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A comparison of two methods for the teaching of signal transformation

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ABSTRACT: The study presented by the authors in this article is concerned with a comparison of two key methods used in order to solve signal transformation problems in a course covering signals and systems. A simple linear transform is introduced into the computing procedures. Students solve the signal transformation problems by utilising the mapping method, which can help to avoid the mistakes in the computing procedures. Utilising simple mapping can also help programmers to design a brief algorithm.

INTRODUCTION

Some students are confused with the signal transformation problems of the signals and systems, because they have to remember the computing sequence of signal shift, time scale and time reversal with the corresponding sign and coefficients in the signal notations. Therefore, some students usually make numerous mistakes in the complex computing procedures.

The study presented in this article introduces another mapping method to help students handle the above-mentioned problems without the need for memorising computing procedures.

METHODS

The general form of the time scaling system can be written as follows:

$$y(t) = x(at + b) \tag{1}$$

where a is the scaling factor, and b is the shifting factor.

That is, if $a>1$, then $y(t)$ is the time-compressed (by a factor of a) version of $x(t)$. If $0<a<1$, then $y(t)$ is the time-extended version of $x(t)$. If a>0, the polarity of time scale is unchanged. If a<0, the time scale is reversal. The output will be shifted by b, the shifting factor, with the new scale.

The computing procedures are scaling, shifting and reversal, corresponding to the value of a, value of b, and sign of a [1]. However, some students do not operate this sequence in order, they shift with the new scale and, shift in the correct direction to make mistakes in calculations. Therefore, the mapping method shown below is introduced in order to reduce the mistakes in the calculations [2].

Assuming that $x(t)$ is shown in Figure 1a. Let $c=at+b$. Then $y(t)=x(c)$, where $x(c)$ is in the same form as $x(t)$, as shown in Figure 1b.

If $c=t_1$, then

$$t_1'=(t_1-b)/a \tag{2}$$

And if $c=t_2$, then

$$t_2'=(t_2-b)/a \tag{3}$$

Therefore, $y(t)$ can be determined, as shown in Figure 1c.

RESULTS

For example, consider a signal shown below:

$$y(t) = x(-2t - 2) = x(-2(t + 1)) \tag{4}$$

If:

$$x(t) = 2u(t) - u(t - 1) - u(t - 2) \tag{5}$$

Please find $y(t)$.

The first solution to this is the traditional method included in traditional textbooks, as shown in Figures 2a-2b. The figures are listed, respectively, as follows:

- $x(t)$;
- Time scaling (the 2 is presented as the half of old scale);
- Forward shifting with two steps in new scale;
- Reversal.

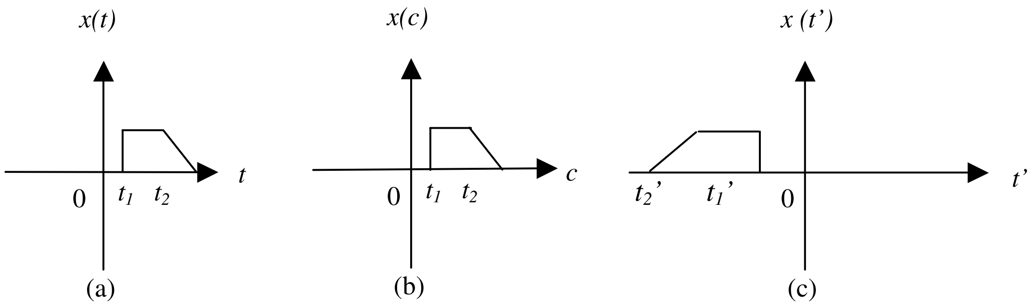

Figure 1: The mapping method to solve the signal transformation problems.

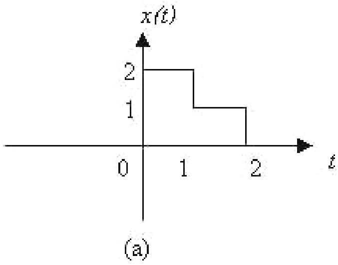

Figure 2a: The traditional method in textbooks: *x(t)*.

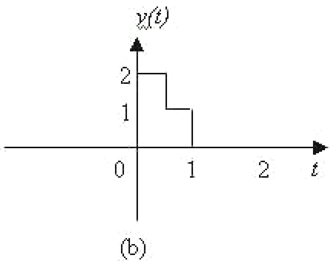

Figure 2b: The traditional method in textbooks: time scaling (the 2 is presented as the half of old scale).

