

Laboratory Test 2019-2020

DSP

Explanations

- There are 9 subjects in all, shown below according to the laboratory they were done in.
- The test will last up to 110 minutes (the 2h of the normal lab session)

Subjects

Lab 2

1. Plot on the same figure the signals $\sin(2\pi ft)$ and $\cos(2\pi ft)$, with $f = 0.3$ and $t \in [0, 10]$.
2. Load the audio file 'Kalimba.mp3' in the Matlab workspace. Only load samples between 1 and 200000 (to avoid out of memory error)
 - a. Play it through the computer's audio device
 - b. Change the sampling frequency to half the correct value, and play again. How will the sound be changed?
 - c. Amplify the sound by multiplying the data by 4. Play the sound and observe the difference.
 - d. Swap the left and right channels (it's a stereo file) and play the sound again.

Lab 3

1. Load the **Lena** image (use `imread()`), convert it to double, convert it to grayscale, scale the values to the $[0, 1]$ range, and display the image (use `imshow()`).

- Construct a new image based on the **Lena**, but in which each pixel value is set as a linear combination of the original pixels around it, as in the following equation:

$$y[i, j] = \frac{1}{9}x[i-1, j-1] + \frac{1}{9}x[i-1, j] + \frac{1}{9}x[i-1, j+1] \\ + \frac{1}{9}x[i, j-1] + \frac{1}{9}x[i, j] + \frac{1}{9}x[i, j+1] \\ + \frac{1}{9}x[i+1, j-1] + \frac{1}{9}x[i+1, j] + \frac{1}{9}x[i+1, j+1]$$

Ignore the first and last row/column, if needed.

Display the resulting image in a new window. How did it change?

- Repeat Exercise 2 but change the values of the coefficients to

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Lab 4

- Load the **Lena** image (use `imread()`), convert it to a grayscale image, convert it to `double` type, adapt the values to the $[0, 1]$ range, and display it (use `imshow()`).
- Create a video sequence by scrolling the Lena image circularly to the right, by 3 pixels at every frame. Display the video at 25fps.

Code template for creating a video sequence in Matlab:

```
height = ...; % desired height
width  = ...; % desired width
NoF    = ...; % desired number of frames
% an array of size height x width x 1 x NoF:
video  = zeros(height, width, 1, NoF);
for i = 1:NoF
    video(:,:,i) = ... the frame number i ... ;
end

% Play the sequence
implay(video);
```

Lab 5

1. Create a function `mysys1()` that implements the following system H_1 :

$$y[n] = H_1\{x[n]\} = \frac{1}{4}x[n] - \frac{1}{2}x[n-1] + \frac{1}{4}x[n-2]$$

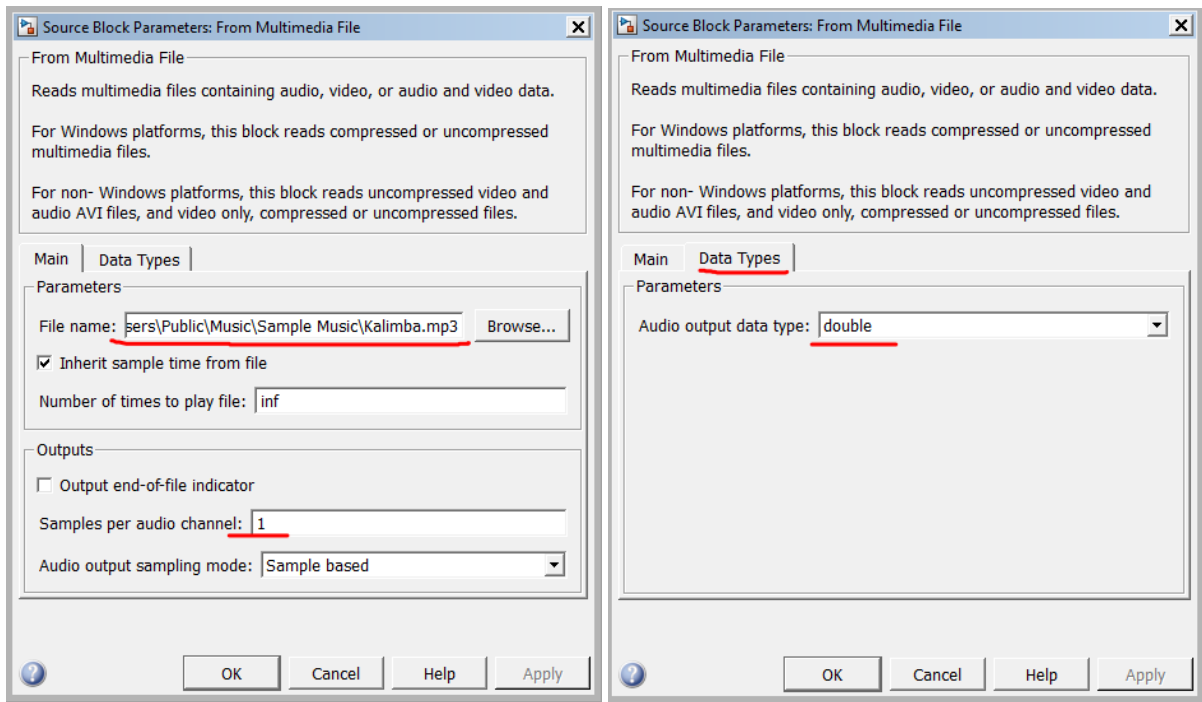
- the function takes 1 input argument `x` and outputs 1 result vector `y`
2. In a separate script, test the linearity of this system in the following way:
 - generate two random vectors `x` and `y` and two random numbers `a` and `b`
 - apply the function `mysys1()` to `a*x`, `b*y`, and `a*x + b*y`, and check if the results verify the linearity equation
 - the check shall be repeated for 5 times, with 5 different randomly generated data
 - is the system linear?

