EDUCATIONAL SUPPORT SYSTEM FOR EXPERIMENTS INVOLVING CONSTRUCTION OF SOUND PROCESSING CIRCUITS

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ABSTRACT

This paper proposes a novel educational support system for technical experiments involving the production of practical electronic circuits for sound processing. To support circuit design and production, each student uses a computer during the experiments, and can learn circuit design, virtual circuit making, and real circuit making. In the proposed system, an analysis system that runs on the internet translates the composition of the circuit that is designed and constructed by the experimenter into the general circuit description language (SPICE). This circuit translation into SPICE enables the simulation of circuit behavior and indicates the presence of incorrect parts in the circuit. The analysis system also provides simulated sound, which is synthesized on the basis of circuit designed or constructed by an experimenter. Therefore, students can individually learn practical circuit making, behaviors of sound-processing circuits, and sound simulation. The proposed system is applicable to various circuit types and learning environments, such as computer-aided circuit design and the manufacture of both virtual and real circuits. The usefulness and effectiveness of the proposed system was evaluated by analyzing circuits made by five university students in an actual class.

KEYWORDS

Electronic circuit experiment, circuit making, sound signal processing, SPICE

1. INTRODUCTION

Knowledge of the design and production of electronic circuits and their practical applications is important for education involving technical experiments. Recently, several educational support systems have been developed to improve students' understanding of electronic circuits and their circuit-making ability. Remote learning systems and virtual laboratories are useful for students lacking experimental facilities (Gurkan, 2008; Oliver, 2009). The simulation systems were developed for learning electronic circuits used in the field of engineering (Abramovitz, 2011; Fitch, 2011). However, these conventional systems cannot cope with the wide variety of circuits constructed by individual experimenters because they are based on all-purpose or ready-made learning tools and are applicable to only specific circuits within a subject area. Moreover, technological experiments in educational institutions have the following problems: (1) student-to-instructor ratios are usually very large and (2) mistakes made in an experimenter's circuits can cause serious accidents such as electric shocks or fire. It is therefore difficult to ensure efficient and secure individual instruction.

To overcome these disadvantages, I have proposed an educational support system for distance learning of experiments involving virtual circuit making (VCM) and real circuit making (RCM) (Takemura, 2011). The previous system (Takemura, 2012) was developed so that a student can learn circuit design and make practical applications of the produced circuit in an electric guitar (Fender Stratocaster). However, the graphical user interface (GUI) used in the preceding VCM systems is not sufficient for practical use. In this paper, a new VCM system including a more user-friendly GUI is proposed (cf., subsection 2.1). Moreover, this study improves the applicability of the system so that a student can learn practical circuits for sound signal processing. The proposed system is applicable to various educational modes and media (e.g., virtual laboratories and e-Learning) for practical electronic circuits and experiments including practical circuit making, such as circuit design, VCM, and RCM (cf., subsection 2.3). The usefulness of the proposed system was evaluated by analyzing the circuits constructed by five students.

2. METHODOLOGY

Figure 1 illustrates the proposed educational support system for experiments involving the design and construction of sound processing circuits. This system consists of individual users' computers and a remote analysis system. To support circuit design and production, each student uses a computer and transmits the circuit image to the analysis system that runs on the internet. The analysis system performs circuit recognition of the designed and constructed circuit using image processing techniques. The analysis system can automatically recognize the circuit construction, and it can also translate the structure of the circuit into a general circuit description language (SPICE) (Rabaey, 2012). This SPICE translation technique (Takemura, 2011) can indicate how the circuit works, and it can identify incorrect parts that may exist in the circuit. This is an important step that aims to improve the efficiency and prevent the occurrence of accidents. The proposed system improves the circuit recognition technique for the VCM and RCM to make it applicable to educational support systems for the practical circuit making of a sound processing circuit. As shown in Fig. 1, the analysis system can provide each experimenter with simulated sound, which was synthesized using the designed or constructed circuit. Therefore, individual experimenters can better understand the effects of sound processing achieved with their circuits.

