研究資料

Development of Interactive Educational Support Tool and Its Learning Effect

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In this paper, we describe the process of developing an educational support tool of "Electric circuit". This tool is called iCASS (interactive Circuits And Systems Seminar). iCASS which enables to understand "Movement" of the model from using interactive animation and "Sound" by an easy GUI (Graphical User Interface) operation. Because this tool uses the WWW (World Wide Web) system as the IT (Information Technology) education, it is possible to introduce as an E-learning tool. In this tool, no numerical value from a keyboard is used. Consequently, a student can understand a physical phenomenon ("Movement" of an engineering model) without dealing with unfastidious numerical values more than required. Furthermore, iCASS might be able to avoid "squiffy doo" of the simulation by connecting an actual model and animation on the web. Here, in order to connect the actual model and iCASS, we use PICNIC (Network Interface Card using Peripheral Interface Controller). By using iCASS in the actual classroom, students' understanding level can be improved and it may attract more students' interest. The E-learning tool proposed can be found at http://www.sia.co.jp/~icass/index. html.

Keywords
E-learning, iCASS, IT education, educational support tool, learning effect

1．Introduction

There are great deals of discussions about declining numbers of students in Electrical Engineering at the university. New methods of teaching will help to make these subjects more attractive to students (R. Ubell 2000, B. H. C howdhury 2000).

Generally, it is difficult for a student (beginner) to intuitively understand the "Movement" of the engineering model as it is a complex technological issue, which obstructs the students' learning of scientific and technological subjects. For example, the use of space and time-dependent vector-valued functions to describe the behavior of the current and the voltage in electric circuits raises many difficulties. In the electric and electronic engineering, learning through experiments and practices is being encouraged to facilitate the understanding of the various phenomena (the "Movement" of the model). The advantages of the learning through experiments and practices are not only the ability to experience the "movement" of the model, but also the followings:

（1）　The understanding of manufacturing such as "preparation", "production", "verification" and "a consideration" can be developed.

（2）　This does not make sense the student can support the ability that abstract physics phenomenon is caught quantitatively and data is brought together as other people understand it needs to be reiterated.

On the other hand, there is the disadvantage in the experiment and the practice to treat the physical phenomenon as follows.

（1）　It is time consuming to prepare and conduct an experiment.

（2）　It is difficult for a learner to easily execute, and to study the experiment and the practice by

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oneself.

As one method of solving these problems, there is a virtual experience by the simulation using EDA (Electronic Design Automation) tool. The advantages of using a simulation are the flexibility which comes from having a system implemented in a general manner, and the lower cost. However, in order to make the simulation useful, it has to offer a feel of using hardware.

Recently, because of the underlying software technology the tool can be used for on-line learning and can be easily integrated into E-learning platform for distance learning (U. Drofenic et. al., Y. Mori and N. Hiroyama 2001). It can be also used in a traditional classroom with a notebook computer and an overhead projector, using the Internet or CD-ROM. An advantage of E-Learning is the independence of working in any place and time. Furthermore, if the content can be presented in a web-browser and programs such as simulation and/or animation are able to run inside the webbrowser, the dependency of the software on the operating system can be eliminated. At the ETH (Eidgenoessische Technische Hochschule) Zurich an E-Learning tool has been developed to fulfill the needs

described above. This tool is called iPES (Interactive Power Electronics Seminar) and is constituted by HTML texts with Java applets.

We describe the development process of this unique web-based interactive animation software for teaching and self-learning electric circuits like iPES (U. Drofenic et. al.) In this paper, we call an interactive education tool in circuits and systems (iCASS). Sound is also used in the interactive animation in iCASS. Moreover, iCASS might avoid "squiffy doo" of the simulation by connecting an actual model and a computer. By using iCASS in the actual classroom, it can improve students' understanding and attract students' interest.

2．Aim of the system development

iCASS is an unique web-based education tool using interactive animation and sound. This system is independent of working place and time. Hence, the students have the opportunity to learn in their favorite environment at the time of their choice. Moreover, this system might avoid "squiffy doo" of the simulation by connecting an actual model and iCASS. In Fig. 1, the concept of the proposed system is shown and those details are described as follows.

