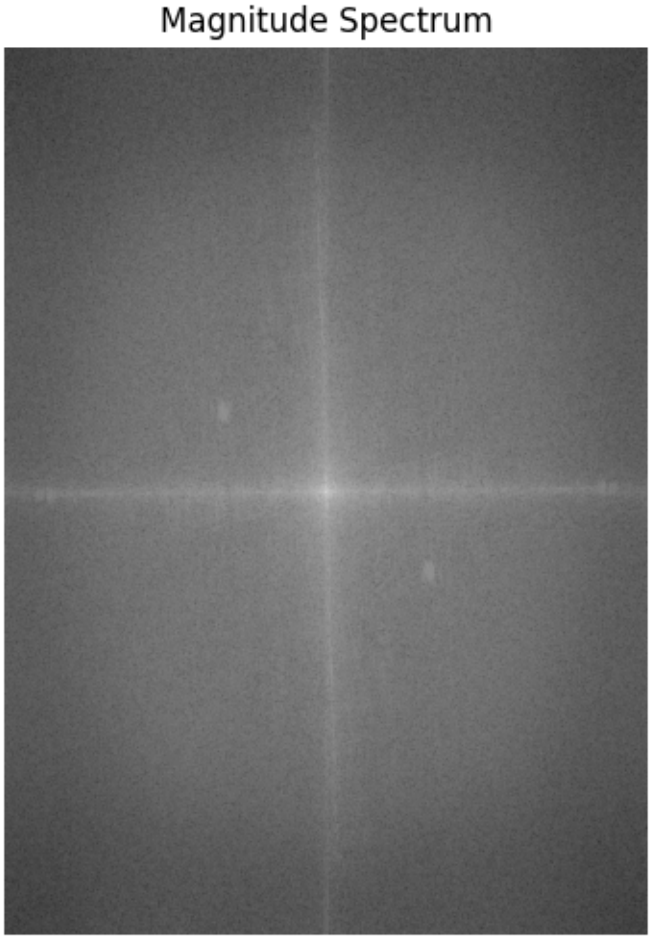
[3]:
```python
def compute_magnitude_spectrum(img_array):
    dft = fft2(img_array)
    dft_shift = fftshift(dft)
    return np.log(1 + np.abs(dft_shift))

image_path = 'image/d (1).png'
img = cv2.imread(image_path)
img_rgb = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
img_gray = cv2.cvtColor(img_rgb, cv2.COLOR_RGB2GRAY)

magnitude_spectrum = compute_magnitude_spectrum(img_gray)

plt.figure(figsize=(6, 6))
plt.imshow(magnitude_spectrum, cmap='gray')
plt.title('Magnitude Spectrum')
plt.axis('off')
plt.show()
```



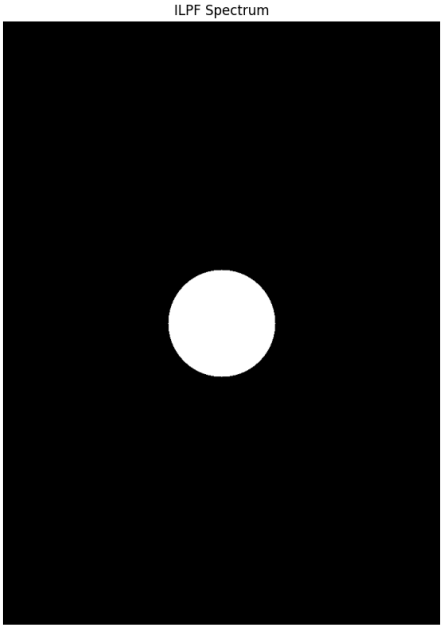
Magnitude spectrum ini menunjukkan garis terang horizontal dan vertikal di tengah, menandakan dominasi frekuensi rendah yang terkait dengan kontur gambar. Pusat terang menunjukkan frekuensi terendah mendominasi, mewakili perubahan intensitas yang lambat. Bintik-bintik redup di sekitar garis utama menandakan adanya noise atau komponen frekuensi tinggi. Komponen frekuensi tinggi berada di tepi gambar, tetapi tidak terlalu dominan, menunjukkan gambar asli memiliki detail halus yang terbatas.

Sehingga, dapat dilakukan filtering untuk mengurangi noise yang terlihat pada gambar, memperhalus area yang kurang rapi, dan meningkatkan kualitas visual agar gambar lebih jelas dan nyaman untuk dilihat.

[4]:
```
def low_pass_filter(img_array, filter_type, cutoff, order=0.5):
    dft = fft2(img_array)
    dft_shift = fftshift(dft)

    rows, cols = img_array.shape
    crow, ccol = rows // 2, cols // 2
    mask = np.zeros((rows, cols), np.float32)

    for i in range(rows):
        for j in range(cols):
            distance = np.sqrt((i - crow) ** 2 + (j - ccol) ** 2)
            if filter_type == 'ILPF':
                mask[i, j] = 1 if distance <= cutoff else 0
            elif filter_type == 'BLPF':
                mask[i, j] = 1 / (1 + (distance / cutoff) ** (2 * order))
            elif filter_type == 'GLPF':
                mask[i, j] = np.exp(- (distance ** 2) / (2 * (cutoff ** 2)))

    dft_shift_filtered = dft_shift * mask
    f_ishift = np.fft.ifftshift(dft_shift_filtered)
    img_back = ifft2(f_ishift)
    return np.abs(img_back), mask

higher_cutoff_ILPF = 90
higher_cutoff_GLPF = 90
higher_cutoff_BLPF = 90

def apply_filter_to_color_image(img_array, filter_type, cutoff, order=1):
    filtered_channels = []
    masks = []
    for channel in range(3):
        filtered_channel, mask = low_pass_filter(img_array[:, :, channel],␣
 ↪filter_type, cutoff, order)
        filtered_channels.append(filtered_channel)
        masks.append(mask)

    filtered_img = np.stack(filtered_channels, axis=-1).astype(np.uint8)
```