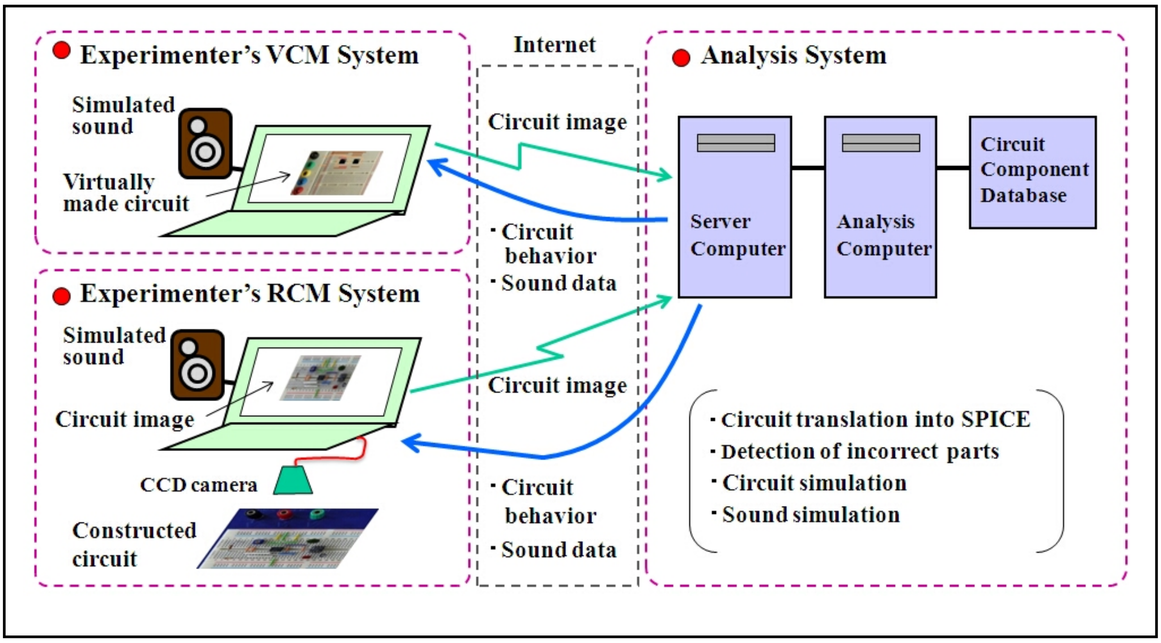

Figure 1. Schematic of the proposed educational support system for experiments involving production of the sound-processing circuits.

2.1 Educational Support System for Circuit Design and Virtual Circuit Making

The VCM system is useful for students lacking the facilities or equipment for RCM (e.g., laboratories, circuit components, and measurement instruments). The previous VCM system (Takemura, 2012) allows individual experimenters to use general graphics editors, which are usually provided in a user's computer. Therefore, this system does not require software to be used exclusively. A virtual circuit image is transmitted to the analysis system along with information pertaining to the color coding of each drawn line, which indicates connected circuit components. The analysis system can differentiate between circuit components and wiring on the basis of line colors, which are defined by the experimenter. However, the virtual circuit image based on the user-defined color lines is actually poor. Thus, the GUI of the preceding system is not user friendly.

This paper improves the GUI of the VCM system so that connections of circuit components on a virtual circuit can be indicated by an experimenter by placing the virtual circuit components and characters representing their parameters (e.g., IC, resistance, and capacitance) on a template circuit-board (breadboard) image using the experimenter's preferred graphic editor. Figure 2 shows examples of the virtual circuit components. Each experimenter can download these virtual circuit components and the template image from the analysis system. The experimenter indicates wirings in the virtual circuit by drawing colored lines on the template image using the graphical editor. The analysis system can perform circuit recognition using image processing techniques (pattern matching) between the image of a virtual circuit and the database of each circuit component in the server computer of the analysis system. The analysis system translates the virtual circuit into SPICE without errors because circuit recognition is based on data that is related to the input of the virtually constructed circuit.