（1）　**Visualize a movement of models**

Generally, it is difficult for a student to understand the "Movement" of the engineering model intuitively. It is difficult to learn a technology through a model as a result. Furthermore, it is difficult to express the "Movement" of the engineering model and complex scientific and technological issues in a conventional class using a black board which is restricted to static diagrams and words only. This sentence dose not makes sense. It needs to be reiterated. Consequently, interactive animation can help a lot. For example, the parameters on model can be changed easily on GUI. Especially, the value of an element is represented in the size of its element in the proposed tool and it helps students visualize the process.

（2）　**Effective use of sound**

The engineering model can not only be watched but also be heard, which attracts students' interest. Using the tool can be a fun for students. For example, if resonance frequency in a resonant circuit is changed, the sound of changing a radio channel is heard. Moreover, if the "width" of the frequency response in the circuit is wide, it has low frequency selectivity. That is, if resonant circuit is lower quality
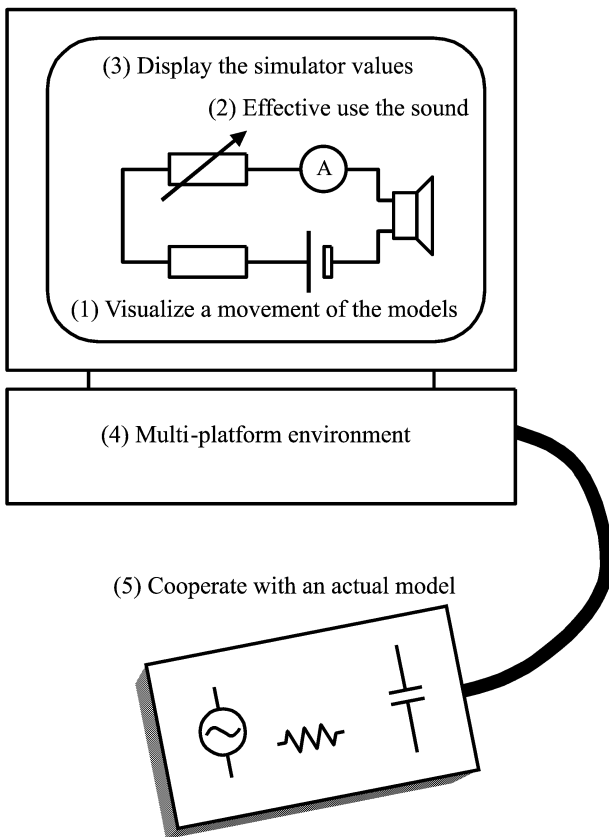

Fig. 1　The concept of iCASS tool

factor Q, sound interferes. Thus, it becomes a more realistic experience for a student that the frequency characteristic and sound change simultaneously.

（3） **Display of the simulator values**

The "Movement" of an engineering model is intuitively understood by displaying animation. Displaying emphatically the changing physical values, however, will teach wrong knowledge to students. Therefore, in this teaching tool, we display the result of the correct calculation by using theoretical formula. That is, it might use a simple EDA tool because it can display the result of obtaining by the simulation. Moreover, the students set circuits parameters without explicitly starting a simulation and immediately see the resulting behavior of various currents, voltages and signals.

（4） **Multi-platform environment**

If the content can be presented in the web-browser and programs such as simulation and/or animation are able to run inside a web-browser, the dependency of the software on the operating system can be eliminated. Java programs make it possible to run within web-browsers. Moreover, Java programs running inside web-browser are embedded in an HTML page and are called Java-applet (M.G. David part1 2000, M.G. David part2 2000). Therefore, iCASS is constituted by HTML texts with Java-applets for interactive animation, sound, circuits design and simulation, and visualization

