Development of A Learning Environment for Playing Erhu by Diagnosis and Advice regarding Finger Position on Strings

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ABSTRACT
So far, there are few existing studies on skill learning support environments for playing string instruments with bows because there are many parameters to acquire skills and it is difficult to measure these parameters. Therefore, the aim of this paper is to propose a design of a learning environment for a novice learner to acquire an accurate finger position skill. For achieving the aim, we developed a learning environment which can diagnose learner's finger position and give the learner advice by using magnetic position sensors. The system shows three windows; a finger position window for visualization of finger position, a score window for diagnosing finger position along the score and command prompt window for showing states of system and advice. Finally, we evaluated the system by an experiment. The experimental group improved accuracy values about finger positions and also improved accuracy of pitches of sounds compared with the control group. These results show significant differences.

Keywords
Magnetic Position Sensors, String Instruments, Skill, Learning Environment, Finger Position

1. INTRODUCTION
Generally, to acquire skills for playing instruments is achieved by means of taking a lesson, practicing by self-learning, referring to a study-aid book, and so on. In case of self-learning, the novices give up acquiring skills because they get into a wrong habit, don't understand how to play instruments and don't make progress. Particularly, the string instruments with bows (e.g. the violin, the cello, and erhu) have many parameters to control. The parameters are the finger positions, the pressures of pressing strings, the motion, the speed, the acceleration, and the angle about bows. So, it is difficult for the novices to play with accurate pitches. Therefore, if we develop a learning environment for playing string instruments with bows, these problems will be solved.

Recently, there are many studies about analysis of skills and the learning environment because of progress of sensors and computers performances [1][2][3][4][5][6][7][8]. In case of using magnetic position sensors, there is analysis of finger movements of a pianist [9]. In case of the string instruments, there is a study about robot which plays the violin [10]. In addition, there are many studies about analysis of playing the violin [11][12][13][14]. Moreover, there is a study about pitch training system for violin learners [15]. However, this pitch training system does not diagnose learner's motion parameters and pressure parameters, but diagnoses only sound pitches. Therefore, the novice learner cannot identify the cause of pitch errors.

Because of these backgrounds, we have analyzed novice players' parameters during playing a string instrument with bow. Specifically, we analyzed erhu playing parameters by novice players [16]. As the results of the analysis, novice learners need supports of finger positions, bow motions, bow speeds, bow accelerations, and bow angles. The sounds depend on these parameters. A novice learner doesn't understand the reasons why the sounds aren't correct because there are many parameters to control. So, a novice learner needs a learning support environment for controlling each parameter. Firstly, we tried to assist a learner to control finger positions. Therefore, the aim of this paper is to propose a design of a learning environment for a novice learner to acquire an accurate finger position skill. Furthermore, we developed a learning environment which can diagnose learner's finger position and give the learner advice by using magnetic position sensors. We expect that the novice learner will improve the skill for playing accurate pitches by acquiring accurate finger position skill.

2. METHOD
In this section, we show the system for achieving the aim.

2.1 Instruments Choice
We have chosen erhu in string instruments with bows. Figure 1 shows an erhu. Figure 2 shows left hand while playing erhu. Figure 3 shows right hand while playing erhu.

There is a reason that we have chosen erhu in string instruments with bows. It is two-stringed instrument. Because of two-stringed instrument, a learner only needs to judge which string he/she touches in those two strings with a bow. In case of violin, a learner needs to judge which string he/she touches in four strings with a bow. So, his/her hand and finger motions are

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very complicated. Therefore, it is very difficult for the novice learner to acquire the skills.

How to play erhu is as follows. Left fingers press strings with pitches as Figure 2. Then, it needs accurate finger position skill. A pitch error reflects a finger position error directly because erhu has no border between pitches. Moreover, if the finger pressures are too weak, the learner cannot play clear sounds. On the other side, right hand holds a bow from underneath as Figure 3. Then, right index finger is attached to the wood part and right middle finger and ring finger control hair tension of the bow. A learner plays sounds by moving the bow between right and left, by the frictions between the bow and the strings. Loudness and expression of sounds depend on pressures between the bow and the strings, moving speed of the bow, and how to move the bow.