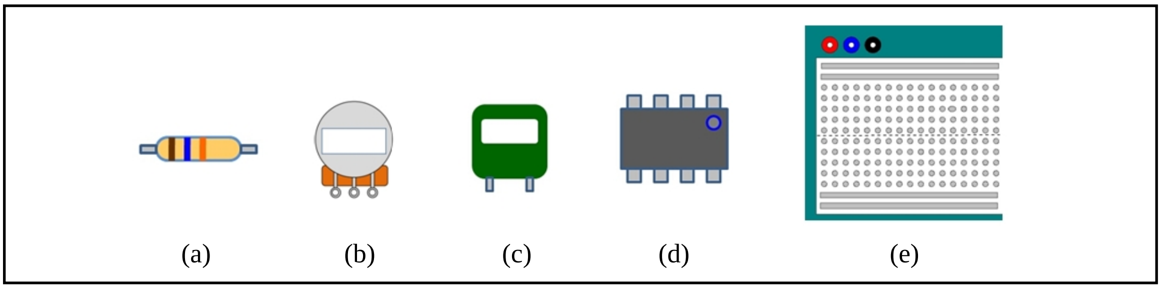

Figure 2. Circuit components for the VCM system: (a)–(d) virtual circuit components prepared for connection on the circuit board image (resistor, potentiometer, capacitor, and IC, respectively), and (e) circuit board image used to construct a virtual circuit.

2.2 Educational Support System for Real Circuit Making

An experimenter transmits the image of a constructed circuit to the analysis system after making the circuit. The analysis system can perform pattern matching between the virtually made circuit (drawn using the VCM system) and the circuit made using the RCM system. This allows the analysis system to automatically differentiate the layout of each device and the circuit wiring. In addition, the analysis system performs circuit recognition based on the training data obtained from this approximate differentiation and the circuit device database (Takemura, 2012). This pattern matching process between the virtual circuit and the real circuit improves the accuracy of circuit recognition and translation into SPICE, and decreases the computational cost of the circuit recognition and translation.

2.3 Combination of the VCM and the RCM Systems

The proposed system has an advantage that individual users can choose preferred modes (combination of VCM and RCM) and media depending on the required purpose or environment. For instance, the proposed system is applied to the following purposes:

- A student lacking circuit components or equipment (measurement instruments) can virtually experience circuit making and measurement.
- An experimenter can learn the behavior of the circuit constructed using the VCM or the RCM system on the basis of circuit translation into SPICE. Measurement instruments are not needed to check the circuit behavior.
- An experimenter can construct the circuit of an electric guitar (Fender Stratocaster) and practical circuits for sound signal processing using the VCM or the RCM system depending on the purpose or

environment. Moreover, the experimenter can experience the simulated sound obtained from the constructed circuit without the need for audio equipment (e.g., audio amplifier and loudspeaker).

3. RESULTS AND DISCUSSION

The proposed system is evaluated by analyzing circuits, which were designed and constructed by five experimenters in an actual class at Tokyo University of Agriculture and Technology. Figure 3 shows an example of the results based on a practical sound processing circuit (low-pass filter) that was used to improve the sounds of an electric guitar. Figure 3(a) shows the diagram of the circuit to be made. Figure 3(b) shows the incorrect circuit of the sound processing circuit, which was drawn using the experimenter's computer. The analysis system automatically indicated the incorrect parts on the circuit image using red broken lines. The experimenter then corrected the circuit accordingly. Based on the corrected circuit [shown in Fig. 3(c)], the analysis system recognized the circuit construction, and translated the circuit into SPICE. Figure 3(d) shows an example of the simulation results (frequency characteristics) obtained from the results of the SPICE translation. The analysis system provided this simulation result and simulated the sounds, and the experimenter could therefore learn the behavior of the circuit and the effect of sound processing (synthesized sound) on the basis of virtual circuit. Figure 3(e) shows the circuit constructed using the RCM system depending on the correct circuit, which was constructed virtually using the VCM system [Fig. 3(c)]. The results of the circuit simulation and sound processing obtained from the real circuit made using the RCM system were the same as those obtained from the virtual circuit, which was previously made using the VCM system. The user can then verify that the circuit made using the RCM system behaves accurately.