（5） **Cooperation with an actual model**

Most teaching tools that has used IT, perform only as simulation on the computer. However, in the field where an actual model like electric circuits and systems can be obtained easily, the teaching tool using both the simulation and the actual model is useful for students. That is, visualizing the phenomenon without "squiffy doo" of the simulation becomes possible. Consequently, this tool connects an actual electric circuit model and iCASS by Ethernet as shown in Fig. 2. At this time, when any value in the resistor, inductor or capacitor in the actual electric circuit model is changed, the Web animation (size of elements and response) on PC will change, interlock with the value. In order to realize this, iCASS needs to supervise the state on the actual electric circuit model. Here, in order to connect an actual electric circuit's model and iCASS, we use PICNIC, as shown in Fig. 3. Since a Java applet cannot communicate with actual electric circuit model directly, we use JSP
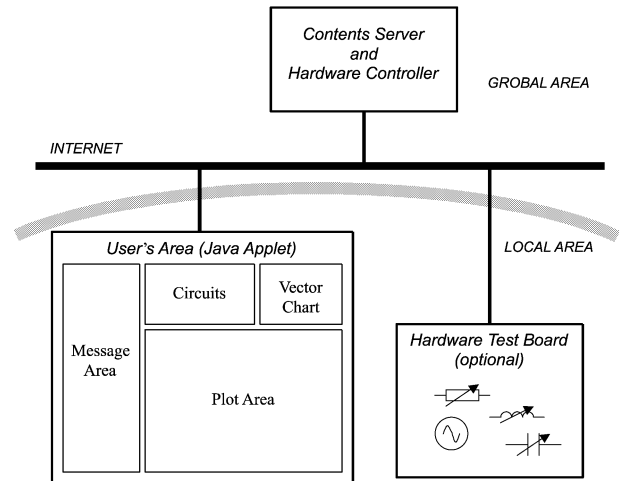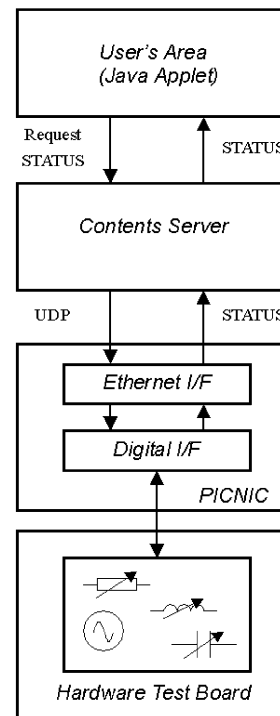

Fig. 2　System structure

Fig. 3　Control method of object model

(Java Server Pages) in order to control PICNIC. Here, JSP is a technology based on the Java language and enables the development of dynamic web sites. JSP files are HTML files with special tags containing Java source code that provide the dynamic content. It should be kept in mind for security that the connection of the actual electric circuit model and iCASS, is restricted within the school.

3．Contents of iCASS

As shown in Fig. 4, iCASS provides an excellent base for teaching an introductory course on electric circuits including the subjects listed in the following:

（0）　Fundamental electric circuits
（1）　DC circuits
（2）　Sinusoidal wave and complex plane
（3）　AC circuits
（4）　AC power
（5）　Resonant circuits
（6）　Mutual induction circuits (waiting)
（7）　Matching circuits (waiting)
（8）　Bridge circuits
（9）　Filter circuits (waiting)
（10）　Transient phenomena
（11）　Fourier series
（12）　Fourier transform (waiting)
（13）　Distribution circuits (waiting)