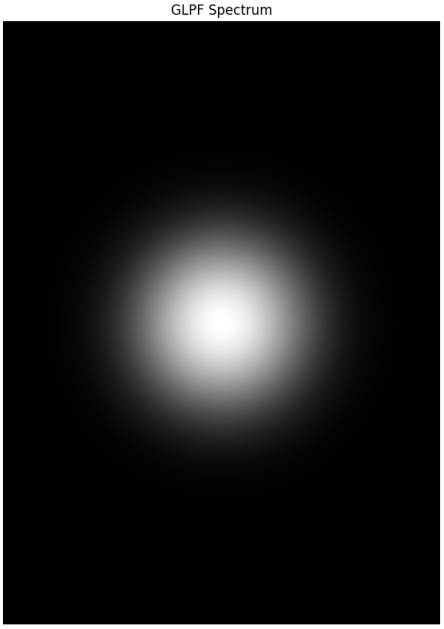
```
    return filtered_img, masks

image_path = 'image/d (1).png'
img = cv2.imread(image_path)
img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)

img_ILPF, masks_ILPF = apply_filter_to_color_image(img, 'ILPF',␣
 ↪higher_cutoff_ILPF)
img_BLPF, masks_BLPF = apply_filter_to_color_image(img, 'BLPF',␣
 ↪higher_cutoff_BLPF)
img_GLPF, masks_GLPF = apply_filter_to_color_image(img, 'GLPF',␣
 ↪higher_cutoff_GLPF)

plt.figure(figsize=(16, 24))

plt.subplot(3, 2, 1)
plt.imshow(np.log(1 + np.abs(masks_ILPF[0])), cmap='gray')
plt.title('ILPF Spectrum')
plt.axis('off')

plt.subplot(3, 2, 2)
plt.imshow(img_ILPF)
plt.title('ILPF Result')
plt.axis('off')

plt.subplot(3, 2, 3)
plt.imshow(np.log(1 + np.abs(masks_GLPF[0])), cmap='gray')
plt.title('GLPF Spectrum')
plt.axis('off')

plt.subplot(3, 2, 4)
plt.imshow(img_GLPF)
plt.title('GLPF Result')
plt.axis('off')

plt.subplot(3, 2, 5)
plt.imshow(np.log(1 + np.abs(masks_BLPF[0])), cmap='gray')
plt.title('BLPF Spectrum')
plt.axis('off')

plt.subplot(3, 2, 6)
plt.imshow(img_BLPF)
plt.title('BLPF Result')
plt.axis('off')

plt.tight_layout()
plt.show()
```