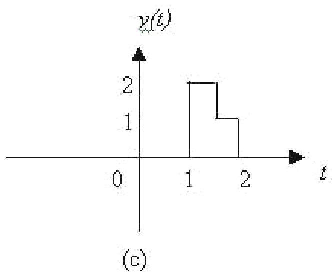

Figure 2c: The traditional method in textbooks: forward shifting with two steps in the new scale.

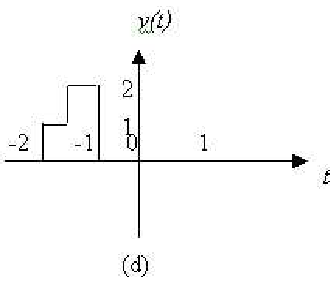

Figure 2d: The traditional method in textbooks: reversal.

Most students make some mistakes in the following areas:

- The sequences of computing procedure;
- The shifting steps with new scale;
- The shifting direction corresponding to the sign of shift factor.

Solution 2 is the mapping method, which is illustrated in Figures 3a-3d.

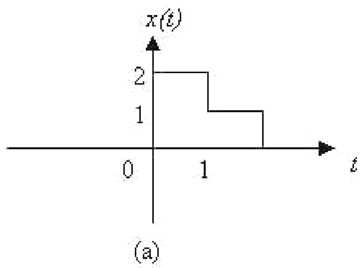

Figure 3a: Solution 2 of the mapping method: *x(t)*.

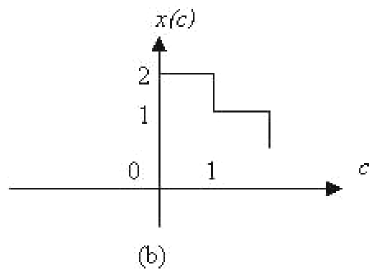

Figure 3b: Solution 2 of the mapping method: *x(c)*.

$$
\begin{aligned}
&t = t' \\
&c = -2t' - 2 \\
&t' = -\frac{c+2}{2} \\
&\textit{Find } t' \textit{ at } c = 0, 1, \textit{ and } 2
\end{aligned}
$$

Figure 3c: Solution 2 of the mapping method: the formula.

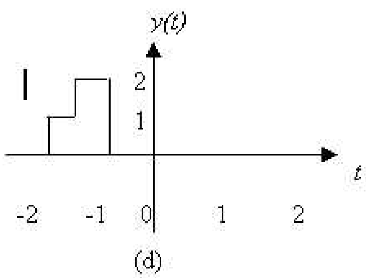

Figure 3d: Solution 2 of the mapping method: *y(t)*.

The linear transformation for Figures 3a-3b is presented by the following equation:

$$c = -2t - 2 \quad (6)$$

Let *t'* replace *t*

$$t' = -(c+2)/2 \quad (7)$$

Therefore, Figure 3b is presented as *x(c)*. By taking *c* into Equation 7, the results are as follows:

$$t' = -1.0 \text{ at } x(c=0) = 2 \quad (8)$$
$$t' = -1.5 \text{ at } x(c=1) = 1 \quad (9)$$
$$t' = -2.0 \text{ at } x(c=2) = 0 \quad (10)$$

Then, y(t) can be generated as shown in Figure 3d.

Classroom Application

This method has been introduced to students engaged in the two-year technological and vocational college/university programme in the Department of Electronic Engineering at Tung-Nan Institute of Technology (TNIT) in Taipei, Taiwan. One class has been organised for full-time students, and another class for part-time students. Students in both classes have been taught to solve signal transformation problems by utilising this method. Most students have given positive responses in both classes.

DISCUSSION

This mapping method not only reduces the computing procedures, but also avoids mistakes. Additionally, it simplifies the algorithm for programming. The key transformation is the Equation 2 in a loop without any branch instructions, such as if, switch, and case, etc, to speed up the process.

CONCLUSION

This mapping method is easy to use with paper and pencil calculations and for computer programming in order to solve signal transformation problems in a course focusing on signals and systems. It is highly recommended that this simple method be widely applied to engineering fields.

ACKNOWLEDGEMENTS

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