Introduction to Video Processing

HW4

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March 13, 2025

HW4: Fourier Transform for Translating Sinusoidal Video

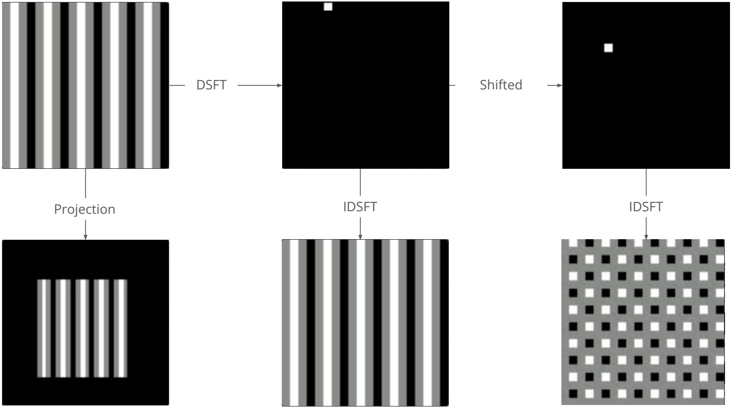


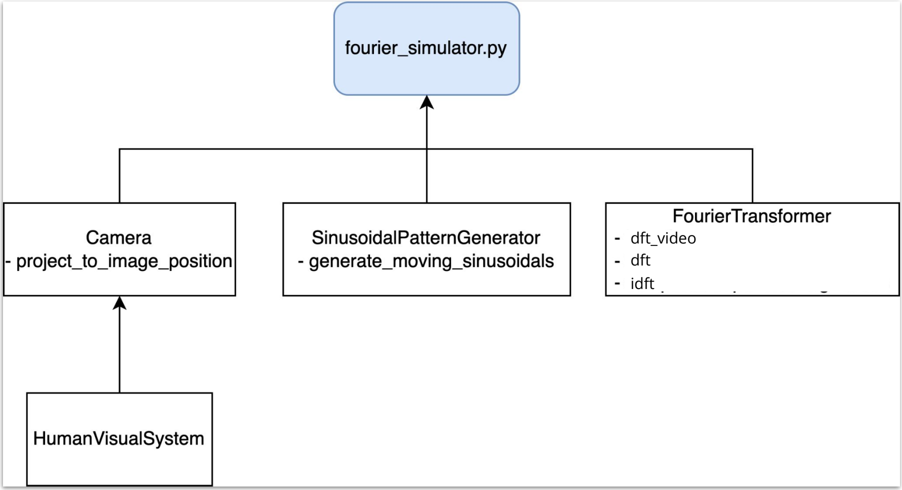
Figure: Overview of the workflow.

You should complete the following tasks:

- Complete the provided codes.
- Provide a HW report (see report guidelines).

Code Completion

(*Code Architecture*)



(Tracing on **fourier_simulator.py**)

```
from sinusoidal_pattern_generator import *
from fourier_transformer import *
from visualizer import *
import os.path

fx_vid = 0.5 # Cycles per mm along horizontal direction
fy_vid = 0.0 # Cycles per mm along vertical direction
vx_vid = 0.2 # Speed along horizontal direction mm/sec
vy_vid = 0.2 # Speed along vertical direction in mm/sec
Tb = 0 # Beginning of the time
dt = 1 # Frame time in seconds
Te = 30 # End of the time in seconds
fps = (Te - Tb) / dt
```

- The spatial temporal signal is a moving sinusoidal pattern.
- *fx_vid, fy_vid, vx_vid, vy_vid, Tb, dt, Te* characterize frequencies of the 3D sinusoidal signal.

(Continue)

```
# Physical Length of the image plane
h_mm = 10
w_mm = 10
d_mm = 15

# Height, width, and interval in pixels
height = 100
width = 100
intv = 5 # Interval for downsampling the frequency and spatial temporal
    variables
```

- *h_mm, w_mm, d_mm, height, width, intv* characterizes the resolution of the signal.

(Continue)

```
print('Generating the sinusoidal signal...')
pattern_generator = SinusoidalPatternGenerator(w_mm, h_mm, width, height, Tb, Te)
spatial_temporal_signal = pattern_generator.generate_moving_sinusoidals(fx_vid, fy_vid, fps, vx_vid, vy_vid, intv)

# Viz for Spatial Temporal Signals
visualize_spatial_temporal_signal(folder_out + '/spatial_temporal.mp4', spatial_temporal_signal, width, height, fps, intv)

# Viz the viewer perspective results
visualize_viewed_signal(folder_out + '/viewing.mp4', spatial_temporal_signal, width, height, fps, intv, w_mm, h_mm, d_mm)
```

- The spatial temporal signal is generated by *generate_moving_sinusoidals*.
- We utilize two visualization functions for visualizing original spatial temporal signal and its viewing version.