ILPF Spectrum



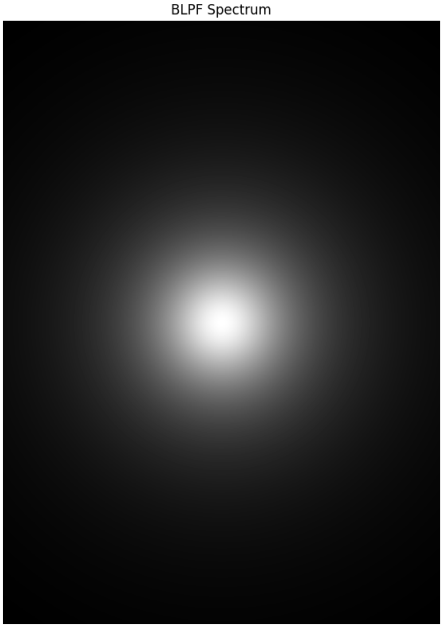
ILPF Result

GLPF Spectrum



GLPF Result

BLPF Spectrum

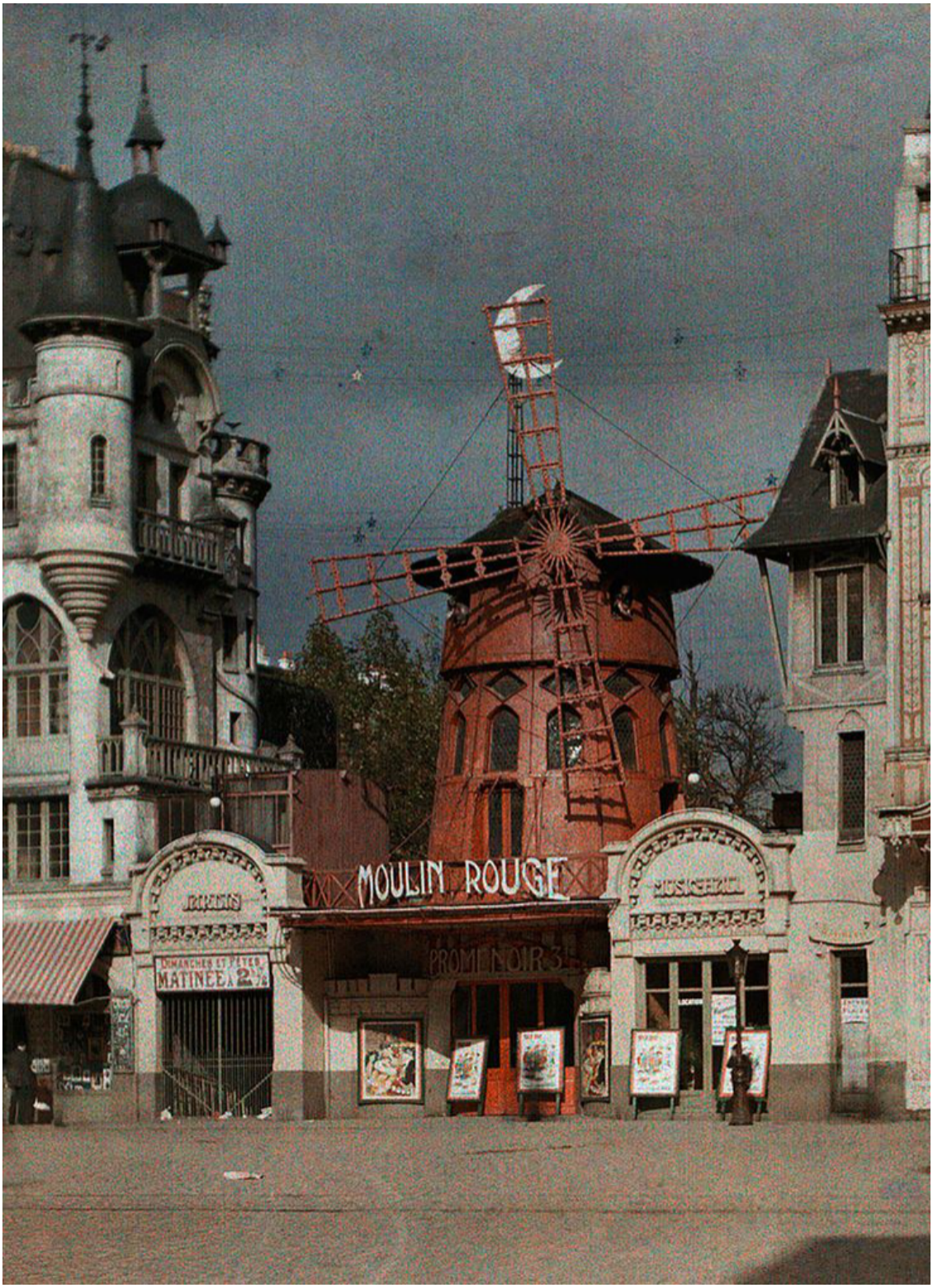


BLPF Result

Filter Type	Spektrum	Hasil Gambar	Keterangan
ILPF (Ideal Low Pass Filter)	Spektrum menampilkan lingkaran tajam. Frekuensi rendah di dalam lingkaran dipertahankan, frekuensi tinggi di luar dihilangkan.	Gambar menunjukkan smoothing yang signifikan, tetapi sering muncul artefak seperti **ringing** pada beberapa area gambar.	ILPF memberikan transisi yang sangat tajam antara frekuensi, menghasilkan gambar yang halus, namun menyebabkan artefak dan hilangnya beberapa detail.
GLPF (Gaussian Low Pass Filter)	Spektrum menunjukkan transisi yang sangat lembut dan gradual.	Gambar dihasilkan dengan smoothing yang sangat halus, tetapi beberapa detail penting mungkin hilang sehingga gambar bisa terlihat lebih soft.	GLPF memberikan hasil smoothing yang sangat natural, namun terkadang berlebihan sehingga menyebabkan hilangnya beberapa detail penting pada gambar.
BLPF (Butterworth Low Pass Filter)	Spektrum menunjukkan transisi yang lebih gradual dibanding ILPF, tetapi tidak sehalus GLPF.	Gambar menunjukkan keseimbangan antara smoothing dan detail, dengan hasil yang lebih jernih dan minim artefak ringing dibanding ILPF.	BLPF sering kali dianggap lebih baik dalam menjaga keseimbangan antara smoothing dan mempertahankan detail gambar, menjadikannya lebih jernih daripada GLPF.

2.1 Result

[5]:
```
cv2.imwrite('result//img_ILPF.png', cv2.cvtColor(img_ILPF, cv2.COLOR_RGB2BGR))
cv2.imwrite('result//img_GLPF.png', cv2.cvtColor(img_GLPF, cv2.COLOR_RGB2BGR))
cv2.imwrite('result//img_BLPF.png', cv2.cvtColor(img_BLPF, cv2.COLOR_RGB2BGR))

display(Image(filename='image/d (1).png'))
display(Image(filename='result//img_ILPF.png'))
display(Image(filename='result//img_GLPF.png'))
display(Image(filename='result//img_BLPF.png'))
```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3 Sharpening

[6]:
```
image_path = 'Image\\istockphoto-1204011139-170667a.jpg'
image = cv2.imread(image_path)
image_rgb = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)

buf = io.BytesIO()
plt.imsave(buf, image_rgb, format='png')
buf.seek(0)

display(IPImage(buf.read(), format='png', embed=True))
```