The contents of "waiting" indicator will be completed in the near future. Figure 5 shows a connection of the actual electric circuits model with iCASS. The actual electric circuit on circuit board consists of 8 IC sockets as shown in Fig. 6 and simple logic circuits as shown in Fig. 7. By connecting an IC socket as shown in Fig. 8 to the socket on a board, various circuits are realizable. If IC sockets that put up the resistor, inductor and capacitor to 1-1' terminal of Fig. 8 are connected with S_1, S_2 and S_3, respectively, the RLC series circuit can be achieved. In the same way, if IC socket that put up the resistor, inductor and capacitor are connected S_6, S_7 and S_8, respectively, the RLC parallel circuit can be achieved. In order to recognize kinds of elements (R, L, C) connected with 1-1' terminal of the IC socket to PC
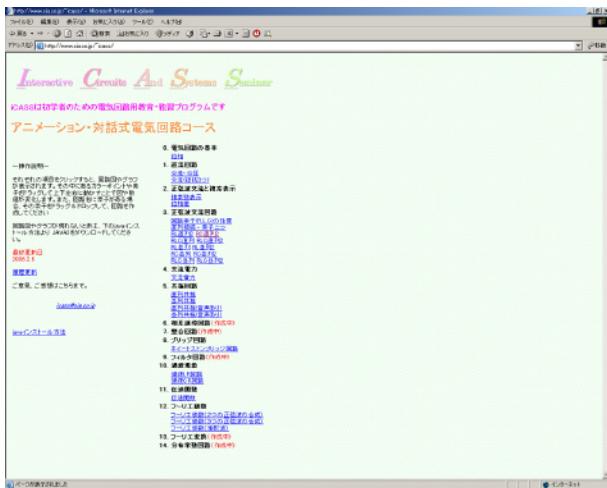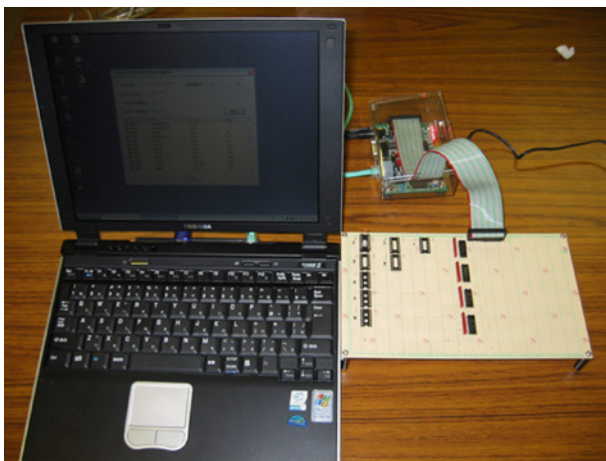

Fig. 4　Main menu of iCASS

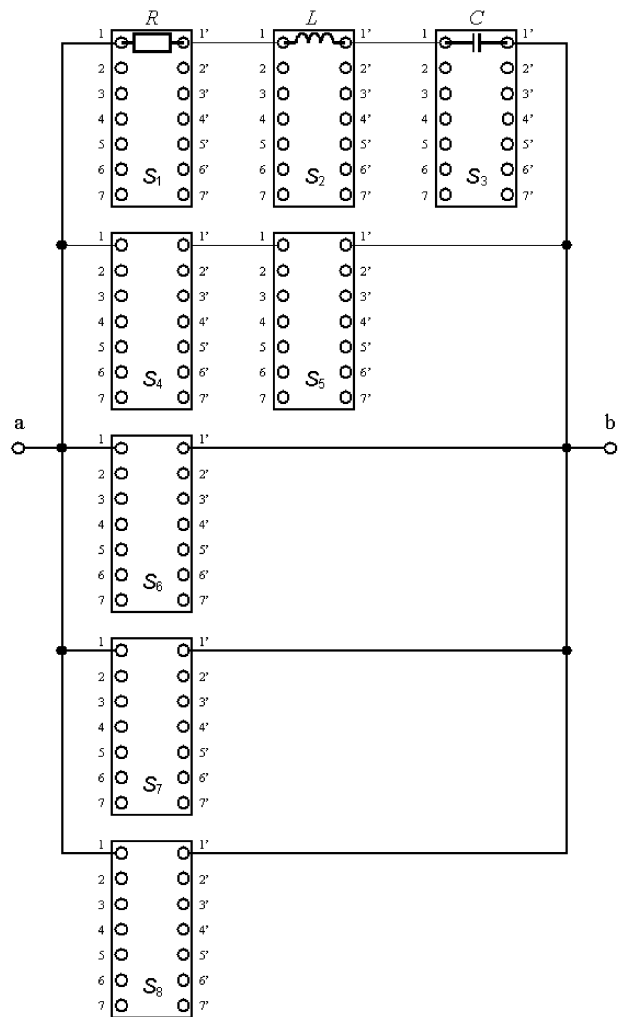Fig. 5　Connection with the practical model

