Teaching Reform of Digital Signal Processing Driven by Probabilistic Neural Network

Weiwei Zhang [1, a, *]

[1] Information Science and Technology College, Dalian Maritime University, Dalian China

[a, *] dlzhangww@126.com

Abstract. In this paper, teaching reform of Digital Signal Processing (DSP) is conducted based on the data analysis by machine learning methodologies. First, the Spearman correlation coefficients between different process assessments and the total scores are computed to show their relevance. Then, a probabilistic neural network is trained based on real data, and the test result proves that one student's final score level can be roughly inferred based on his/her process assessment. Hence, several reform schemes are proposed centering at the process assessment to help strengthen learning of important knowledge points. Finally, the assessment results show that the proposed teaching reform plans are reasonable and effective in improving the achievability of DSP teaching.

Keywords: Probabilistic neural network; machine learning; digital signal processing; teaching reform.

1. Introduction

Assessment is quite important for higher education[1]. Digital Signal Processing is an important basic compulsory course for Electronic Information Science and Technology, Electronic Information Engineering, Communication Engineering and other related majors. It is also a theoretical and technical backbone course.

After completing Signals and Systems, students will continue to learn DSP. It includes Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), basic structure of digital filters, theoretical analysis and design of Infinite Impulse Response (IIR) and Finite Impulse Response (FIR) filters, etc [2]. Through the study of this course, students should be skilled in the basic theories and methods of discrete time signal and discrete time system analysis. They should also be able to design FIR and IIR filters based on some given requirements. This course is also the basis of other subsequent professional courses such as Digital Audio Signal Processing, Image Processing, Communication Theorem.

There are still many problems in the current curriculum teaching, mainly reflected in the following aspects: First, previous teaching of DSP mainly focused on the integrity of knowledge. This course took teachers' knowledge teaching and students' knowledge acquisition as the main curriculum objectives without much consideration of actual requirement of companies. In the course teaching process, the teaching focus is mainly on the basic principles and methods of system analysis and filter design, ignoring students' abilities in solving sophisticated problems. As a result, there is a great gap between the students' ability and actual needs.

Second, the content of DSP is relatively complex. If the students are not good at mathematics, they would encounter various problems when learning this course. In addition, during theoretical teaching, students lack attention to the application of digital signal processing techniques in solving corresponding problems, which leads to insufficient training of students' practical ability, The disjunction between theory and practice has a negative impact on improving students' ability to solve practical problems.

Third, some assessment schemes are based on experiences of years. And some evaluation methods are too simple to evaluate students' basic professional knowledge and practical ability. The important standard of engineering education professional certification is to enable students to have the ability to find and solve complex engineering problems. In order to be consistent with the requirements of engineering education professional certification, it is necessary to reform the previous assessment which mainly focus on final examination.

Some teaching reforms have already been proposed to improve the teaching effectiveness of this curriculum. For instance, Si et al, tried to find some solutions by means of combining online and offline mixed teaching practice [3], Li et al, put forward reforms based on cognition principles [4]. As far as experimental teaching is concerned, some teachers try to employ some softwares or hardwares to improve the students' ability to solve related problems [5-8].

Most existing reforms are based on how to improve the students' knowledge absorption, ignoring how to remedy various aspects in order to assure the achievability of this course. Based on the aforementioned problems, we tried to formulate the DSP teaching reform in the framework of artificial intelligence to optimize the teaching procedure. In more detail, the correlation coefficients of different assessment aspects are first explored based on the Spearman correlation calculation. Then, the outcome-based education reform is proposed focusing more on how to improve the achievability.

The rest of this paper is organized as follows. Related mathematical knowledge is provide in Section 2. Data driven teaching reform as well as experimental results is elaborated in Section 3. Conclusions are drawn in Section 4.

2. Related Mathematical Knowledge

Achievability is one important evaluation factor in engineering education professional certification. In order to improve the achievability and educational performance, the outcome is analyzed is a data-driven manner. In this section. the analysis related mathematical methodologies will be presented in detail.