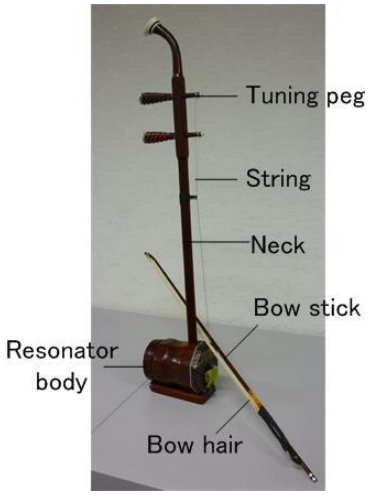

Figure 1. Erhu

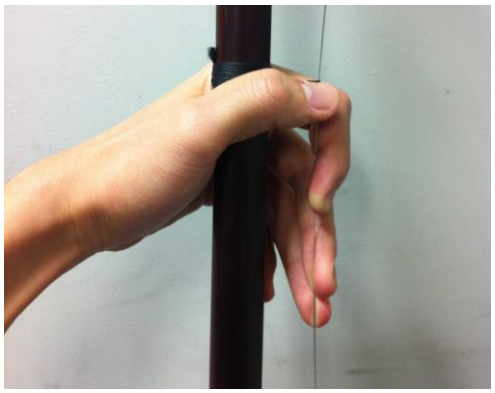

Figure 2. Left hand during playing erhu

Figure 3. Right hand during playing erhu

2.2 Magnetic Position Sensors LIBERTY

LIBERTY is magnetic position sensors developed by Polhemus Inc. A transmitter and up to 16 receivers are connected to a main unit for use. Figure 4 shows magnetic position sensor LIBERTY. A transmitter generates magnetic fields which have three directions by passing an electric current in turn through coils around three axes. Receivers also have coils around three axes. When a magnetic field is generated by the transmitter, an induced electric current is generated in the receivers. Then, position and orientation of each receiver is measured by this amperage. This measured data is transmitted to a connected PC as ASCII or binary data. Liberty is connected with PC through USB ports or serial ports.

Figure 4. Magnetic position sensors LIBERTY

2.3 Analysis of Novices' Erhu Playing Skills

We analyzed novices' erhu playing skills for developing a learning environment for playing string instruments with bows. We have experimented on eleven subjects for analysis of novices' erhu playing skills. We have given them a piece of music. Then, we have explained how to play erhu. After that, they have practiced in thirty minutes. After that, we have measured data, while they were playing a set piece of music. Analysis items are their eyes motion, finger pressures of left and right hands, and fingering.

We have found that they need to support their style, finger pressure, fingering, and pitches by analyzing the result of experiment. However, novices can concentrate only on one item or two items during playing erhu. So, we aim to support a skill for playing accurate pitches instead of support all items.

2.4 System Composition

Figure 5 shows system composition. The system consists of a PC, a magnetic position sensor LIBERTY and an erhu. The erhu is equipped with a transmitter of LIBERTY. Learner's index finger, middle finger and ring finger are equipped with receivers of LIBERTY for measuring finger positions. The system diagnoses learner's finger positions and gives advice by using data measured by the receivers. The learner learns playing skills by using this information.

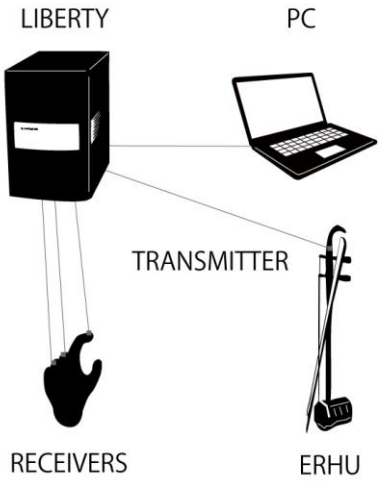

Figure 5. System composition

2.5 System Screen

Figure 6 shows screen shot of the system. There are three windows on the screen, finger position window for visualization of finger position, score window for diagnosing finger position along score and command prompt window for showing states of system and advice.

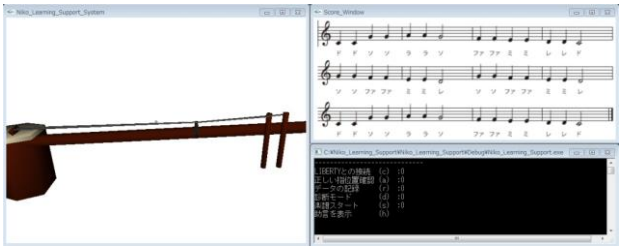

Figure 6. Screen shot of the system

2.6 Finger Position Window

Figure 7 shows finger position window. It shows totally six colored small spheres with virtual erhu model in the virtual 3D space. Three spheres of them represent learner's left finger positions measured by magnetic position sensors. The positions of index finger, middle finger and ring finger are colored light red, light blue and light green, respectively. The other three spheres represent correct accurate finger positions. The correct positions of index finger, middle finger and ring finger are colored red, blue and green, respectively. Viewpoint in the virtual 3D space is changeable freely. The learner can recognize differences between his/her finger positions and correct finger positions.