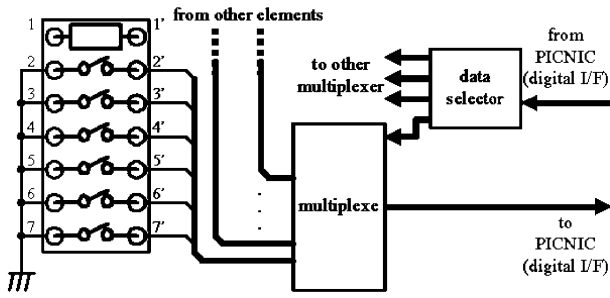Fig. 6　Actual electric diagram on board
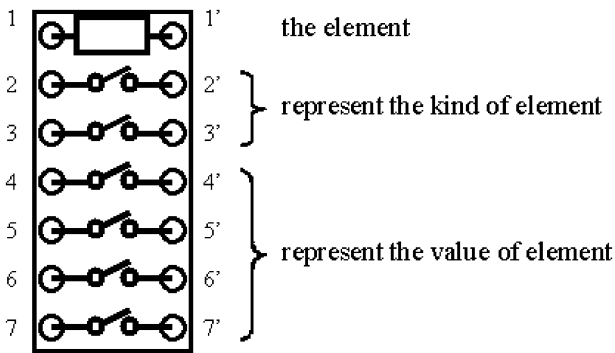
Fig. 7　Logic circuits

Fig. 8　Structure of IC socket

by using logic circuits as shown in Fig. 7, 2-2' and/or 3-3' terminals are open-circuits and/or short-circuits. In the same way, in order to recognize value of elements connected with 1-1' terminal of that, terminals from 4-4' to 7-7' are open-circuited and/or short-circuited. Moreover, by connecting measuring instruments to the position which can measure the amount of physics as shown in iCASS and power supply with the terminal a and b (see Fig. 6) by the teacher's instruction, the experiment to which actual electric circuits model and the display of iCASS are corresponding can be conducted. Here, you note that neither the value of the measuring instrument nor the value of the element is observed directly on the iCASS as previously mentioned. However, in order to lose "squiffy doo" of a simulation, the proposed method is devised so that directions of a measuring instrument and the display of iCASS may be in agreement. Moreover, it can also be used as a simple design tool (EDA).

4．Example of iCASS

As an example of iCASS, the example of WWW system dealing with a series resonant circuit is shown in Figs. 9 and 10. In the circuit of Fig. 9, the GUI of the
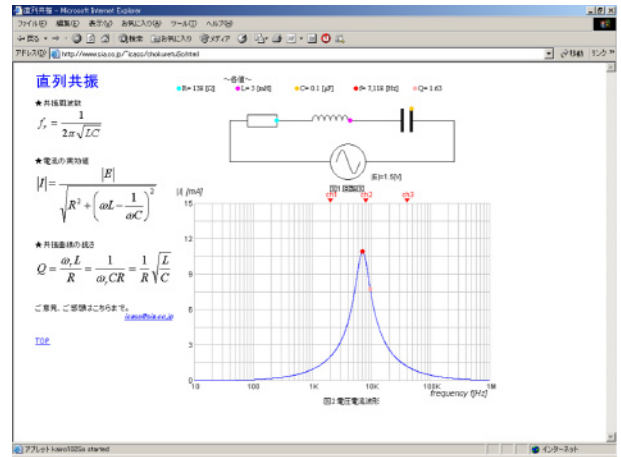

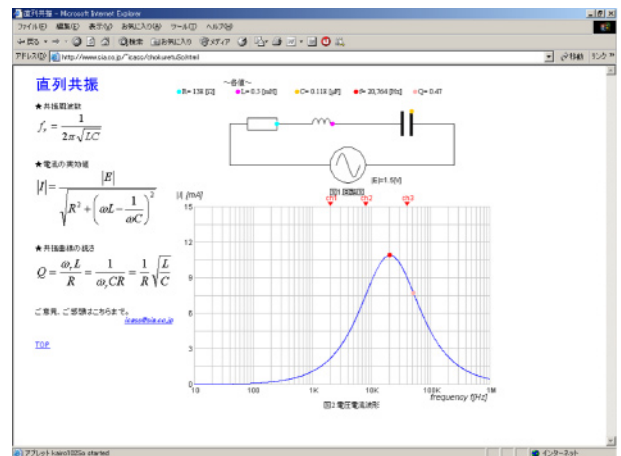Fig. 9　An example of the teaching materials for Resonance

