Definition and Graphic Representation of Signals in Matlab

1 Goals

The aim of this laboratory sessions is to acquire skills at defining and plotting different kind of signals in Matlab. For this purpose, the main commands provided by this software will be revisited paying attention to the nature of the signals: continuous-/discrete-variable continua/discrete, real-/complex-valued, etc.

> **!** Although the commands relative to axis labeling will be omitted in this document, it is important to take into account that these commands (`xlabel`, `ylabel`, `title`, `axis`, etc.) must be used in any formal document (e. g., an exam) and, therefore, it is advised to included them in your figures.

2 Definition and Graphic Representation of continuous-variable signals

2.1 Definition and graphical representation of continuous signals

As you probably know, Matlab is able to plot continuous-variable signals by means of the command `plot`, which takes two arguments corresponding to the arrays `x` and `f`. These arrays comprise the values of the points, on which the function is evaluated, and the corresponding values of the function, respectively.

In general, the values of the abscissa axis are computed by means of the command `linspace`, by providing the initial and final point of the interval as well as the number of points.

TASK

1. Plot the signal $f(x) = e^{-x}$ over the interval $[0, 2]$ using 101 points.
2. Repeat the previous tasks over the interval $[-10, 2]$. Note that the range of the function has increased exponentially.

2.2 Definition and graphical representation of piecewise functions

It is usual to work with piecewise functions, which are defined by multiple sub-functions, each sub-function applying to a certain interval. In order to define these functions in Matlab, there are several approaches. One of them is to choose the corresponding indexes by means of logical operations (less than or equal to, greater than or equal to, etc.). Note that these operations are pointwise operations in Matlab. The following example illustrates how to plot the signal:

$$f(x) = \begin{cases} 3 & x < -2 \\ \sin x & -2 \leq x < 1 \\ -\sin x & x \geq 1 \end{cases}$$

```
x = linspace (-3, 3, 101 );
f = zeros ( 1 ,101) ; %Zero initialization
f ( x< - 2) = 3;

ind = (x>= -2 & x <1);
f ( ind ) = sin ( x(ind) );

ind = (x>=1);
f ( ind) =  -sin ( x(ind) );

plot(x,f)
```

TASK

1. In order to understand the previous approach, plot the index array `ind= (x>=-2 & x<1)`. Note that this vector only comprises logical (or Boolean) values as they are the result of logical operations.

2. Plot the signal $f(x) = \Pi\left(\frac{x-3}{2}\right) + \Pi(x-3)$. The pulse function is defined as: $\Pi(x) = \begin{cases} 1 & |x| < \frac{1}{2} \\ 0 & |x| > \frac{1}{2} \end{cases}$.

3. Plot the signal $f(x)$ over the interval $[-3, 3]$ using 51 points:

$$f(x) = \begin{cases} |x| & x \neq 0 \\ 3 & x = 0 \end{cases}$$

   Does the Matlab representation match the real representation?

2.3 Definition and graphical representation of periodic signals

In a similar fashion, several approaches can also be applied. On one hand, if the signal can be analytically, e.g., $f_0(x) = \cos x$, then the previously described approaches for aperiodic signals are still valid.

On the other hand, if the signal is the definition is given over a single interval, which covers at least the fundamental period, then a more elaborated process is required. For instance, if we wish to plot the signal over an integer number of periods, a simple and effective strategy is to build the signal by repeating a period of the signal, which can be evaluated as in the previous section, by means of the command `repmat(f,1,N)` where `f` is the signal defined over a period, which is defined as a row vector, and `N` is the number of periods under consideration. It is also worthy noting that the last sample of each interval must be drop to avoid the repetition with the first sample of the next interval.

Regarding the values of the abscissas x, some manual calculations are required. In this case, it can be helpful to firstly calculate the first and last point of the interval over which the signal is to be plotted, and the number of total number of points can be set to NM, being M the number of points per period.

TASK

1. Plot the signal $f_0(x)$ over the interval $[-2.5, 2.5]$, where $f_0(x) = |x|$ over the fundamental period $x \in [-\frac{1}{2}, \frac{1}{2})$
2. Plot the signal $f_0(x)$ over the interval $[-10, 10]$, where $f_0(x) = e^{-x}$ over the fundamental period $x \in [-1, 4)$.

If we do not wish to define the function over a integer number of periods, then a possible approach is to define the signal over a larger interval, whose size is a integer number of periods, and, after that, truncate the interval for both vectors f and x.

OPTIONAL

1. Plot the signal $f_0(x)$ over the interval $[-8, 6]$, where $f_0(x) = e^{-x}$ over the fundamental period $x \in [-1, 4)$.

2.4 Graphical representation of complex-valued signals

Real-valued functions have been considered so far. In the case of complex-valued signals, the definition can be carried out in the same terms without any relevant difference. Nevertheless, the graphical representation has to take into account the nature of these signals by resorting to one of the following choices:

- Real and imaginary part: it is possible to plot the real and imaginary parts of a complex-valued signal f, using either two different plots (in two separated figures or in the same one by means of the command `subplot`) or in the same plot by resorting to the command `hold on`. The real and imaginary parts of an array are computed by the commands `real` and `imag`.
- Modulus and argument: this kind of representation is very usual in engineering. In this case, the same plot is typically *not* used because the range of the modulus and the argument are usually very different[1]. The amplitude and phase are calculated by means of the commands `abs` and `angle`, respectively. Note that `angle` returns the phase in radians and, in general, it is preferred to convert it into degrees just before plotting.
- Complex plane: this representation is also usual in engineering. In this case, the abscissas and ordinate axes represent the real and imaginary parts of the signal, respectively. In these cases, it is recommended to use the command `axis equal` to keep the same aspect ratio for both axes.

[1]Interested reader is referred to the command `plotyy`, which allows two different y-axes with different scales.

TASK

Let $f(x) = e^{(j\pi-2)x}$:

1. Plot the real and imaginary parts over the interval $[0, 3]$.
2. Plot the modulus and argument of the function over the interval $[0, 3]$. Explain what happens if the command `angle` is used instead of `phase`
3. Plot the signal on the complex plane over the interval $[0, 3]$. Note that it is not possible to determine the value of x corresponding to each point of the plot unless some additional information is included.

2.5 Transformations on the independent variable

Since Matlab works with vectors comprising the evaluated function, it is not straightforward to perform operations such as reversal or compression, because it can require evaluating the function at points different to the points at which the function has been evaluated. In this case, the best choice is to reevaluate the function by considering the definition after the transformation.

TASK

Let $f(x) = e^{-x}\sin x$, plot the following signals over the interval $[-2, 2]$

1. $g(x) = f(-x)$
2. $g(x) = f(2x)$
3. $g(x) = f(3-2x)$

3 Definition and graphical representation of discrete-variable signals

The definition of discrete-variable signals $x(n)$ can be performed in a similar way to continuous-variable but using an array of values for the independent variable n given by `n=N1:N2`, where `N1` and `N2` represent the first and last point under consideration.

Regarding the graphical representation, the previous considerations remain valid. However, it is usually preferred to use the command `stem` instead of `plot` as the graphical representation matches the conventions for this kind of figures.

TASK

Plot the following signals over the interval $[-4, 4]$:

1. $x(n) = e^{-n}\sin(\pi n)$
2. $x(n) = \begin{cases} 2 & n \leq -2 \\ 3 & -2 < n \leq 0 \\ |n-2| & n > 0 \end{cases}$
3. $x(n) = e^{-j3n}$