Reform and Exploration in the Teaching of Digital Signal Processing

Jia Wang*, Yang Li, Huaqun Liu and Yang Lu
Beijing Institute of Graphic Communication, Beijing, China, 100026
*Corresponding author

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Abstract: The teaching reform of digital signal processing emphasizes the role of graphics in understanding and memorizing knowledge, and the role of mind map in integrating knowledge points. Using the flip classroom to increase teaching interaction, which can improve the effectiveness of teaching and stimulate students' interest in learning.

Introduction

China is in an upsurge of innovation, especially in the fields of information technology, emerging industries, robots and so on. With the gradual disappearance of "demographic dividend", the prospect of "engineer dividend" is very bright. Big data, artificial intelligence and Internet are the main trends of the development of modern information technology, while digitalization is the research foundation. Therefore, the course of Digital Signal Processing has become the main course for almost all electronic, electrical and information majors, such as electronic information, communication engineering, automatic control and computer. Teaching the course of Digital Signal Processing well is very important to train students to be qualified engineers.

Digital Signal Processing is usually considered as a course with many mathematical contents. One of the remarkable features is its abstraction of concepts, numerous mathematical formulas and complex derivation. In the process of teaching, teachers often focus on the deduction of mathematical formulas, while ignoring the practical application of the course itself. Many students, especially those in general applied undergraduate colleges and universities, are unable to understand and clarify the course, so be tired even afraid of learning.

Therefore, in the course of teaching, the main task of the teacher is to make the abstract theory easy to understand, to make the complex mathematical deduction simple and clear, to summarize the numerous knowledge points, and to facilitate memory. Many teachers have carried out in-depth teaching reform research on this course. Hao Xiaoli [1] discussed how to construct the new curriculum system of signal processing courses, integrate and update the teaching content, and put forward the specific methods of teaching reform. Xie Shouqing [2] and others use software to optimize the teaching of integrated signal and system and digital signal processing courses, so as to visualize the basic principles. Hanjian [3] et al. use speech signal as processing object, carry out frequency conversion and digital filtering of speech signal, cover the main knowledge points of this course, improve students' practical ability and innovative consciousness in engineering, and achieve good results in teaching.

According to the actual situation of Department of Electronic Information Engineering in Beijing Institute of Graphic Communication, this paper explores the teaching reform of digital signal processing course by introducing graphics and mind map into teaching and increasing teaching interaction by using flipping classroom mode.

Emphasizing the Role of Graphics in Understanding and Memorizing Knowledge

Bruner put forward the importance of learning knowledge structure that "unless one thing is put into a constructed model, it will soon be forgotten. Detailed information is stored in memory by means of a simplified way of expressing it. "If the acquired knowledge is not connected by a perfect structure, it will be mostly forgotten".[4] According to the teaching practice and the characteristics
of the course, the graphical teaching method is proposed in the teaching. The knowledge points are interpreted in the form of graphs or flow charts, so as to cultivate students' ability to construct knowledge structure, so as to achieve the goal of memory.

For example, complex exponential signal is a very important basic signal in signal analysis theory, and can be used to describe various basic signals, such as DC signal, exponential signal, sine or cosine signal, and sine and cosine signals with growth or attenuation. Complex exponential signals can simplify many operations and analyses. If a complex exponential signal is input to a system, the output must also be a complex exponential signal, and the amplitude of the output signal is the square sum of the real part and the imaginary part of the response, and the phase of the output signal is the arc tangent of the ratio of the imaginary part to the real part. Understanding the physical meaning of complex exponential signals \( e^{j\omega t} \) is crucial to understanding the Euler formula and five major transformations of Fourier transform (FT).

During teaching, the complex exponential signal \( e^{j\omega t} \) is illustrated graphically as a unit rotation vector with zero initial phases on the complex plane. The projection of the vector on the real axis is \( \cos \omega t \), the projection on the imaginary axis is \( \sin \omega t \):

\[

e^{j\omega t} = \cos \omega t + j \sin \omega t
\]

\[
\sin \omega t = \frac{e^{j\omega t} - e^{-j\omega t}}{2j}, \quad \cos \omega t = \frac{e^{j\omega t} + e^{-j\omega t}}{2}
\]

Fig. 1 can also easily explain why complex exponential signals are periodic, and further leads to the concept of Fourier series: the continuous periodic signals are expanded into a series of linear combinations of complex exponential signals with harmonic relations. When the period of periodic signals is extended to infinity, the expansion of aperiodic signals is obtained, which is Fourier transform. Continue expand \( j\omega \) to complex plane, which means \( s = \sigma + j\omega \), we will get complex frequency domain Fourier transform - Laplace transform (LT). The above concepts are sorted out in Table 1. The knowledge structure is clear. Various transformations compare and verify the formulas to help students analyze and memorize. The table takes square wave signal and its spectrum as an example, eliminating the longitudinal axis and other parameters, showing the waveform in a simplest way, highlighting the characteristics of signal and spectrum, and facilitating teachers' blackboard writing.
Table 1. Relation between Continuous Signal FS and FT.

| SIGNAL | FS | FT |
|--------|----|----|
| $\tilde{x}(t) = \sum_{k=-\infty}^{\infty} X(jk\Omega_0)e^{jk\Omega_0t}$ | continuous, periodic | $x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(j\Omega)e^{j\Omega t}d\Omega$ | continuous, aperiodic |
| $X(jk\Omega_0) = \frac{1}{T_0} \int_{t_0}^{t_0+T_0/2} x(t)e^{-jk\Omega_0t}dt$ | aperiodic, discrete | $X(j\Omega) = \int_{-\infty}^{\infty} x(t)e^{-j\Omega t}dt$ | aperiodic, continuous |