2.1 Problem Formulation

For each student, his/her final score is influenced by several aspects, including midterm exam, usual tests, homework, experiments and so on. Hence, the final score of one student is formulated as

$$S(i) = f(m_i, c_i, h_i, e_i) \tag{1}$$

where $S(i)$, m_i, c_i, h_i and e_i are scores of final exam, midterm exam, usual tests, homework and experiments of the i-th student, respectively.

The following teaching reform are based on this model elaborated in Eq.(1). It can be seen from this model that it's important to find the complicated function $f(\cdot)$ such that the achievability is assured. However, teaching and learning is one complex procedure, which is influenced by many latent aspects, such as students' effort, teacher's teaching ability, knowledge structure, theoretic framework, and so on. Thus, it's still not easy to find the exact mapping function from these aspects to the final score.

2.2 Spearman Correlation Coefficient

Spearman correlation coefficient is named after Charles Spearman. It assesses how well the relationship between two arbitrary variables which may not follow the normal distribution. In statistics, Spearman's rank correlation coefficient is defined as [9]

$$r_s = \frac{Cov(R(X), R(Y))}{\sigma_{R(X)}\sigma_{R(Y)}} \tag{2}$$

where $Cov(R(X), R(Y))$ is the covariance of the rank variables, $\sigma_{R(X)}$ and $\sigma_{R(Y)}$ are the standard deviations of the rank variables, respectively.

Specifically, the Spearman correlation coefficient can be rewritten as

$$r_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)} \tag{3}$$

where n is the number of observations and d_i is the difference between the two ranks of each observation.

2.3 Probabilistic Neural Network

Probabilistic neural network (PNN) can be regarded as a radial basis function neural network, which combines density function and Bayes decision theory. There are three layers in PNN. Given an input, the first layer calculates the distances between the input vector and the training input vectors, and generates a vector whose elements indicate how close the input is to a training input. The second layer combines these contributions for each class of inputs to produce its net output as a vector of probabilities. Finally, a compete transfer function after the output of the second layer selects the maximum of these probabilities, and produces a 1 for that class and a 0 for the others [9]. The architecture of PNN is given in Fig.1, where R is the number of elements in input vector, Q is the number of input/target pairs and K is the number of classes of input data.

