MATLAB-Based Demo Program for Discrete-Time Convolution

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1. Introduction

Though the field of engineering has changed dramatically in the last 20 years, the teaching engineering has changed relatively little[1]. Many of the engineering lecture courses are taught using a traditional method i.e. only with the support of a blackboard or transparencies. The major disadvantages of traditional teaching methods are that students usually have to choose between taking notes and listening to the lecturer. As a result, most of the learning in traditional teaching is individual, since the students in the classrooms are taking notes or listening instead of participating[2]. Consequently, many students in conventional classrooms develop little confidence in their own ability to learn[3].

Demonstrations that illustrate concepts with visual aids are one of the important tools in the field of engineering education. They help students connect theory with practice; they realize how theory and systems are connected[4]. Students learn better, remember longer and are better able to identify the appropriate concepts to solve new problems when they learn by addressing concrete problems and actively participate in exploration and pursuit of knowledge[3].

The availability of personal computers (PCs), their increasing calculation power, and their enhanced graphical possibilities enable teachers to take the advantage of the pedagogical possibilities afforded by new technologies[5]. Computer-aided learning has become extremely popular and its use in classroom can be very helpful by adding more analytical capabilities in all engineering areas[6]. It can be applied in the aspects of teaching, learning, validation, and research in engineering education[4]. Besides, it is beneficial especially in terms of saving time and efforts for both teaching and learning in the educational process[4].

Our experience at the National Institute INAOE[7-9], shows that the development and usage of software tools represent an effective teaching approach and increase students' learning. Such software tools must be reliable, student-friendly and with no requirements for the corresponding programming knowledge. In pursuance of this goal we developed the educational demo program to support the theory provided in basic courses in which the fundamentals of Digital Signal Processing are taught. The next section provides a brief description of the program. Section 3 shows the demo program in details. Last section is dedicated to the demo program evaluation issue.

2. Description of the program

The package was implemented in MATLAB. We choose MATLAB because MATLAB along with the accompanying toolboxes is the tool of choice for most educational and research purposes[10]. We used the MATLAB tool `makeshow` which allows the student to create her/his own interactive slideshows without building her/his own graphic interface. There are two windows in each slide. We used the upper windows for specific explanations as in Slide 1, Fig.1, or for graphics, as in Slide 2 (Section 3). The bottom window is used for general explanations as in Slide 2, or for the explanations of the upper graphics, as in Slide 3 (Section 3). The order of the slide and the command buttons are on the right side of each slide.

The student can change the slides automatically using the option `AutoPlay`. In this case the student may use the button `Stop` to stop the presentation and later hit `Continue` to continue it. The student can also choose the option to change slides manually with the mouse, by clicking `Next` to go forward or `Prev`, to go backward. The buttons `Reset` and `Close` are used to reset the demos and exit the program, respectively.

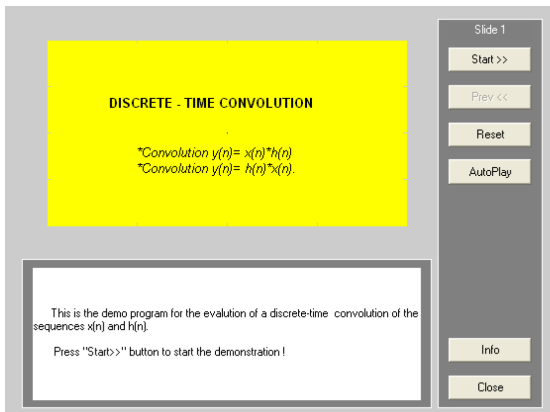


Fig.1. First slide.

2. Discrete-time convolution

The Discrete-time convolution is one of the most important operations in a discrete-time signal analysis[11]. The operation relates the output sequence $y(n)$ of an linear-time invariant (LTI) system, with the input sequence $x(n)$ and the unit sample sequence $h(n)$, as shown in Fig.2.

$$y(n) = \sum_k x(k)h(n-k) = x(n) * h(n)\,, \tag{1}$$

where the asterisk "$*$" indicates the convolution operation.