Lab 6

1. Create a Simulink model to implement the following system H_1 :

$$y[n] = H_1\{x[n]\} = \frac{1}{4}(x[n] + x[n-1] + x[n-2] + x[n-3])$$

- the system should be implemented as a Subsystem block with one input and one output signal
2. Apply the system to the audio data (mp3 file) loaded with `FromMultimediaFile` block and play the resulting output using `Buffer` and `ToAudioDevice` blocks.
 - make sure you set the properties of the `FromMultimediaFile` block as shown below:



Lab 7

1. Create a Simulink model to implement the following system H_1 :

$$y[n] = H_1\{x[n]\} = 0.8y[n-1] + 0.25x[n] + 0.1x[n-1]$$

- the system should be implemented as a Subsystem block with one input and one output signal
2. Test linearity of this system as follows:
 - create three copies of the system inside the model (copy/paste)
 - use two random input vectors \mathbf{x} and \mathbf{y} (use two *Random* blocks)
 - apply input signals \mathbf{x} , \mathbf{y} and $\mathbf{x}+\mathbf{y}$ to the three copies of the system
 - add the outputs of the systems which have \mathbf{x} and \mathbf{y} as inputs, then subtract the output of the system which has $\mathbf{x} + \mathbf{y}$ as input
 - show the resulting signal. Is the system linear?

Lab 9

1. Generate a 100 samples long signal \mathbf{x} defined as $x[n] = 0.7 \cos(2\pi f_1 n) + 1.2 \sin(2\pi f_2 n)$, with $f_1 = 0.05$ and $f_2 = 0.1$.
 - a. Plot the signal in the top half of a figure (use `subplot()`).
 - b. Compute the Fourier series coefficients with `fft()` and plot their magnitude in the lower half of the figure.

2. Take the Fourier series coefficients of the above signal \mathbf{x} , and keep only the coefficients of the DC + first two sinusoidal components. Generate the signal from the Fourier coefficients with `ifft()` and plot it. What is the resulting signal?

Lab 11

1. Use the Filter Design tool in Matlab (call `fdatool` in command line) to design a Low-Pass filter of order 5, IIR, with cutoff frequency 0.1. Export the coefficients to the Matlab workspace.
2. Generate a signal composed of 30 values of 1 followed by 30 values of 0. Filter the signal with the designed filter (use `filter()`). Plot a figure with 2 subfigures showing the original signal and the filtered signal.

Lab 12

1. Use the Filter Design tool in Matlab (`fdatool`) to design an oscillator with frequency 0.05. Implement it in Simulink, visualize & play the output signal.
 - design a system of order 2 with 2 conjugate poles placed **on the unit circle** at the correct frequency, and 2 zeros at low & high frequencies
 - implement the system in Simulink. You can **omit the input signal** (not necessary, an oscillator has no input)
 - set a non-zero initial condition in the system, to start-up the oscillator
 - play the resulting output using **Buffer** and **ToAudioDevice** blocks. What frequency do you hear when running the simulation?