Fig. 10　An example of the teaching materials for Movement by changing elements

applets is very intuitive as like iPES. The general role (with some exceptions) is: One can click or drag all colored round mark with mouse as well as iPES. In order to give the student an intuitive image, there is no function of a numerical input at iCASS and the value of an element is imagined in the size of an element. Namely, the student can interactively influence parameters. In the series resonant circuit, when circuit elements (R, L, C) are changed, it is important to understand how resonance frequency, quality factor and current change. The student can change the each element value as shown in Fig. 10 by simply dragging the colored round mark of resistor, inductor and capacitor, as shown in Fig. 9, with the mouse, and can immediately see the appearance of the change in the resonance frequency and quality factor. Because the colored round mark is also set up in the characteristic frequency

curve, when characteristic is dragged with a mouse, it is shown how each element value at the circuit changes. Moreover, the role of resonance and the quality factor can be felt to "sound" in iCASS. In Figs. 9 and 10, three channels are prepared, and if the channel is matched to the resonance frequency, sound can be heard most greatly. In addition, it is important to understand that circuits possessing a higher quality factor Q have a narrower bandwidth, or a sharper response curve; they have greater frequency selectivity or higher quality factor. For example, if a quality factor Q is small, the student can feel by the sound that interference between channels will occur. The size of each element and the resonance characteristic on the screen synchronize and change, when the actual model is connected and the each element value of the resistor, inductor and capacitor on the model is changed. Here, you note that the size of element and the resonance

Fig. 11　An example of the connecting measuring instrument

characteristic on the WWW system become "discrete movements" corresponding to this value, since element value can represent only eight kinds in iCASS. By connecting an actual model, the student might become possible not only like an intuitively recognize but also experiment for the relation between an element value and the characteristic. Furthermore, the measuring instruments are also connectable with iCASS as shown in Fig. 11. Here, the transmitter is connected with terminal a-b and the Chirp signal is output. Additionally, an oscilloscope is connected with terminal 1-1' of the S1 socket. At this time, because the plot area display on iCASS and the display of the oscilloscope become the same, this system might be canceled "squiffy doo" of the simulation.

iCASS is comprised by Java applets embedded into HTML pages. The text explaining the theory is written in simple HTML. The student might use as a self-learning tool without depending on working place and time.