[7]:
```
def check_image(image):
    if image is None or image.size == 0:
        raise ValueError("Image is empty or not loaded properly. Please check␣
↪the image path or content.")
```

```
def apply_butterworth_high_pass(image, D0, n, alpha, beta):
    check_image(image)

    dft = np.fft.fft2(image)
    dft_shift = np.fft.fftshift(dft)

    rows, cols = image.shape
    crow, ccol = rows // 2, cols // 2

    x = np.linspace(-ccol, ccol, cols)
    y = np.linspace(-crow, crow, rows)
    X, Y = np.meshgrid(x, y)
    D = np.sqrt(X**2 + Y**2)

    D[D == 0] = 0.0001
    BHPF = 1 - 1 / (1 + (D0 / D)**(2 * n))

    fshift = dft_shift * BHPF
    f_ishift = np.fft.ifftshift(fshift)
    img_back = np.fft.ifft2(f_ishift)
    img_back = np.abs(img_back)

    image_float = image.astype(np.float32)
    img_back_float = img_back.astype(np.float32)

    sharpened = cv2.addWeighted(image_float, alpha, img_back_float, beta, 0)

    return sharpened

def apply_ihpf(image, D0, alpha, beta):
    check_image(image)

    dft = np.fft.fft2(image)
    dft_shift = np.fft.fftshift(dft)

    rows, cols = image.shape
    crow, ccol = rows // 2, cols // 2

    mask = np.ones((rows, cols), np.uint8)
    r = D0
    center = [crow, ccol]
    x, y = np.ogrid[:rows, :cols]
    mask_area = (x - center[0])**2 + (y - center[1])**2 <= r*r
    mask[mask_area] = 0

    fshift = dft_shift * mask
    f_ishift = np.fft.ifftshift(fshift)
```

```
    img_back = np.fft.ifft2(f_ishift)
    img_back = np.abs(img_back)

    image_float = image.astype(np.float32)
    img_back_float = img_back.astype(np.float32)
    sharpened = cv2.addWeighted(image_float, alpha, img_back_float, beta, 0)

    return sharpened

def apply_ghpf(image, D0, alpha, beta):
    check_image(image)

    dft = np.fft.fft2(image)
    dft_shift = np.fft.fftshift(dft)

    rows, cols = image.shape
    crow, ccol = rows // 2, cols // 2

    x = np.linspace(-ccol, ccol, cols)
    y = np.linspace(-crow, crow, rows)
    X, Y = np.meshgrid(x, y)
    D = np.sqrt(X**2 + Y**2)

    GHPF = 1 - np.exp(-(D**2) / (2 * (D0**2)))

    fshift = dft_shift * GHPF
    f_ishift = np.fft.ifftshift(fshift)
    img_back = np.fft.ifft2(f_ishift)
    img_back = np.abs(img_back)

    image_float = image.astype(np.float32)
    img_back_float = img_back.astype(np.float32)
    sharpened = cv2.addWeighted(image_float, alpha, img_back_float, beta, 0)

    return sharpened

image_path = 'Image\\istockphoto-1204011139-170667a.jpg'
image = cv2.imread(image_path)

check_image(image)

image_yuv = cv2.cvtColor(image, cv2.COLOR_BGR2YCrCb)
y_channel, Cr, Cb = cv2.split(image_yuv)

D0_ihpf = 1
alpha_ihpf = 50.0
beta_ihpf = -5.0
```

```
D0_ghpf = 2
alpha_ghpf = 45.0
beta_ghpf = -4.5

D0_bhpf = 2
alpha_bhpf = 45.0
beta_bhpf = -4.5

ihpf_y_channel = apply_ihpf(y_channel, D0_ihpf, alpha_ihpf, beta_ihpf)
ghpf_y_channel = apply_ghpf(y_channel, D0_ghpf, alpha_ghpf, beta_ghpf)
bhpf_y_channel = apply_butterworth_high_pass(y_channel, D0_bhpf, 2, alpha_bhpf,␣
 ↪beta_bhpf)

ihpf_y_channel_uint8 = cv2.normalize(ihpf_y_channel, None, 0, 255, cv2.
 ↪NORM_MINMAX).astype(np.uint8)
ghpf_y_channel_uint8 = cv2.normalize(ghpf_y_channel, None, 0, 255, cv2.
 ↪NORM_MINMAX).astype(np.uint8)
bhpf_y_channel_uint8 = cv2.normalize(bhpf_y_channel, None, 0, 255, cv2.
 ↪NORM_MINMAX).astype(np.uint8)

ihpf_image_color = cv2.merge((ihpf_y_channel_uint8, Cr, Cb))
ghpf_image_color = cv2.merge((ghpf_y_channel_uint8, Cr, Cb))
bhpf_image_color = cv2.merge((bhpf_y_channel_uint8, Cr, Cb))

ihpf_image_bgr = cv2.cvtColor(ihpf_image_color, cv2.COLOR_YCrCb2BGR)
ghpf_image_bgr = cv2.cvtColor(ghpf_image_color, cv2.COLOR_YCrCb2BGR)
bhpf_image_bgr = cv2.cvtColor(bhpf_image_color, cv2.COLOR_YCrCb2BGR)

plt.figure(figsize=(20, 15))

plt.subplot(3, 4, 1)
plt.imshow(cv2.cvtColor(image, cv2.COLOR_BGR2RGB))
plt.title('Original Image')
plt.axis('off')

plt.subplot(3, 4, 3)
plt.imshow(cv2.cvtColor(ihpf_image_bgr, cv2.COLOR_BGR2RGB))
plt.title('IHPF Image with Enhanced Edges')
plt.axis('off')

plt.subplot(3, 4, 5)
plt.imshow(cv2.cvtColor(ghpf_image_bgr, cv2.COLOR_BGR2RGB))
plt.title('GHPF Image with Enhanced Edges')
plt.axis('off')

plt.subplot(3, 4, 7)
```

```
plt.imshow(cv2.cvtColor(bhpf_image_bgr, cv2.COLOR_BGR2RGB))
plt.title('BHPF Image with Enhanced Edges')
plt.axis('off')

plt.show()
```

Gambar	Deskripsi
Original Image	Gambar asli tanpa penajaman atau pengolahan tambahan. Tekstur kulit tampak natural dan detail halus belum terlihat menonjol.
IHPF	Gambar yang diproses dengan Ideal High Pass Filter. Penajaman tepi sangat kuat, membuat garis-garis halus pada kulit terlihat tajam. Metode ini mengutamakan detail pada frekuensi tinggi, tetapi dapat menghasilkan efek yang lebih kasar pada tepi, terutama pada area-area yang sangat bertekstur.
GHPF	Gambar yang diproses dengan Gaussian High Pass Filter. Penajaman lebih halus dibandingkan IHPF, tetapi menyebar merata pada tepi. Filter ini menghasilkan efek penajaman yang lebih halus dan natural pada kulit, dengan transisi yang lebih lembut sehingga detail tampak lebih menonjol tanpa efek kasar.

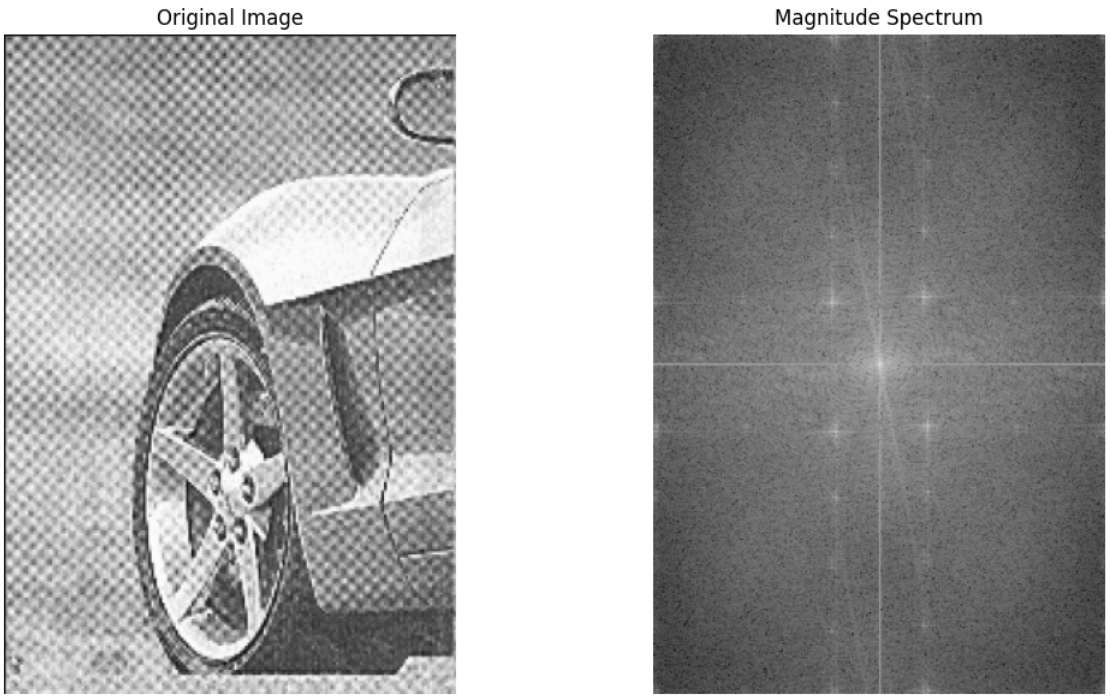
Gambar	Deskripsi
BHPF	Gambar yang diproses dengan Butterworth High Pass Filter. Hasil penajaman terlihat lebih halus dengan transisi yang sangat lembut. Filter ini memberikan peningkatan detail yang signifikan, namun dengan efek yang lebih menonjol daripada GHPF. Tekstur kulit tampak lebih jelas tanpa meningkatkan kontras secara ekstrem.