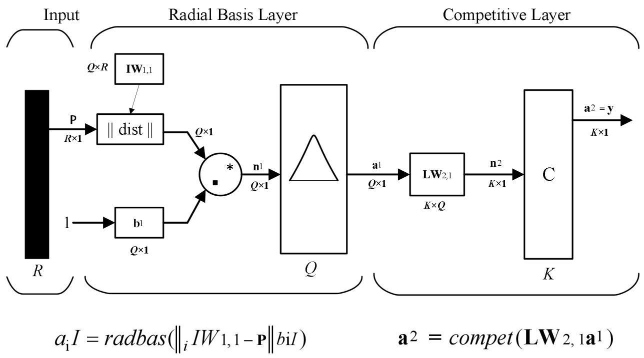

Fig. 1 PNN architecture

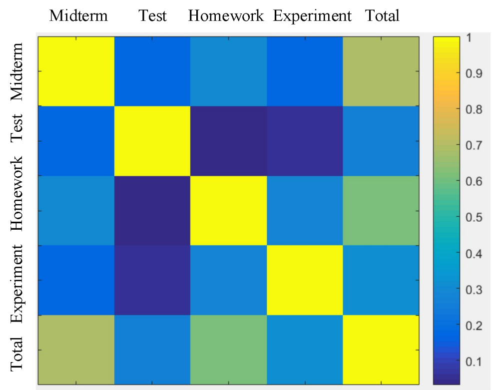

Fig. 2 SCC of different aspects

3. Data DrivenTeaching Reform in DSP

3.1 Relevance between Different Aspects and Total Score

The Spearman correlation coefficients (SCC) of different aspects for quality assessment are first evaluated during this study. The evaluation result is provided in Fig.2. It can be seen from this figure that the final score is more relative to the midterm exam and homework. This phenomenon is also reasonable since the students have to study hard for a higher score during midterm exam. Moreover, students who get higher midterm scores comparatively perform better than the others. Performance in homework can also reflect the students' levels. From this perspective, it's an effective way to improve the teaching effectiveness by means of midterm exam and homework. In other words, elaborate design is useful for improving the achievability of this course. From this figure, it can be seen that the relevance between test and total score is not as significant as midterm exam. That may originate from the fact that test accounts for a smaller proportion of the total score. Moreover, there isn't obvious relevance between homework and test, as well as experiment and test.

3.2 Prediction of Score Level

According to the SCC results in the previous subsection, midterm exam, tests, homework and experiments all positively correlate with the total score. Besides, tests are important for evaluating the students' knowledge mastery, though it accounts for a smaller proportion for the final score. To further explore if the score level of one student can be inferred by the usual performance of him/her. We built a PNN based on the usual evaluation results and the final score level.

Specifically, $X_i \in \mathbb{R}^4$ is the i-th input of the PNN, which is a feature vector including midterm exam, test, homework and experiment scores of the i-th student. Y_i is his/her final score level, where

$$Y_i = \begin{cases} 1 & S_i \geq 90 \\ 2 & 80 \leq S_i < 90 \\ 3 & 70 \leq S_i < 80 \\ 4 & 60 \leq S_i < 70 \end{cases} \tag{4}$$

where S_i is the score of the i-th student.

There are 74 samples in this experiment. We randomly select 55 samples for training PNN and the other 19 for test. The predicted output and the ground truth results are demonstrated in Fig. 3. It can be observed from this figure that 16 of them are correctly predicted. That is to say, the prediction accuracy is 84.2% based on the light-weight training set. This experimental result indicates that the students' final scores can be roughly predicted based on the students' usual performance. The deviation is also reasonable since the final exam is still determined by the endeavor in the later stage except for usual performance.

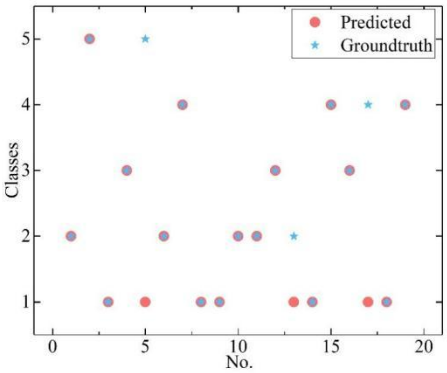

Fig. 3 Score level prediction based on PNN

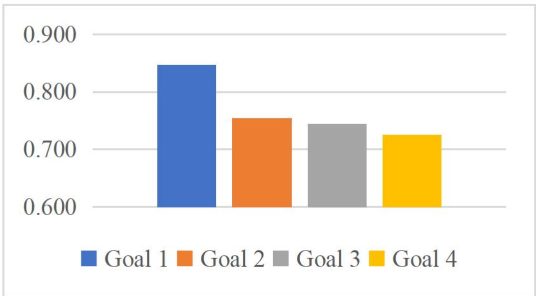

Fig. 4 Achievability bar chart

3.3 Teaching Reform Scheme

Based on the aforementioned data analysis results, several teaching reforms have been taken into account to improve the achievability of DSP. First, teaching content of DSP is reintegrated based on the engineering education professional certification. Some overlapped teaching content with Signals and Systems has been omitted or reduced, and more complex problems from actual industrial demands have been adopted among teaching.

Second, an investigation is conducted to find the actual requirements of companies currently. As the presented theory is based on one-dimensional signal, some actual signal processing tasks such as musical signal processing, which is also one-dimensional, are adopted as cases during theoretical teaching. In this way, the students' ability to solve actual problems can be improved such that they can do better in experiments.