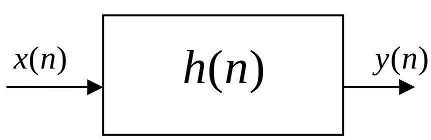
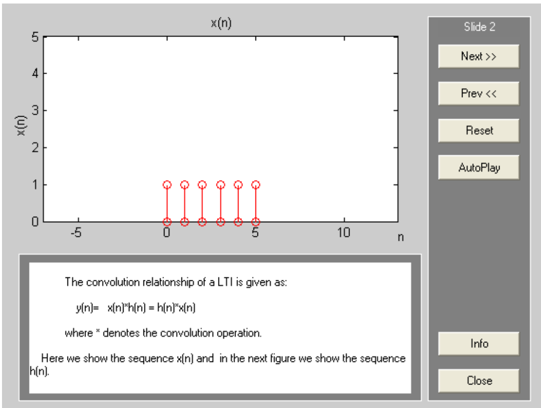
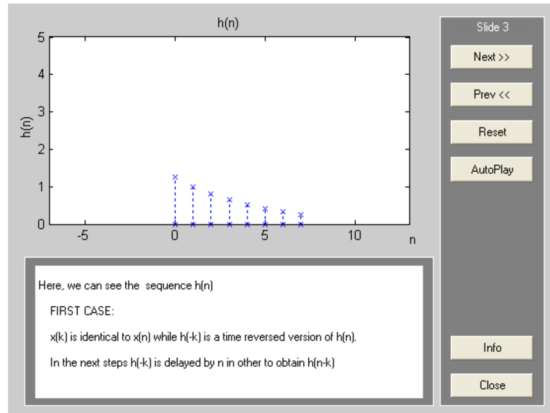


Fig.2. LTI Discrete-time system.

The input and impulse response sequences are given in Fig.3. The sequence $h(k)$ is time reversed about the zero index to become $h(-k)$ as shown in Fig.4. In the following steps $h(-k)$ is shifted to the right by the index n to form the offset sequence $h(n-k)$. Figure 4 shows the starting position where n=0. The sequence $x(k)$ and $h(n-k)$ are multiplied, as shown in the upper figure. The result of the multiplication is the value of the output sequence at the index n, as shown in the bottom figure. Figure 5 demonstrates all steps from n=1 until n=12. The final result is shown in Fig.5.



a. Input sequence.



B. Impulse response sequence.

Fig.3. Input and unit sample response sequences.

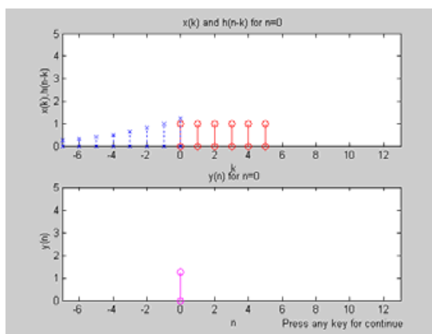
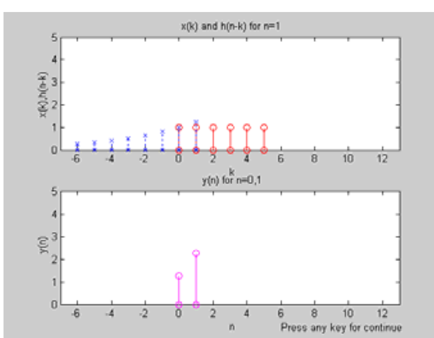
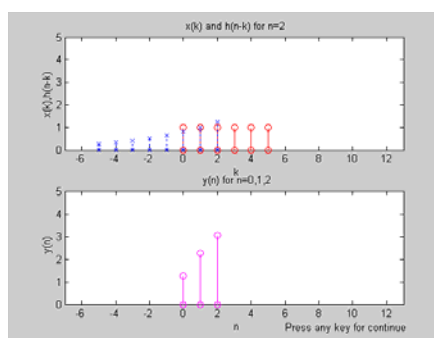


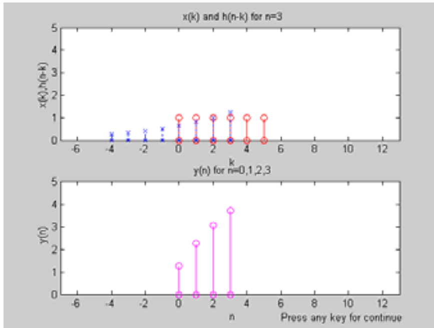
Fig. 4. n=0.