[8]:
```
def save_image_to_bytes(image_data, is_color=False):
    buf = io.BytesIO()
    if is_color:
        plt.imsave(buf, cv2.cvtColor(image_data, cv2.COLOR_BGR2RGB),␣
 ↪format='png')
    else:
        plt.imsave(buf, image_data, cmap='gray', format='png')
    buf.seek(0)
    return buf

original_buf = save_image_to_bytes(image, is_color=True)
ihpf_buf = save_image_to_bytes(ihpf_image_bgr, is_color=True)
ghpf_buf = save_image_to_bytes(ghpf_image_bgr, is_color=True)
bhpf_buf = save_image_to_bytes(bhpf_image_bgr, is_color=True)

display(IPImage(original_buf.read(), format='png', embed=True))
display(IPImage(ihpf_buf.read(), format='png', embed=True))
display(IPImage(ghpf_buf.read(), format='png', embed=True))
display(IPImage(bhpf_buf.read(), format='png', embed=True))
```

4 Notch Reject Filter

[9]:
```
img = cv2.imread('Image\\hiIzt.png', 0)

f = np.fft.fft2(img)
fshift = np.fft.fftshift(f)
magnitude_spectrum = 20 * np.log(np.abs(fshift))

plt.figure(figsize=(12, 6))

plt.subplot(121)
plt.imshow(img, cmap='gray')
plt.title('Original Image')
plt.axis('off')

plt.subplot(122)
```

```
plt.imshow(magnitude_spectrum, cmap='gray')
plt.title('Magnitude Spectrum')
plt.axis('off')

plt.tight_layout()
plt.show()
```

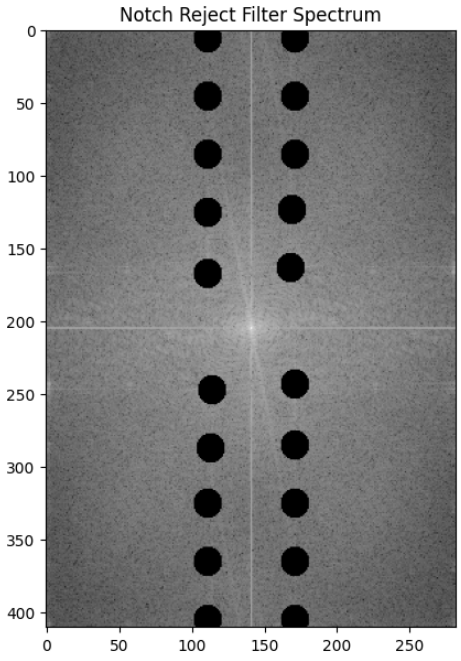


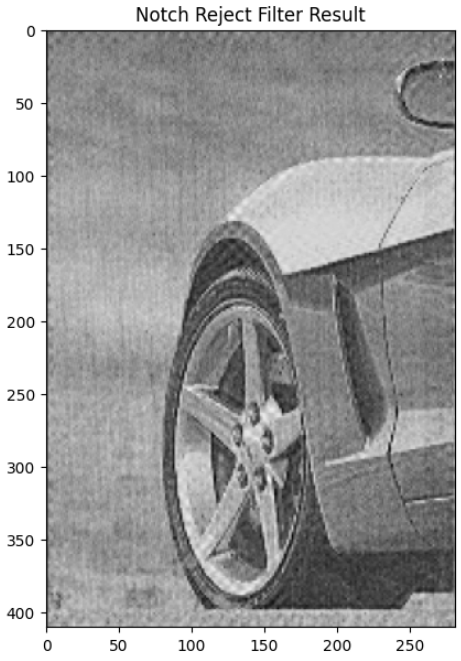
[10]:
```
def notch_reject_filter(shape, d0, u_k, v_k):
    P, Q = shape
    H = np.ones((P, Q))
    for u in range(P):
        for v in range(Q):
            D_uv = np.sqrt((u - P / 2 + u_k) ** 2 + (v - Q / 2 + v_k) ** 2)
            D_muv = np.sqrt((u - P / 2 - u_k) ** 2 + (v - Q / 2 - v_k) ** 2)
            if D_uv <= d0 or D_muv <= d0:
                H[u, v] = 0.0
    return H

def butterworth_notch_reject_filter(shape, d0, u_k, v_k, n):
    P, Q = shape
    H = np.ones((P, Q))
    for u in range(P):
        for v in range(Q):
            D_uv = np.sqrt((u - P / 2 + u_k) ** 2 + (v - Q / 2 + v_k) ** 2)
```

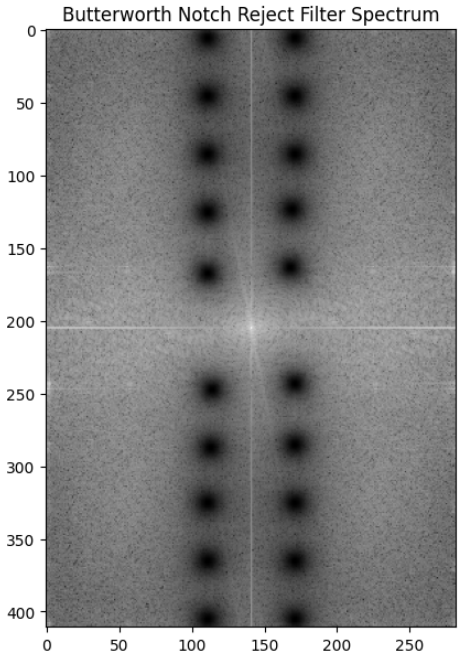
```
            D_muv = np.sqrt((u - P / 2 - u_k) ** 2 + (v - Q / 2 - v_k) ** 2)
            H[u, v] = 1 / (1 + (d0 / (D_uv + 1e-5)) ** (2 * n)) * 1 / (1 + (d0 /
 ↪ (D_muv + 1e-5)) ** (2 * n))
    return H

notch_params = [
    (10, 38, 30),
    (10, -42, 27),
    (10, 80, 30),
    (10, -82, 28),
    (10, 120, 30),
    (10, -120, 30),
    (10, 160, 30),
    (10, -160, 30),
    (10, 200, 30),
    (10, -200, 30),
]

butterworth_params = [
    (10, 38, 30, 1),
    (10, -42, 27, 1),
    (10, 80, 30, 1),
    (10, -82, 28, 1),
    (10, 120, 30, 1),
    (10, -120, 30, 1),
    (10, 160, 30, 1),
    (10, -160, 30, 1),
    (10, 200, 30, 1),
    (10, -200, 30, 1),
]
```