(Continue)

```python
xformer = FourierTransformer()

# Compute frequency response
print('Computing Fourier transform for the sinusoidal signal...')
frequency_signal = xformer.dft_video(spatial_temporal_signal)

# Cache the results for testing or debugging
cache_signal(folder_out + '/frequency.sg', frequency_signal)
'''
# Load cached signal if you do not want to compute the same transform again, used for debugging.
frequency_signal = load_signal(folder_out + '/frequency.sg', spatial_temporal_signal.shape)
'''

# Viz for Frequency Response
visualize_frequency_signal(folder_out + '/frequency_response.mp4', frequency_signal, width, height, fps, intv)
```

- Create the fourier transformer.
- Use *dft_video* for the video transformation.
- We can cache or load signal for debugging or testing.

(Continue)

```
# Reconstruct spatial temporal signal via inverse fourier transform
print('Recovering the spatial temporal signal by inverse Fourier
    transform...')
recovered_signal = xformer.idft(frequency_signal)

# Cache reconstructed signal
cache_signal(folder_out + '/reconstruction.sg', recovered_signal)

# Visualize reconstructed signal (SHOULD be visually the same as
    original spatial temporal signal)
visualize_recovered_signal(folder_out + '/reconstruction.mp4',
    recovered_signal, width, height, fps, intv)
```

- We use *idft* for performing the inverse Fourier transform.
- The reconstructed signal should be ideally the same as original spatial temporal signal.

(Continue)

```
# Shift the frequency signal
print('Shifting the frequency signal...')
dx = 0
dy = 5
dt = 0
resized_height, resized_width, frames = frequency_signal.shape[0],
    frequency_signal.shape[1], frequency_signal.shape[2]
shifted_frequency_signal = np.zeros([resized_height, resized_width,
    frames], dtype=complex)
# TODO #2: Implement a shifting operation to move the frequency
    responses. The shifted responses are stored in
# shifted_frequency_signal

# Viz for Shifted Frequency signal
visualize_frequency_signal(folder_out + '/shifted_frequency.mp4',
    shifted_frequency_signal, width, height, fps, intv)
```

- Implement the frequency response shifting here by using *dx, dy, dt*.

(Continue)

```
# Generate the corresponding spatial temporal signal, it SHOULD be
    changed.
print('Generating new spatial temporal signal according to the shifted
    frequency signal...')
edited_spatial_temporal_signal = xformer.idft(shifted_frequency_signal)

# Cache the new spatial temporal signal
cache_signal(folder_out + '/edited_spatial_temporal.sg', edited_spatial
    _temporal_signal)

# Visualize the new spatial temporal signal
visualize_recovered_signal(folder_out + '/edited_spatial_temporal.mp4',
     edited_spatial_temporal_signal, width, height, fps, intv)
```

- Perform inverse Fourier transform on the shifted frequency signal, we will see the changed spatial temporal signal.

(Tracing on **fourier_transformer.py**)

```
class FourierTransformer():
    def __init__(self):
        pass

    '''
    Inputs:
        - video: 3D numpy array with real numbers
    Outputs:
        - output_signal: 3D numpy array with complex numbers
    '''
    def dft_video(self, video):
        # Convert the input video type into complex type
        video_complex = video.astype(complex)
        return self.dft(video_complex)
```

- The *dft_video* convert the type from real to complex.

(Continue)

```
    '''
    Inputs:
        - input_signal: 3D numpy array with complex numbers.
    Outputs:
        - output_signal: 3D numpy array with complex numbers.
    '''
    def dft(self, input_signal):
        # Get width, height, frames of the input_signal.
        height, width, frames = input_signal.real.shape[0], input_signal.real.shape[1], input_signal.real.shape[2]

        # Get frequency response by computing fourier dft on the input signals
        output_signal = np.zeros([height, width, frames], dtype=complex)

        # TODO #3: Implement 3D fourier transform for output_signal according to the DSFT formulas provided in the slides.
        # You are NOT ALLOWED to use any third party API to execute the Fourier transform

        return output_signal
```

(Continue)

```
    '''
    Inputs:
        - input_signal: 3D numpy array with complex numbers
    Outputs:
        - output_signal: 3D numpy array with complex numbers.
    '''
    def idft(self, input_signal):
        # Get width, height, frames of the input_signal.
        height, width, frames = input_signal.real.shape[0], input_
            signal.real.shape[1], input_signal.real.shape[2]

        # Get frequency response by computing fourier dft on the input
            signals
        output_signal = np.zeros([height, width, frames], dtype=complex
            )

        # TODO #4: Implement 3D inverse Fourier transform for output_
            signal according to the IDSFT formulas provided in the
            slides.
        # You are NOT ALLOWED to use any third party API to execute the
             inverse Fourier transform

        return output_signal
```

(Tracing on **visualizer.py**)

```
def visualize_spatial_temporal_signal(filename, signal, width, height,
     fps, intv):
   fourcc=cv2.VideoWriter_fourcc(*'mp4v')
   video = cv2.VideoWriter(filename, fourcc, fps, (width, height))
   image = np.zeros([height, width, 3], dtype = np.uint8)
   # Frame index of viz.
   f_viz = 0
   frames = signal.shape[2]
   for f in range(frames):
       for y in range(height):
           if y % intv == 0:
               # Get corrsponding y in signal
               resized_y = y // intv
               for x in range(width):
                   if x % intv == 0:
                       # Get corresponding x in signal
                       resized_x = x // intv
                       (See next page)
   video.release()
```

- The visualization images have more pixels than original signal.
- *resized_x, resized_y*: corresponding spatial position in the signal.