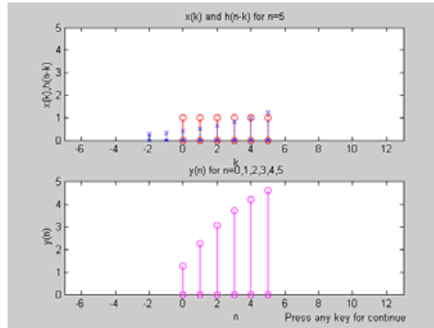
n=1.



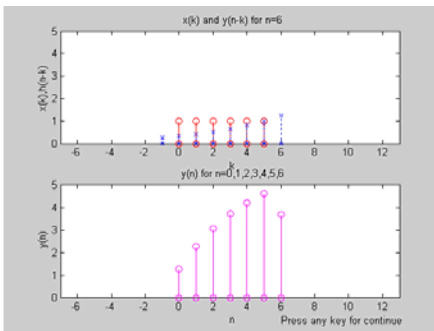
n=2.



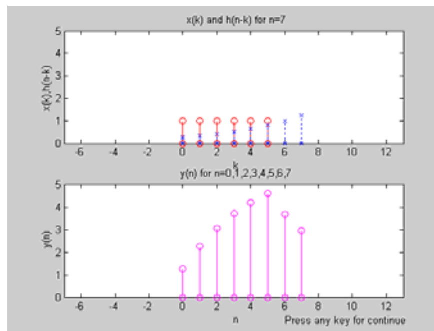
n=3.



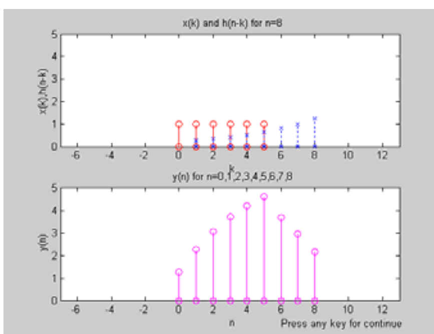
n=5.



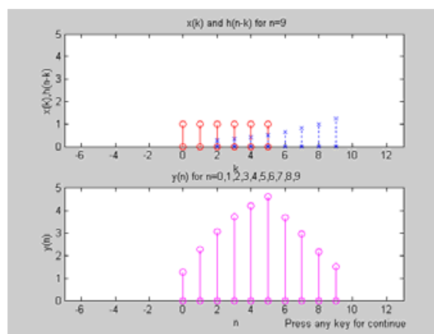
n=6.



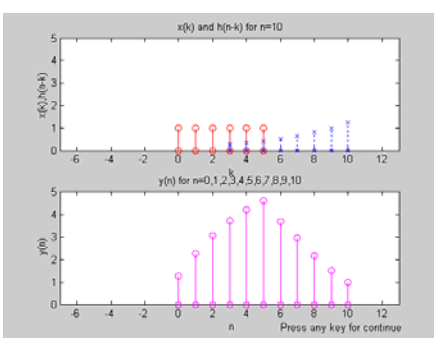
n=7.



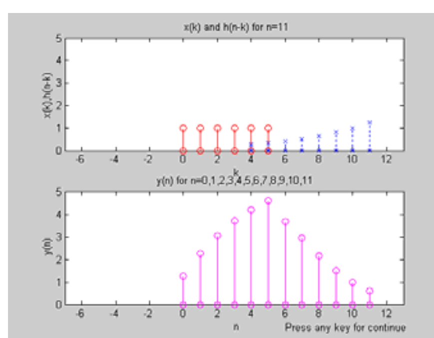
n=8.



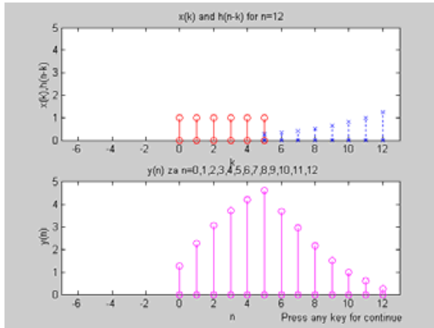
n=9.



n=10.



n=11.



n=12.
Fig.4. Convolution step by step.