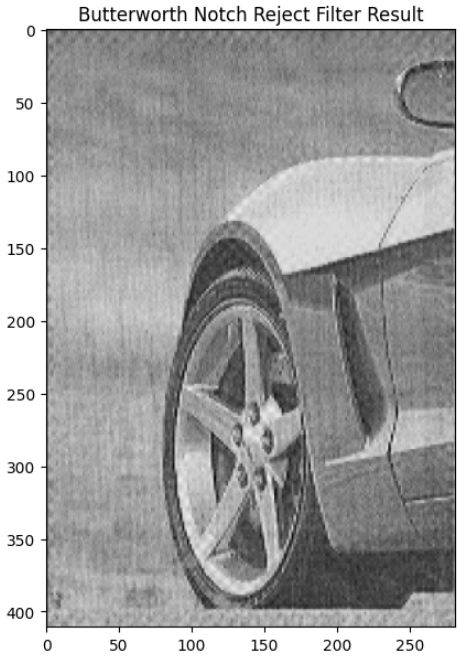
[11]:
```
img_shape = img.shape

NotchFilter = np.ones(img_shape)
for params in notch_params:
    d0, u_k, v_k = params
    NotchFilter *= notch_reject_filter(img_shape, d0, u_k, v_k)

NotchRejectCenter = fshift * NotchFilter
NotchReject = np.fft.ifftshift(NotchRejectCenter)
inverse_NotchReject = np.fft.ifft2(NotchReject)
NotchRejectResult = np.abs(inverse_NotchReject)

ButterworthFilter = np.ones(img_shape)
for params in butterworth_params:
    d0, u_k, v_k, n = params
```

```
    ButterworthFilter *= butterworth_notch_reject_filter(img_shape, d0, u_k,␣
 ↪v_k, n)

ButterworthRejectCenter = fshift * ButterworthFilter
ButterworthReject = np.fft.ifftshift(ButterworthRejectCenter)
inverse_ButterworthReject = np.fft.ifft2(ButterworthReject)
ButterworthRejectResult = np.abs(inverse_ButterworthReject)

plt.figure(figsize=(12, 18))

plt.subplot(321)
plt.imshow(magnitude_spectrum * NotchFilter, cmap='gray')
plt.title('Notch Reject Filter Spectrum')

plt.subplot(322)
plt.imshow(NotchRejectResult, cmap='gray')
plt.title("Notch Reject Filter Result")

plt.subplot(323)
plt.imshow(magnitude_spectrum * ButterworthFilter, cmap='gray')
plt.title("Butterworth Notch Reject Filter Spectrum")

plt.subplot(324)
plt.imshow(ButterworthRejectResult, cmap='gray')
plt.title("Butterworth Notch Reject Filter Result")

plt.tight_layout()
plt.show()
```







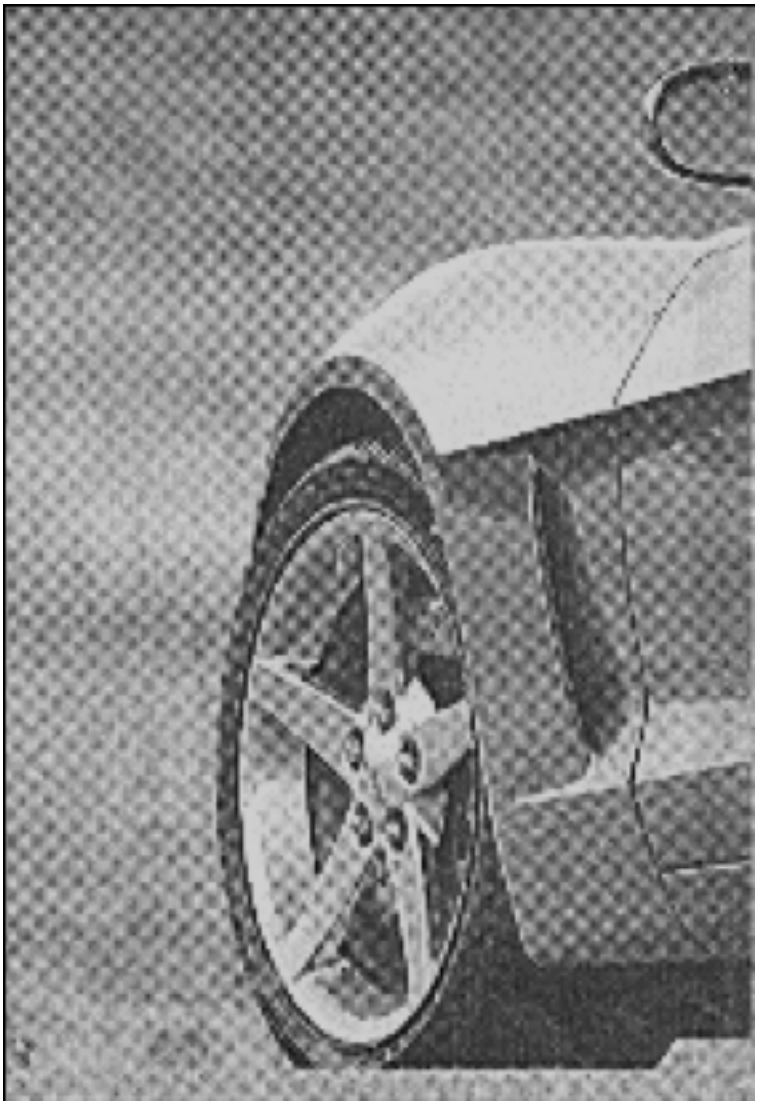


Jenis	Penjelasan Spektrum	Deskripsi
Notch Reject Filter	Spektrum menunjukkan beberapa titik hitam pada garis horizontal dan vertikal, yang mengindikasikan frekuensi yang telah diblokir secara tajam oleh filter.	Gambar hasil setelah filter menunjukkan noise yang berkurang terutama pada area dengan detail tajam seperti roda mobil. Filter ini lebih tajam dan dapat menyebabkan sedikit artefak.