Third, the assessment content and process are modified. In more detail, the processing assessment is strengthened, and important knowledge points are emphasized by homework, tests and midterm exam. Some students have already accustomed to absorbing knowledge in practice. In this way, not only the students know the key contents of this course, but also their skills are improved by a repeated practice process.

3.4 Teaching Reform Result

There are four goals in this course, i.e., (1) master the basic concepts and principles of discrete Fourier transform, fast algorithm and digital filter design; (2) understand the basic properties of discrete Fourier transform, and master the Fourier representation and analysis methods of discrete time signals; (3) be able to apply discrete Fourier transform and fast Fourier transform to analyze the spectrum of continuous signals, calculate linear convolution, etc; (4) be able to design and implement IIR and FIR filters according to the technical specifications of the filter and analyze the characteristics. They are depicted as Goal 1 to Goal 4 in this paper.

Based on the aforementioned teaching reform schemes, the achievability of this course has been evaluated, as is demonstrated in Fig.4. It can be seen from this figure that each achievability item of this course is greater than 0.6, satisfying the requirements of engineering education professional certification.

4. Conclusions

In this paper, the teaching reform is proposed based on the data-driven analysis, aiming to satisfy the requirements of engineering education professional certification. First, the SCC is computed to find the correlations between different aspects and total score. Then, a PNN is trained and tested based on real samples. And the testing result proves that the final score of one student can be partly inferred according to his/her process assessment performance. Based on the data-driven analysis, several schemes have been proposed to improve the achievability of this course. Finally, the experimental results show that these schemes do work well, and the achievability can satisfy the requirements of engineering education professional certification. The proposed schemes are outcome oriented and based on theoretical knowledge. The data-driven teaching reform is also suitable for other courses except for DSP.

References

[1] Fiseha M. Guangul, Adeel H. Suhail, M. I. Khalit, and B. A. Khidhir, "Challenges of remote assessment in higher education in the context of COVID-19: a case study of Middle East College," Educational Assessment, Evaluation and Accountability, vol. 32, pp. 519–535, 2020.

[2] J. Dong, H. Liu, W. Zhang, and Y. Shi, "Reform and Implementation of FIR Filter Experiment Teaching in the Course of Online Digital Signal Processing," in The Sixth International Conference on Information Management and Technology, 2021, pp. 1-5.

[3] S. Boyu, H. Lijun, B. Baodan, and Y. Jiayong, "Online and offline mixed teaching practice of ‘digital signal processing course design’in the context of medical and industrial combination," in 2021 International Conference on Education, Information Management and Service Science (EIMSS), 2021: IEEE, pp. 76-79.

[4] S. Li, K. Li, and Y. Cao, "Teaching Reform and Practice Research of DSP Technology Curriculum," in International Conference on Education, E-learning and Management Technology, 2017, pp. 390-393.

[5] M. K. Banavar et al., "Teaching Signal Processing Applications using an Android Echolocation App," Computers in Education Journal, vol. 12, no. 1, 2021.

[6] W. Hao, H. Liu, and Y. Wang, "A DSP teaching example based on Simulink for undergraduates of electrical engineering," in 2017 20th International Conference on Electrical Machines and Systems (ICEMS), 2017: IEEE, pp. 1-4.

[7] X. Tian, L. Chen, and J. Pang, "The teaching design of digital signal processing based on MATLAB and FPGA," in Frontier and Future Development of Information Technology in Medicine and Education: Springer, 2014, pp. 2109-2114.

[8] Y. Wang and L. Zhang, "Application Research of Digital Signal Processing Course Based on Matlab Teaching," Contemporary Education and Teaching Research, vol. 1, no. 2, pp. 113-118, 2020.

[9] Spearman's rank correlation coefficient [Online]. Available: https://en.wikipedia.org/wiki/Spearman%27s_rank_correlation_coefficient.

[10] M. H. Beale, M. T. Hagan, and H. B. Demuth, "Neural network toolbox," User's Guide, MathWorks, vol. 2, pp. 77-81, 2010.