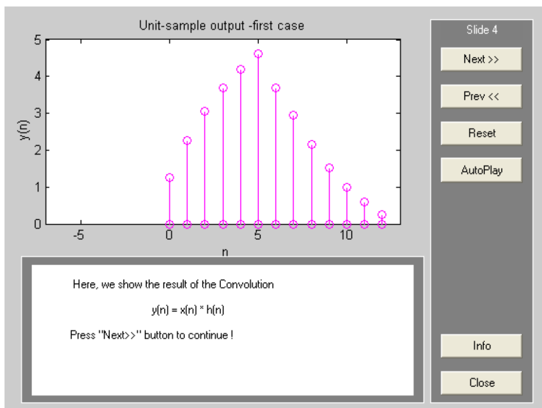


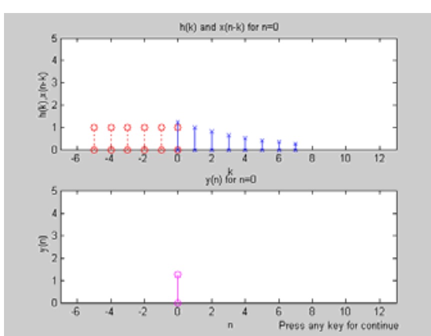
Fig.5.The final result.

4. Commutative characteristic

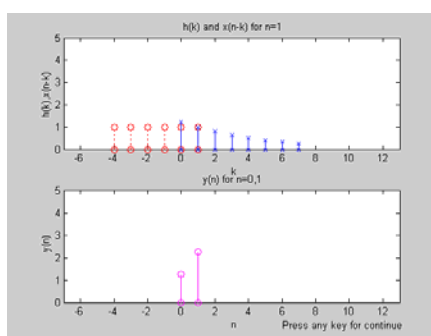
In following is demonstrated that the convolution is commutative operation, i.e.

$$y(n) = \sum_k x(k)h(n-k) = \sum_k h(k)x(n-k)\,. \qquad (2)$$

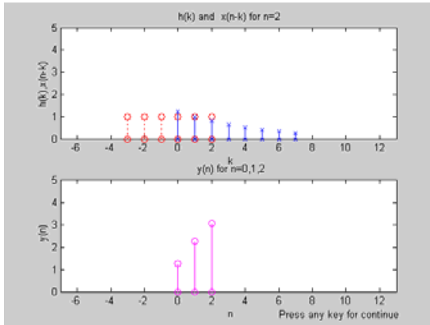
Figure 6 shows all steps from *n*=0 until *n*=12, and Fig.7 shows the final result.



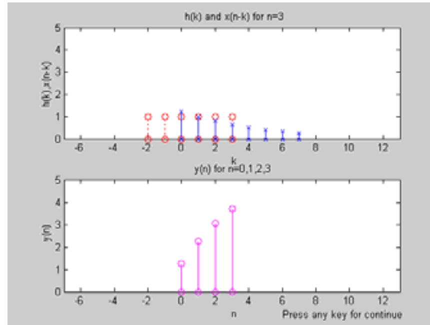
n=0.



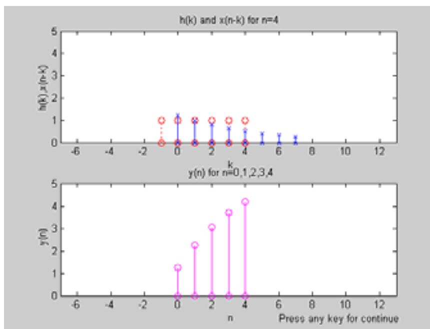
n=1.



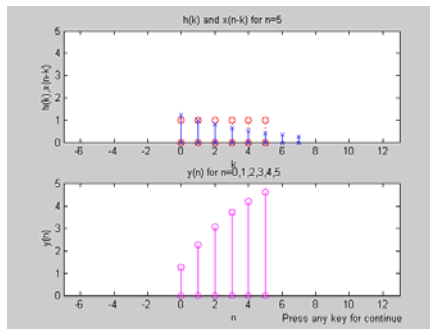
n=2.



