REPORT

Subject: Digital Signal Processing
Lecturer: prof. dr hab. Vasyl Martsenyuk

Laboratory #1 Date: 27.09.2024 Topic: Wprowadzenie do narzędzi i środowiska pracy w przetwarzaniu sygnałów cyfrowych: Python + biblioteki. Analiza sygnałów deterministycznych: implementacja podstawowych operacji na sygnałach czasowych. Second variant (2)	Bartosz Bieniek IT Science II degree, 1 semester, gr.A

1. Task:

Synthesize a discrete-time signal by using the IDFT in matrix notation for different values of N. Show the matrices W and K. Plot the signal synthesized.

Variant #2: [10, 5, 6, 6, 2, 4, 3, 4, 5, 0, 0, 0, 0]

2. Code description [Github Repository]

```python
# Zadanie 1
# Synthesize a discrete-time signal by using the IDFT in matrix notation for different values of N. Show the matrices W and K. Plot the signal synthesized.

import numpy as np
import matplotlib.pyplot as plt

# Given signal in the frequency domain
x_mu = np.array([10, 5, 6, 6, 2, 4, 3, 4,5,0, 0, 0, 0])

# Number of points (length of the signal)
N = len(x_mu)

# Create the W matrix (N x N)
W = np.exp(-2j * np.pi / N * np.outer(np.arange(N), np.arange(N)))

# Compute the IDFT (inverse discrete Fourier transform)
x = (1 / N) * np.dot(W, x_mu)

# Plot the synthesized signal (real part)
plt.figure(figsize=(10, 6))
plt.plot(np.arange(N), np.real(x), marker='o', linestyle='-', color='b', label="Real part")
plt.title(f"Synthesized signal using IDFT (N={N})")
plt.xlabel("n")
plt.ylabel("Amplitude")
plt.grid(True)
plt.legend()
plt.show()

# Print W and K matrices
print("Matrix W (N x N):")
print(W)
print("\nFrequency-domain signal (X_mu):")
print(x_mu)
```

TD. 1. Source code

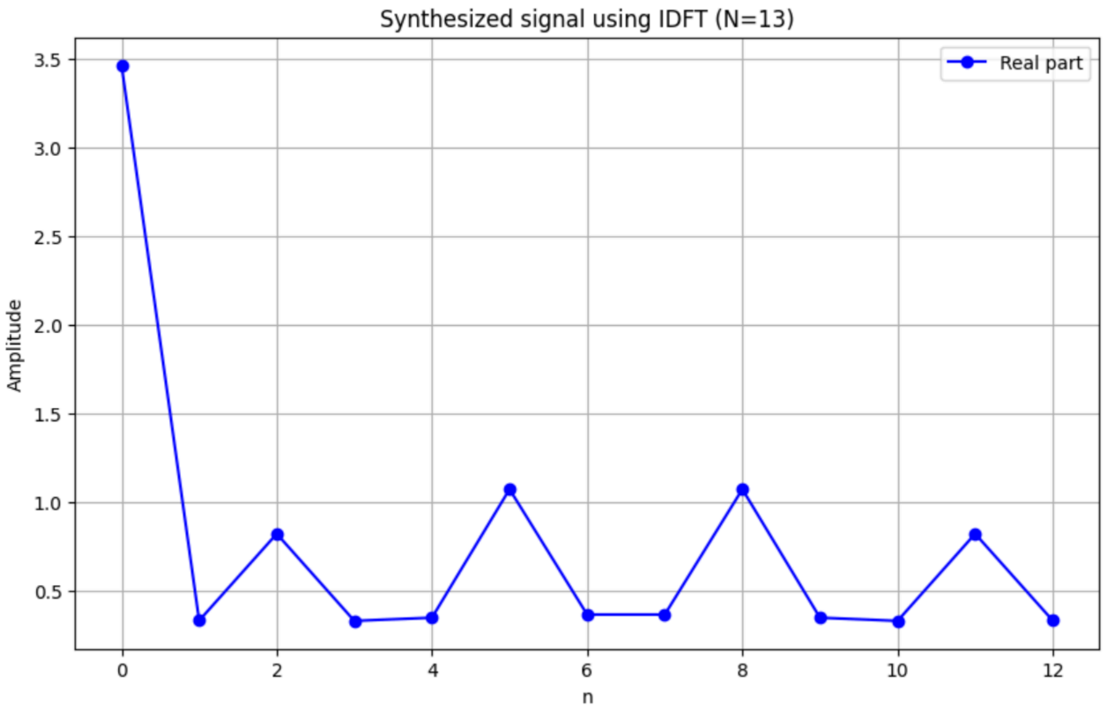
x_mu: This is the variable of frequency-domain signal provided by task variant.

W: This matrix represents the N-th root of unity. We create it using numpy's np.outer() method to generate the complex exponentials.

x: The time-domain signal is obtained by performing the matrix multiplication between WW and the frequency-domain signal Xμ.

Plotting: We use matplotlib to visualize the real part of the synthesized time-domain signal.