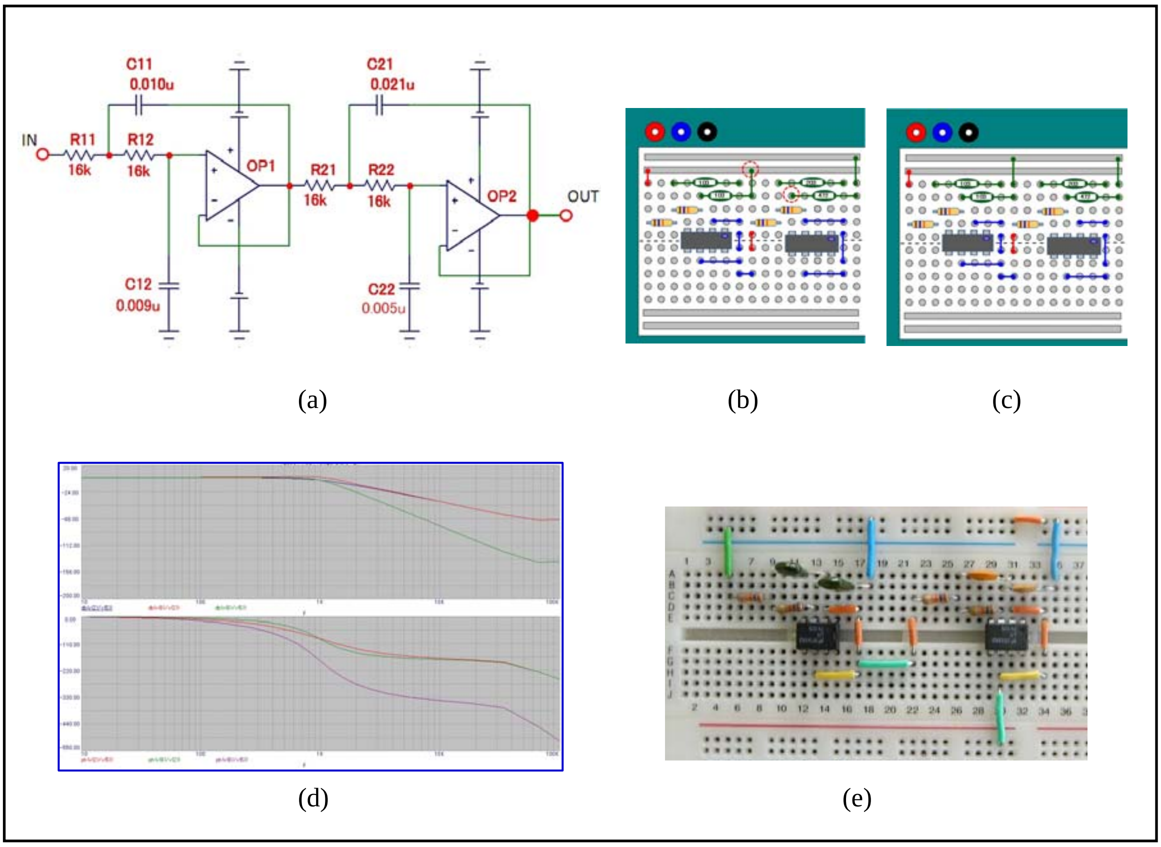

Figure 3. Results of automatic circuit translation and simulation using the VCM and RCM systems: (a) diagram of a circuit to be made; (b) incorrect circuits made using the VCM system; (c) correct circuits made using the VCM system; (d) SPICE simulation based on the circuit translation of the circuit (e); and correct circuit constructed using the RCM system.

The proposed system was evaluated by analyzing the circuits made by five students at Tokyo University of Agriculture and Technology. The following positive responses, which pertain to the usefulness and efficiency of the proposed system, were obtained from all of the students:

- The proposed systems are useful because it enables remote learning of topics such as circuit design and experiments involving practical circuit making for sound signal processing.
- The proposed system is instructive because individual students can learn the practical circuits for sound signal processing, and also the behavior of circuits on the basis of SPICE and simulated sounds.
- The GUI for VCM is user-friendly and useful.

However, there were also a few technical disadvantages and suggestions for improvement:

- A remote educational system to learn both analog and digital circuits for signal processing is expected.
- The size of the experimenter’s system is expected to be reduced.

4. CONCLUSION

This paper proposed an educational support system for experiments, which are performed in different environments such as computer-aided circuit design, VCM, and RCM. The system can teach methods related to the production of basic circuits for processing sound signals. The usefulness and effectiveness of the system were verified by analyzing electronic circuits made by five students in an actual university class. The following steps are necessary to practically realize the proposed system:

- The usefulness of the proposed system must be first validated by a larger number of experimenters.
- There is a need for an educational support system, which can be used by users to learn various techniques and practical circuit making (e.g., larger scale circuits).

ACKNOWLEDGMENT

This study was partly supported by a Grant-in-Aid for Scientific Research (KAKENHI) 22500878 from the Japan Society for the Promotion of Science (JSPS).

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