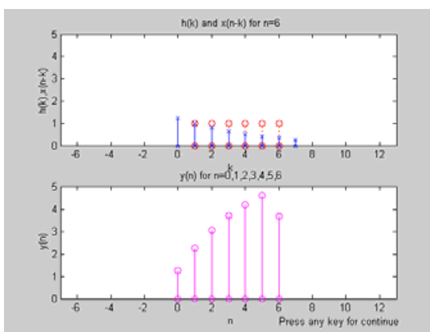
n=3.



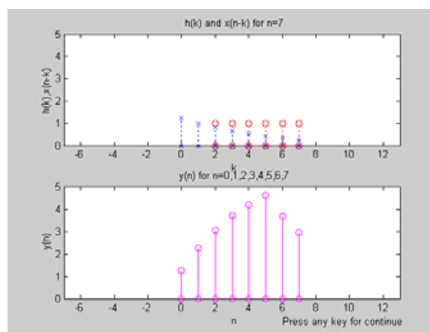
n=4.



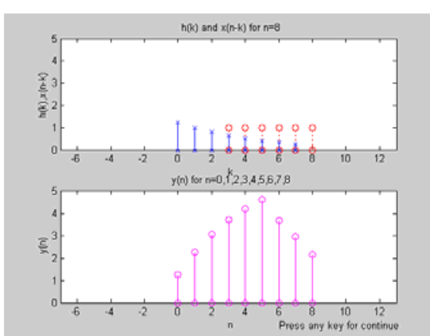
n=5.



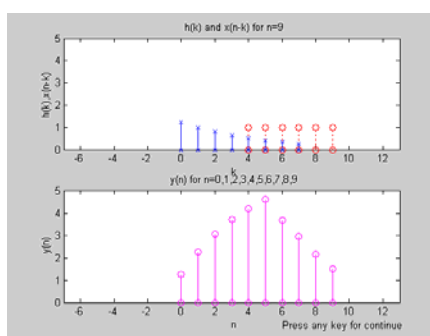
n=6.



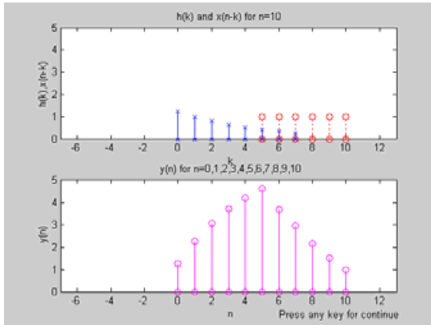
n=7.



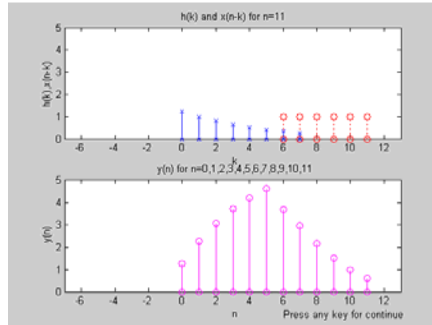
n=8.



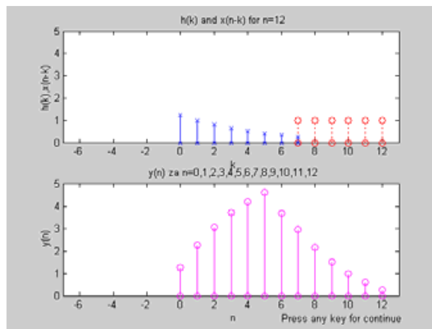
n=9.



n=10.



n=11.



n=12.

Fig.6. Convolution: Step by Step.

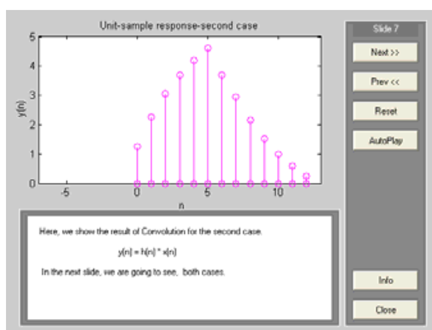


Fig.7. Final result.

Finally Fig.8 confirms that results from Fig.4 are equal to the results from Fig. 6, i.e. that the convolution is a commutative operation.