Jenis	Penjelasan Spektrum	Deskripsi
Butterworth Notch Reject Filter	Spektrum menunjukkan titik hitam yang lebih kabur dibandingkan Notch Reject Filter, yang menandakan transisi frekuensi yang lebih halus dan lembut pada frekuensi yang diblokir.	Hasil filter menunjukkan pengurangan noise yang lebih halus, menghasilkan gambar yang lebih natural, meskipun beberapa detail halus tetap terlihat. Filter ini lebih lembut dan minim artefak.

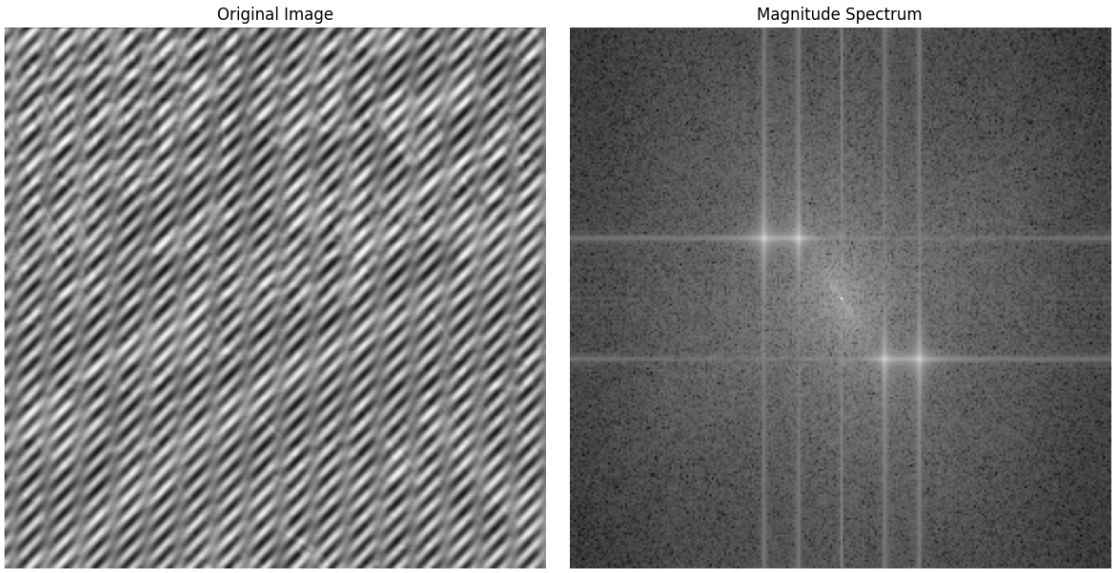
4.1 Result

[12]:
```
display(Image(filename='Image\\hiIzt.png'))
cv2.imwrite('result/NotchRejectResult.png', NotchRejectResult)
cv2.imwrite('result/ButterworthRejectResult.png', ButterworthRejectResult)
display(Image(filename='result/NotchRejectResult.png'))
display(Image(filename='result/ButterworthRejectResult.png'))
```



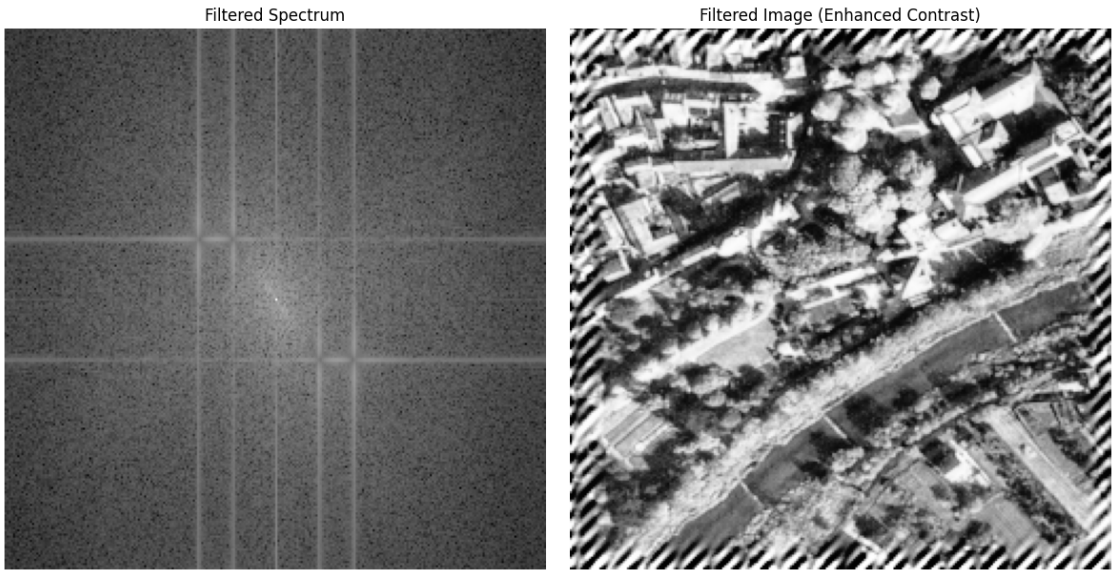
[13]:
```
# Read the image
img_path = 'Image\\YmW3f.png'
img = cv2.imread(img_path, 0)

# Compute the FFT and magnitude spectrum
f = np.fft.fft2(img)
fshift = np.fft.fftshift(f)
magnitude_spectrum = 20 * np.log(np.abs(fshift))

# Plot the image and its magnitude spectrum
plt.figure(figsize=(12, 6))

plt.subplot(121)
plt.imshow(img, cmap='gray')
```

```
plt.title('Original Image')
plt.axis('off')

plt.subplot(122)
plt.imshow(magnitude_spectrum, cmap='gray')
plt.title('Magnitude Spectrum')
plt.axis('off')

plt.tight_layout()
plt.show()
```