5．The educational effect of iCASS

In this section, educational effect of iCASS is examined for an actual class. In order to measure the educational effect of iCASS, the lesson with iCASS and the one without iCASS were given to the same 14 students for 45 minutes, respectively, and the exercise were given after each lesson. Here, although the students attended the same lesson twice, it was different from lesson the attended previously. Concretely, at first, 7 students took the lesson with iCASS and the rest of 7 students took the lesson without iCASS. Next, it was reversed in the class of the next time. The lesson with iCASS was held with only the teacher operating iCASS, and the student attended the lesson while seeing the screen. On the other hand, in the lesson without iCASS, the teacher taught by writing the part of the animation of iCASS on the blackboard. Figure 12 shows the evaluation average point of the exercise when the turn of the lesson was changed at random. It is clear from this figure that the evaluating point of the lesson with iCASS is better than the evaluating point of the lesson without iCASS in 5 lessons even if we change the turn of the lesson. Especially, the improvement in the results of the lecture for the character of fundamental elements and series-parallel circuit is remarkable. In circuits that contain inductor or capacitor, the deviation of the phase between the current and the voltage
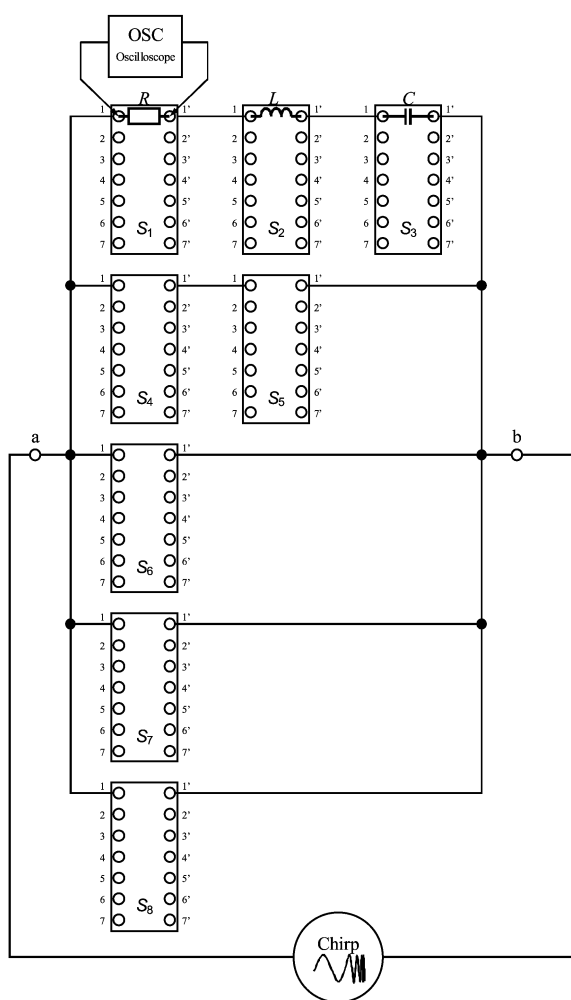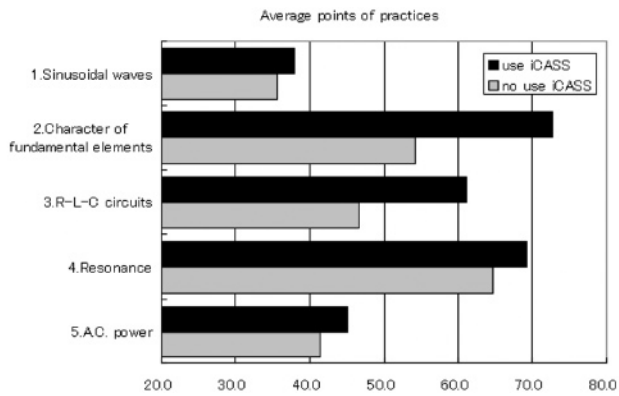
Fig. 12　An evaluation of iCASS for Average points of practices
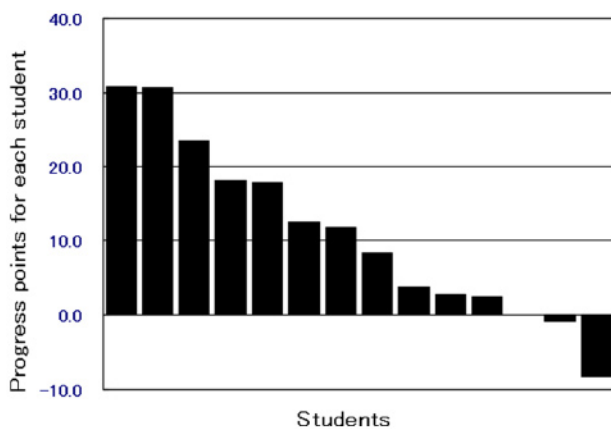
Fig. 13　An evaluation of iCASS for Progress points for each student

Table 1　Contents of ICASS

	Theme of lecture	Contents
1	Sinusoidal waves	instantaneous value, phase, amplitude, frequency etc., reactance
2	Character of fundamental elements	Ohm's law, phase difference between a voltage and a current, reactance
3	R-L-C circuits	shunt/voltage divide circuits, impedance, vector locus
4	Resonance	resonance frequency, quality factor resonance curve
5	A.C. power	instantaneous/effevtive/ reactive power, powerfactor, complex power

Table 2　A result of the questionnaire

Question	Average points
Interest degree for the electrical circuits	3.8
Understanding level for the electrical	4.0

more effective. The improvements in results of the lecture for the character of fundamental elements and series-parallel circuit have to be presented in a way that is easy to follow and understand.

can be understood by animation of iCASS. On the other hand, there are not so many differences in the students' understanding of phenomenon because the phase difference between the current and the voltage doesn't relate in the lesson of sinusoidal waves. Figure 13 shows the improvement in 11 out of 14 students.