Matrix Printout: The code prints the WW matrix and the frequency-domain signal for verification. The result of plotting shows technical drawing number two:



TD. 3. Source code

The IDFT matrix WW contains complex numbers corresponding to the N-th roots of unity. The matris is shown down below:

```
Matrix W (N x N):
[[ 1.        +0.j          1.        +0.j          1.        +0.j
   1.        +0.j          1.        +0.j          1.        +0.j
   1.        +0.j          1.        +0.j          1.        +0.j
   1.        +0.j          1.        +0.j          1.        +0.j
   1.        +0.j        ]
 [ 1.        +0.j          0.88545603-0.46472317j  0.56806475-0.82298387j
   0.12053668-0.99270887j -0.35460489-0.93501624j -0.74851075-0.66312266j
  -0.97094182-0.23931566j -0.97094182+0.23931566j -0.74851075+0.66312266j
  -0.35460489+0.93501624j  0.12053668+0.99270887j  0.56806475+0.82298387j
   0.88545603+0.46472317j]
 [ 1.        +0.j          0.56806475-0.82298387j -0.35460489-0.93501624j
  -0.97094182-0.23931566j -0.74851075+0.66312266j  0.12053668+0.99270887j
   0.88545603+0.46472317j  0.88545603-0.46472317j  0.12053668-0.99270887j
  -0.74851075-0.66312266j -0.97094182+0.23931566j -0.35460489+0.93501624j
   0.56806475+0.82298387j]
 [ 1.        +0.j          0.12053668-0.99270887j -0.97094182-0.23931566j
  -0.35460489+0.93501624j  0.88545603+0.46472317j  0.56806475-0.82298387j
  -0.74851075-0.66312266j -0.74851075+0.66312266j  0.56806475+0.82298387j
   0.88545603-0.46472317j -0.35460489-0.93501624j -0.97094182+0.23931566j
   0.12053668+0.99270887j]
 [ 1.        +0.j         -0.35460489-0.93501624j -0.74851075+0.66312266j
   0.88545603+0.46472317j  0.12053668-0.99270887j -0.97094182+0.23931566j
   0.56806475+0.82298387j  0.56806475-0.82298387j -0.97094182-0.23931566j
   0.12053668+0.99270887j  0.88545603-0.46472317j -0.74851075-0.66312266j
  -0.35460489+0.93501624j]
 [ 1.        +0.j         -0.74851075-0.66312266j  0.12053668+0.99270887j
   0.56806475-0.82298387j -0.97094182+0.23931566j  0.88545603+0.46472317j
  -0.35460489-0.93501624j -0.35460489+0.93501624j  0.88545603-0.46472317j
  -0.97094182-0.23931566j  0.56806475+0.82298387j  0.12053668-0.99270887j
  -0.74851075+0.66312266j]
 [ 1.        +0.j         -0.97094182-0.23931566j  0.88545603+0.46472317j
  -0.74851075-0.66312266j  0.56806475+0.82298387j -0.35460489-0.93501624j
   0.12053668+0.99270887j  0.12053668-0.99270887j -0.35460489+0.93501624j
   0.56806475-0.82298387j -0.74851075+0.66312266j  0.88545603-0.46472317j
  -0.97094182+0.23931566j]
 [ 1.        +0.j         -0.97094182+0.23931566j  0.88545603-0.46472317j
  -0.74851075+0.66312266j  0.56806475-0.82298387j -0.35460489+0.93501624j
   0.12053668-0.99270887j  0.12053668+0.99270887j -0.35460489-0.93501624j
   0.56806475+0.82298387j -0.74851075-0.66312266j  0.88545603+0.46472317j
  -0.97094182-0.23931566j]
 [ 1.        +0.j         -0.74851075+0.66312266j  0.12053668-0.99270887j
   0.56806475+0.82298387j -0.97094182-0.23931566j  0.88545603-0.46472317j
  -0.35460489+0.93501624j -0.35460489-0.93501624j  0.88545603+0.46472317j
  -0.97094182+0.23931566j  0.56806475-0.82298387j  0.12053668+0.99270887j
  -0.74851075-0.66312266j]
 [ 1.        +0.j         -0.35460489+0.93501624j -0.74851075-0.66312266j
   0.88545603-0.46472317j  0.12053668+0.99270887j -0.97094182-0.23931566j
   0.56806475-0.82298387j  0.56806475+0.82298387j -0.97094182+0.23931566j
   0.12053668-0.99270887j  0.88545603+0.46472317j -0.74851075+0.66312266j
  -0.35460489-0.93501624j]
 [ 1.        +0.j          0.12053668+0.99270887j -0.97094182+0.23931566j
  -0.35460489-0.93501624j  0.88545603-0.46472317j  0.56806475+0.82298387j
  -0.74851075+0.66312266j -0.74851075-0.66312266j  0.56806475-0.82298387j
   0.88545603+0.46472317j -0.35460489+0.93501624j -0.97094182-0.23931566j
...
   0.88545603-0.46472317j]]

Frequency-domain signal (X_mu):
[10  5  6  6  2  4  3  4  5  0  0  0  0]
```

TD. 3. Output of the program

3. Conclusions

In this report, we have explored the process of synthesizing discrete-time signals using the Inverse Discrete Fourier Transform (IDFT) in matrix notation. By representing the IDFT as a matrix multiplication, we were able to efficiently compute the time-domain signal from the frequency-domain components for various signal variants.

The results of the IDFT computations were visualized through the plotting of the synthesized signals, showing the real parts of the time-domain sequences. The plots confirmed that the IDFT is capable of accurately reconstructing the original signals from their frequency-domain representations.