[14]:
```
def norm_img(img):
    return (img - np.min(img)) / (np.max(img) - np.min(img))

def show_spec(img):
    spectrum = norm_img(np.log(np.abs(img) + 1.0001))
    plt.imshow(spectrum, cmap='gray')

def gNotch(v, mu, cov):
    diff = v - mu[:, np.newaxis]
    return 1 - np.exp(-0.5 * np.sum(diff * (np.linalg.inv(cov) @ diff), axis=0))

f = np.fft.fft2(img)
fshift = np.fft.fftshift(f)
m, n = fshift.shape

cx, cy = 129, 129
wx1, wx2 = 149.5 - cx, 165.5 - cx
```

```
wy = 157.5 - cy
sigma = 5

filt = np.ones((m, n))

y, x = np.meshgrid(np.arange(1, n+1), np.arange(1, m+1))
X = np.vstack((y.ravel(), x.ravel()))

coords = [
    [cx + wx1, cy + wy],
    [cx + wx2, cy + wy],
    [cx - wx1, cy - wy],
    [cx - wx2, cy - wy]
]

for coord in coords:
    filt *= gNotch(X, np.array(coord), np.eye(2) * sigma**2).reshape(m, n)

fshift_filtered = fshift * filt

ifft_ = np.fft.ifft2(np.fft.ifftshift(fshift_filtered))
img_res = norm_img(np.abs(ifft_))

# Enhance contrast using histogram equalization
img_res_enhanced = cv2.equalizeHist((img_res * 255).astype(np.uint8))

plt.figure(figsize=(12, 6))

plt.subplot(121)
show_spec(fshift_filtered)
plt.title('Filtered Spectrum')
plt.axis('off')

plt.subplot(122)
plt.imshow(img_res_enhanced, cmap='gray')
plt.title('Filtered Image (Enhanced Contrast)')
plt.axis('off')

plt.tight_layout()
plt.show()
```



Reference:

- https://stackoverflow.com/questions/65483030/notch-reject-filtering-in-python
- https://stackoverflow.com/questions/29235421/find-proper-notch-filter-to-remove-pattern-from-image

5 Image Compression

[15]:
```
image = cv2.imread(r'Image\d (1).png', cv2.IMREAD_COLOR)
image = cv2.cvtColor(image, cv2.COLOR_BGR2RGB)  # Convert BGR to RGB

def compress_dct(image, keep_fraction=0.1):
    compressed_image = np.zeros_like(image)
    for i in range(3):  # Apply DCT to each color channel
        dct_transformed = dct(dct(image[:, :, i].T, norm='ortho').T,␣
 ↪norm='ortho')
        rows, cols = dct_transformed.shape
        dct_transformed[int(rows*keep_fraction):, int(cols*keep_fraction):] = 0
        compressed_image[:, :, i] = idct(idct(dct_transformed.T, norm='ortho').
 ↪T, norm='ortho')
    return np.uint8(compressed_image)

def compress_fourier(image, keep_fraction=0.1):
    compressed_image = np.zeros_like(image)
    for i in range(3):  # Apply Fourier Transform to each color channel
        f_transform = fft2(image[:, :, i])
        r, c = f_transform.shape
        f_transform[int(r*keep_fraction):, int(c*keep_fraction):] = 0
```

```
        compressed_image[:, :, i] = np.real(ifft2(f_transform))
    return np.uint8(compressed_image)

compressed_dct = compress_dct(image, keep_fraction=0.2)
compressed_fourier = compress_fourier(image, keep_fraction=0.2)

original_size = image.nbytes
dct_size = compressed_dct.nbytes
fourier_size = compressed_fourier.nbytes

plt.figure(figsize=(15, 5))

plt.subplot(1, 3, 1)
plt.title("Original Image")
plt.imshow(image)
plt.axis('off')

plt.subplot(1, 3, 2)
plt.title("DCT Compressed Image")
plt.imshow(compressed_dct)
plt.axis('off')

plt.subplot(1, 3, 3)
plt.title("Fourier Compressed Image")
plt.imshow(compressed_fourier)
plt.axis('off')

plt.tight_layout()
plt.show()
```

[16]:
```
# Convert images to BGR for saving with OpenCV
compressed_dct_bgr = cv2.cvtColor(compressed_dct, cv2.COLOR_RGB2BGR)
```

```
compressed_fourier_bgr = cv2.cvtColor(compressed_fourier, cv2.COLOR_RGB2BGR)

cv2.imwrite('result/compressed_dct.jpg', compressed_dct_bgr, [int(cv2.
 ↪IMWRITE_JPEG_QUALITY), 90])
cv2.imwrite('result/compressed_fourier.jpg', compressed_fourier_bgr, [int(cv2.
 ↪IMWRITE_JPEG_QUALITY), 90])

# Calculate the original and compressed image sizes
original_size = image.nbytes
dct_jpg_size = os.path.getsize('result/compressed_dct.jpg')
fourier_jpg_size = os.path.getsize('result/compressed_fourier.jpg')

print(f"Original Image Size: {original_size} bytes")
print(f"After DCT Compression (saved as JPG): {dct_jpg_size} bytes")
print(f"After Fourier Compression (saved as JPG): {fourier_jpg_size} bytes")
```

```
Original Image Size: 2243328 bytes
After DCT Compression (saved as JPG): 262949 bytes
After Fourier Compression (saved as JPG): 230138 bytes
```

Keterangan	Ukuran Gambar (bytes)	Deskripsi
Ukuran Gambar Asli	2,243,328	Gambar original tanpa kompresi dengan resolusi penuh.
Setelah Kompresi DCT (disimpan sebagai JPG)	262,949	Gambar dikompresi menggunakan DCT dengan menghilangkan frekuensi tinggi, menghasilkan ukuran lebih kecil dengan sedikit penurunan kualitas.
Setelah Kompresi Fourier (disimpan sebagai JPG)	230,138	Gambar dikompresi menggunakan Fourier Transform, menghasilkan ukuran paling kecil tetapi dengan lebih banyak distorsi pada detail halus.