(Continue)

```
# Get corresponding signal
b = signal[resized_y, resized_x, f]

# Dump to signal if current frame is filled.
if (f > f_viz):
    video.write(image)
    f_viz += 1

# Normalization
b_viz = (b + 1) / 2 # Mapping the value from
    (-1, 1) to (0, 1)

# Draw response with thickness as the specified
    interval
image[y:y+intv, x:x+intv, :] = int(b_viz * 255)
    # Mapping to integer
```

- Visualize the signal by filling square areas for every 3D variable.

(Continue)

(Tracing on **sinusoidal_pattern_generator.py**)

```
class SinusoidalPatternGenerator():
    '''
    Inputs:
        w_mm: plane width in milli meters
        h_mm: plane height in milli meters
        width: number of pixels on the horizontal direction
        height: number of pixels on the vertical direction
        Tb: Beginning of the time
        Te: End of the time
    '''
    def __init__(self, w_mm, h_mm, width, height, Tb, Te):
        self.w_mm = w_mm
        self.h_mm = h_mm
        self.width = width
        self.height = height
        self.Te = Te
        self.Tb = Tb
```

- A moving sinusoidal pattern in a plane.

(Continue)

```
'''
Inputs:
    fx: frequency on horizontal direction in cycles per mm
    fy: frequency on vertical direction in cycles per mm
    ft: frequency on temporal direction in frames per sec
    vx: velocity along horizontal direction in mm/sec
    vy: velocity along vertical direction in mm/sec
    intv: Interval for downsampling the frequency and spatial
        temporal variables
Outputs:
    video: temporal spatial signal. A list of 4D vectors: [b, x, y,
         t], where x, y, t represents the temporal
    sample, and b represents the brightness (singal) on (x, y, t)
'''
def generate_moving_sinusoidals(self, fx, fy, ft, vx, vy, intv):
    (See next page)
```

- The actual function to generate sinusoidal signal.

(Continue)

```python
        # Set video dimension
        pix_per_mm = self.width / self.w_mm # Resolution

        # Build time sequence with the interval (Tb, Te, dt)
        times = []
        dt = self.Te / ft
        t = self.Tb
        while t < self.Te:
            times.append(t)
            t += dt
```

- Build time sequence and set the resolution (*pix_per_mm*).

(Continue)

```
        # Pre-compute video samples based on the interval
        frames = len(times)
        resized_height = (self.height - 1) // intv + 1
        resized_width = (self.width - 1) // intv + 1
        video = np.zeros([resized_height, resized_width, frames])
        for f in range(frames): # Frame
            for y in range(self.height):
                if y % intv == 0: # Downsampling for reducing the
                    computing
                    for x in range(self.width):
                        if x % intv == 0: # Downsampling for reducing
                            the computing
                            (See next page)
```

- Downsampling the signal by *intv*.

(Continue)

```
# Compute input signal value as the brightness according to the specified sin pattern
x_mm = x / pix_per_mm # In mm
y_mm = y / pix_per_mm # In mm
t = times[f]
dx = vx * t
dy = vy * t
b = np.sin(fx * 2 * np.pi * (x_mm + dx) + fy * 2 * np.pi * (y_mm + dy)) # Should located in (-1, 1)
resized_y = y // intv
resized_x = x // intv
video[resized_y, resized_x, f] = b
```

- The brightness is changed by the three factors *fx, fy, dx, dy*.
- *dx* and *dy* are varied with the speed and time.

Report Guidelines

- Describe your implementation. (Do NOT paste code screen shot figures)
- Describe your understanding of theories.
- Describe your experiment settings and results.
  - Examine and analyze variations in results by adjusting the settings of the sinusodal patten.
  - Examine and analyze variations in results by adjusting the response shift of the frequency signal.
  - Share any additional noteworthy insights.
  - Raise any additional problems or sharing any additional insights.
- Describe your proofs.
- Write your division of labor (same rules as those of previous homework).
- Only .pdf file format is allowed.

Grading Criteria

- Richness of your experiments.
- Readability of the report.
- Clarity of your insights and the division of labor.

Scoring

- Code completion (80%)
- Report (20%)

Submission Guidelines

- Put all the codes into a folder *codes*.
- This time, the required videos/images are automatically put into the subfolder *results* in *codes*.
- Put all the experiemented videos (with additional experiment setting) into a folder *supplementary-material*.
- Put **videos**, **supplementary-material** (optional) and report.pdf into a folder **hw4** (i.e., they are under same level of the file tree)
- Compress **hw4** and specify the file format as hw4.zip.
- Upload hw4.zip onto Digital Platform 3.
- Deadline: 12:00 a.m. on March 27th.

Origin of The Latex Template

The latex template is downloaded from:
https://www.LaTeXTemplates.com

The Author: Vel (vel@latextemplates.com)

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