When the complex exponential signal is sampled, $e^{jo\tau}$ change to $e^{j\omega n}$. When $\omega = \frac{2\pi}{N} k \ (N,k$ are integers), the discrete complex exponential signal is periodic, so the concept of Discrete Fourier Series (DFS) is introduced: the discrete periodic signal is expanded into a series of linear combinations of complex exponential signals in harmonic relation. If the period of the discrete periodic signal is extended to infinity, we will get the expansion of aperiodic discrete signal-Discrete Time Fourier Transform (DTFT). Then if the complex exponential signal is extended to the complex plane, the discrete time Fourier transform in the complex frequency domain is obtained, which is Z Transform (ZT). Similarly, the transformations of discrete signals with clear structure are obtained as follows:

Table 2. Relations between discrete signal DFS and DTFT.

| SIGNAL | DFS | DTFT |
|--------|-----|------|
| $\tilde{x}(n) = \frac{1}{N} \sum_{k=-N/2}^{N/2} \tilde{x}(k)e^{j\frac{2\pi}{N}nt}$ | discrete, periodic | $x(n) = \frac{1}{2\pi} \int_{-\pi}^{\pi} X(e^{j\omega})e^{j\omega n}d\omega$ | discrete, aperiodic |
| $\tilde{X}(k) = \sum_{n=0}^{N-1} \tilde{x}(n)e^{-j\frac{2\pi}{N}nk}$ | periodic, discrete | $X(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x(n)e^{-j\omega n}$ | periodic, continuous |

**Emphasizing the Role of Mind Map in Integrating Knowledge Points**

Mind map is a radial way of thinking expression. It is a new mode of thinking invented by Tony Buzan. It calls the logic, order, regulations, words, mathematics of the left brain and the image, imagination, color, space, whole and other factors of the right brain, and makes full use of them. The function of the brain, using the rules of memory, reading and thinking, helps people develop in a balanced way between science and art, logic and imagination, thus opening up the infinite potential of the human brain[5, 6].

In the teaching of digital signal processing, mind map can be used to show any content related to the subject in the form of branches, or only key knowledge points. The relationship among knowledge points can also be expressed conveniently and intuitively on the mind map, and guide students to think actively. For example, unit sampling signal $\delta(n)$ is a common basic signal, which has many special properties. If students are not familiar with it, they will often forget how to use it in the process of problem solving. In teaching processing, the properties are summarized as a mind map, which is shown in the figure below. The expression of knowledge is systematically integrated.
and visualized in the mind map, and the students' understanding of knowledge points can be deepened.

\[
T[\delta(n)] = h(n)
\]

1. \(\sum_{n=-\infty}^{\infty} \delta(n) = 1\)

2. \(x(n) \cdot \delta(n) = x(0) \cdot \delta(n)\)
   \(x(n) \cdot \delta(n-n_0) = x(n_0) \cdot \delta(n-n_0)\)

3. \(x(n) * \delta(n) = x(n) \Rightarrow x(n) = \sum_{m=-\infty}^{\infty} x(m) \delta(n-m)\)
   \(x(n) * \delta(n-n_0) = x(n-n_0)\)

4. \(\delta(n) = u(n) - u(n-1)\)
   \(u(n) = \delta(n) + \delta(n-1) + \delta(n-2) + \ldots = \sum_{n=0}^{\infty} \delta(n-m)\)

5. \(p(n) = \sum_{k=-\infty}^{\infty} \delta(n-k)\)

Figure 2. Mind Map - properties of \(\delta(n)\).

Mind map can not only guide students to summarize the knowledge, rules and methods they have learned, but also help students make learning plans. For example, there are five kinds of transformations in the course, including FT, LT, DTFT, ZT and DFT. Each transformation has three knowledge points: definition, common transformation pair and properties. Teachers draw templates and students draw mind maps according to templates. By constantly improving mind maps, students summarize and recall what they have learned, which enable students to understand the relationship between various knowledge points as a whole and form a clear knowledge network map in their minds.

Use Flip Classroom to Improve Teaching Effect

Flip classroom is a student-oriented interactive teaching. It is the main method to improve learning enthusiasm and teaching effect. It can greatly cultivate students' awareness and ability of active learning. Under the scientific guidance of teachers, students' active participation, active acquisition, self-construction, self-development and self-improvement are the aims and objectives of active learning. This paper attempts to improve learning interest and initiative. Instead of using the form of "watching teaching videos before class + discussing in class", it adopts in-class flipping strategy and role flipping strategy, in order to enhance the applicability of the curriculum and stimulate learning interest.

For example, in the explanation of examples, teacher makes demonstration first, then students practice and summary. Thus students' interests and their independent learning are stimulated. In the process of experimental teaching, let some student explain the code to others and stimulate their potential. These measures break down the difficulty of knowledge internalization, increase the number of times of knowledge internalization [7], and achieve better teaching results.

Summary

To sum up, the teaching reform of this course mainly explores the use of graphics and mind maps to summarize the knowledge, which can improve the effectiveness of classroom teaching, reduce learning difficulties for students, and increase interactive teaching to stimulate students' interest. Through these measures, enhance the effectiveness of the teaching of digital signal processing and greatly improve the enthusiasm of students. The way of teaching should be changed from teaching
the content of books to teaching content as a carrier, inspiring and guiding students to learn the essence of knowledge in learning, to understand the true meaning of knowledge in inquiry, and to feel the charm of knowledge in practice. As a teacher, we should prepare teaching materials from the students' point of view, stimulate students' thirst for knowledge, consciously cultivate students' autonomous learning ability, cultivate outstanding talents with innovative consciousness and practical ability, and do our best to improve the quality of higher engineering education in China.

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