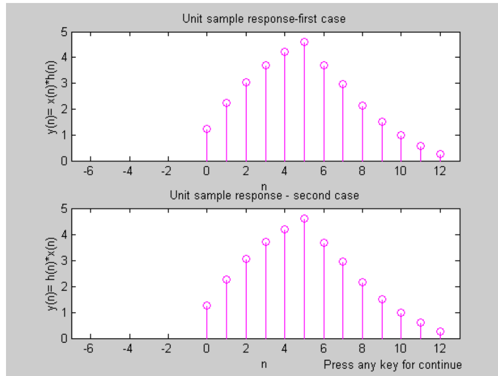


Fig.8. Comparison.

5. Evaluation

We considered that is very important to get information from students about to the usefulness of the software in the teaching-learning process. To this end we developed a suitable tool to evaluate quality of the program of the software in the teaching-learning process. The set of questions attempted to test the program design aspects and usefulness of the software for teaching convolution was generated. All questions in the form are rated with marks from 1 to 4 with the latter being the highest mark.

Evaluation form:

1. Justification for the computer use in teaching DSP. (1=unjustified; 4=absolutely justified).
2. Contribution to study of DSP by demo program use. (1=irrelevant; 4= very effective).
3. Clarity of explanations and features of demo. (1=confusing; 4=absolutely clear).
4. Did this demo help you to understand better the Convolution? (1=NO; 4=Absolutely YES).
5. Did this demo help you to understand better the Commutative characteristic of Convolution? (1=NO; 4=Absolutely YES).
6. Special knowledge or programming skills required. (1=excessive; 4=null).
7. Ease of operation. (1=complex; 4= very easy).
8. Flexibility & Repeatability (Possibility to come back to previous slide/slides and repeat it/them many times). (1=unnecessary; 4=very useful).
9. General quality of presentation (figures, resolution, visibility, etc). (1=pure; 4=excellent).

The test is applied for the group of students enrolled in basic course of DSP. The rating scheme in terms of the average marks is given in plot in Fig.9. The results clearly demonstrated that students liked this way of teaching and they find this demo very useful for understanding the convolution operation. They especially highly rated the features of the program like flexibility and repeatability, ease of operation, and no programming skills required to run the program.

5. Concluding remarks

The paper presents the demo program for the discrete time convolution. All steps of the convolution are presented. It is also shown that the convolution is a commutative operation.

The package is implemented in MATLAB and uses graphical tool `makeshow`, available in MATLAB. The demo is composed of slides that contain the plots of the corresponding signals and a short explanation. The demo can run automatically or manually, and each slide can be repeated many times. In that way the student can compare the actual result with any previous one.

This demo program is utilized for teaching the basic curse on Digital Signal Processing. By their opinions obtained through the evaluation test, this program helped them to understand and remember this important operation.

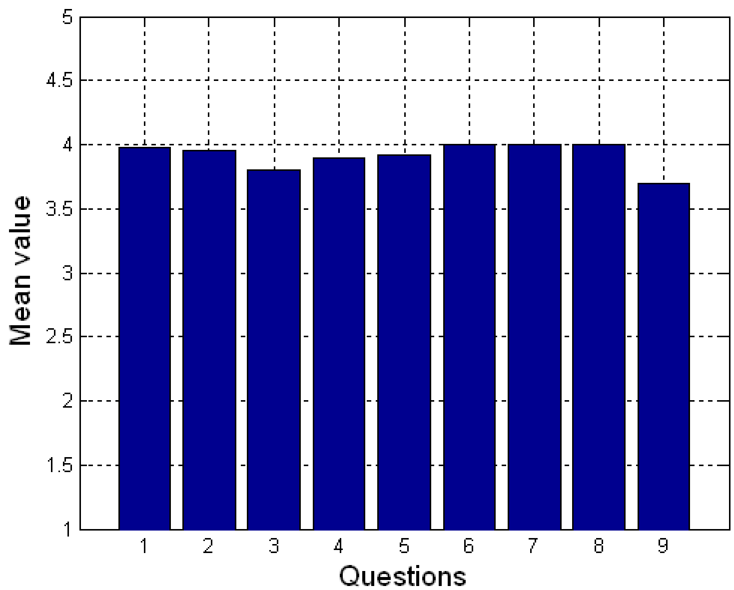


Fig. 9. Rating scheme.

Acknowledgement

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