To evaluate iCASS, we questioned students as follows, using the five-point Likert type scale.

（1）　Did you improve the degree of the interest toward electric circuits?

（2）　Did you improve the understanding of electric circuits?

Table 2 shows the result of the questionnaire, where it means that evaluation 5 improved most and evaluation 1 the least. It is clear from Table 2 that iCASS is effective in Raising the interest level and improving the understanding of a student.

iCASS might not only make studying electric circuits more interesting to student, but also make teaching

6 ． Conclusion

In this paper, a new operating-system-independent E-Learning tool (iCASS) for education electric circuits and system was proposed. iCASS is made of Java applets which are embedded in HTML text. Moreover, sound is used with the interactive animation in iCASS. Therefore, adding the applets and sounds to traditional teaching might motivate students and allow to speed up the learning process.

Furthermore, iCASS might avoid "squiffy doo" of the simulation by connecting an actual model and computer. When this tool was used in an actual classroom, we described that this tool would have an effect for attracting students' interest and speed up the learning process.

The E-Learning tool proposed can be found at http://www.sia.co.jp/~icass/index.html/ (Y. Mori et. al. iCASS). The tool is still under development and web page is continuously updated.

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studied industrial electronics at the University of Technology Vienna, Austria, where he also received the Ph.D. degree (summa cum laude). From 1984 to 2001 he was with the University of Technology in Vienna, where he was teaching and working in research in close collaboration with the industry in the fields of high performance drives, high frequency inverter systems for process technology and uninterruptible power supplies. He has proposed numerous novel converter topologies, e.g., the VIENNA Rectifier and the Three-Phase AC-AC Sparse Matrix Converter concept. Dr. Kolar has published over 150 scientific papers in international journals and conference proceeding and has filed more than 50 patents. He was appointed Professor and Head of the Power Electronics Systems Laboratory at the Swiss Federal Institute of Technology (ETH) Zurich on Feb. 1, 2001.
The focus of his current research is on novel AC-AC and AC-DC converter topologies with low effects on the mains for telecommunication systems, More-Electric-Aircraft applications and distributed power systems utilizing fuel cells. A further main area of research is the realization of ultra-compact intelligent converter modules employing latest power semiconductor technology (SiC) and novel concepts for cooling EMI filtering Dr. Kolar is a Senior Member of the IEEE and member of the IEEJ and of Technical Program Committees of numerous international conferences in the field (e.g. Director of the Power Quality branch of the International Conference on Power Conversion and Intelligent Motion). From 1997 through 2000 he served as an Associate Editor of the IEEE Transactions on Industrial Electronics and since 2001 as an Associate Editor of the IEEE Transactions on Power Electronics

対話的教育支援システムの開発とその学習効果

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　本稿ではインタラクティブ性とアニメーション効果を利用し、簡単なGUI操作で工学的モデルの「動き」を理解でききかつ、「音」の効果を取り入れた「電気回路」用教育支援教材iCASS（interactive Circuits And Systems Seminar）を開発する。iCASSは従来のITを用いた教材と同様に、WWWシステムを用いているため、E-Learning教材として学習できる。この教材において、学習者には必要以上に数値にこだわらず、純粋に物理現象（工学的モデルの「動き」）のみを理解させるため、キーボードからの数値入力機能は設けていない。さらに、iCASSは実機（モデル）とウェブ上のアニメーションを連携させることにより、シミュレーションによる「うそ臭さ」を解消している。また、実機モデルとiCASSの連携にはPICNIC（Network Interface Card using Peripheral Interface Controller）を用いてEthernetにより接続する。本稿には実際にiCASSを用いた教育方法と一般的な黒板を用いた教育方法との比較・評価を行い、iCASSの学習効果の有効性を示す。この教育支援教材はhttp://www.sia.co.jp/~icass/index. html/で閲覧可能である。

キーワード
E-Learning、iCASS、IT教材、教育支援教材、学習効果

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