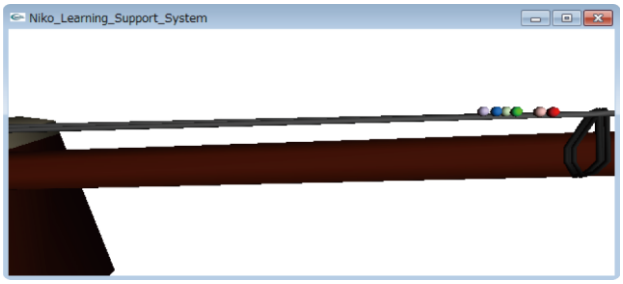

Figure 7. Finger position window

2.7 Score Window

Figure 8 shows score window. It shows score of the music, point of diagnosing, and results of diagnosing. Point of diagnosing is shown by black line, and it moves along the score. A learner plays erhu by synchronizing a playing note with a note on this black line. The learner's playing is diagnosed by the system on real-time. Then, the results of diagnosis are indicated with red line or purple line or nothing. A red line represents that learner's finger position is upper than correct accurate position. A purple line represents that learner's position is lower than correct accurate position. If neither red line nor purple line is indicated, it means learner's finger position is correct. The learner can recognize where he/she made errors of finger positions and how to correct his/her errors.

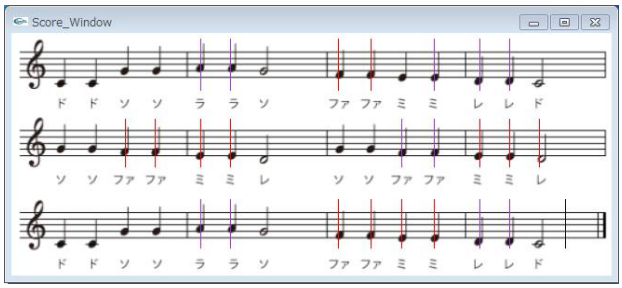

Figure 8. Score window

2.8 Command Prompt Window

Command prompt window shows system status transition by key operation and advice. A learner operates the system with confirming command prompt window. After playing, it shows each average difference between learner's finger positions and correct accurate positions and also shows advice by each average difference.

3. EVALUATION

In this section, we explain evaluation experiment.

3.1 Experiment Method

Figure 9 shows evaluation experiment outline. Twenty novices regarding playing erhu, who are students in their early twenties, are divided into an experimental group who use the system and a control group who use conventional learning support method by watching DVDs. The experimental group has ten subjects from A to J. The control group also has ten subjects from K to T.

We explained how to play erhu to both groups at the beginning. After that, we conducted pre-test to each subject in both group. In the pre-test, each subject in both group played a music with an erhu without using the system. The played music title was "Twinkle Twinkle Little Star".

After the pre-test, subjects in the experimental group trained himself/herself for 15 minutes by using the system and a tuner. Specifically, they played the music with an erhu repeatedly by using the system and a tuner.

On the other hand, subjects in the control group trained himself/herself for 15 minutes with DVD contents and a tuner. Specifically, they played the music with an erhu repeatedly watching an experts' playing in a DVD, and also using a tuner.

After the training, we conducted post-test with the same procedure and condition as the pre-test.

We have prepared two evaluation items. They are finger position evaluation and pitches evaluation. Furthermore, we conducted questionnaire survey to evaluate learners' awareness and usability of the system.

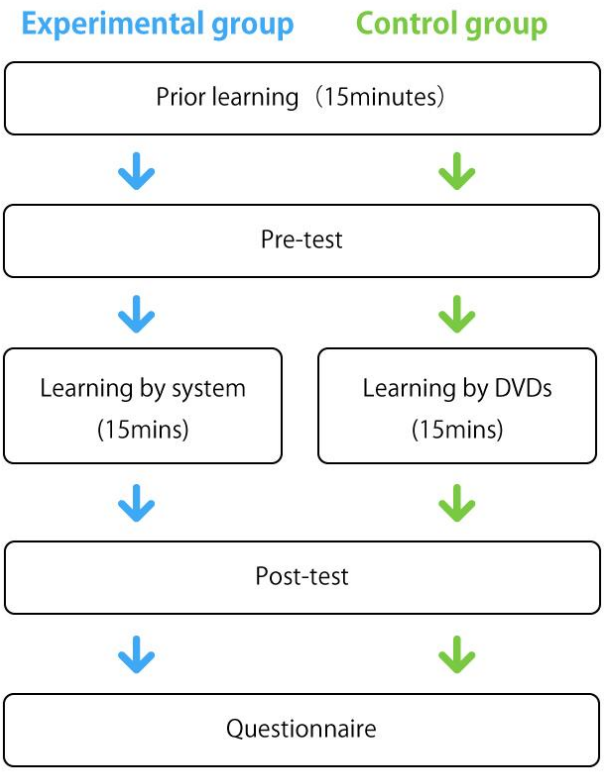

Figure 9. Evaluation experiment outline

3.2 Finger Position Evaluation

This item evaluates whether or not subjects acquired a skill for putting their finger tips on the strings of an erhu with the accurate finger positions. We define this skill as "Finger position skill". Figure 10 shows fingers of subject's left hand equipped with receivers of LIBERTY. We measured finger position according to each sound in a piece of music by using LIBERTY. We evaluated differences between subjects' finger positions and accurate finger positions.

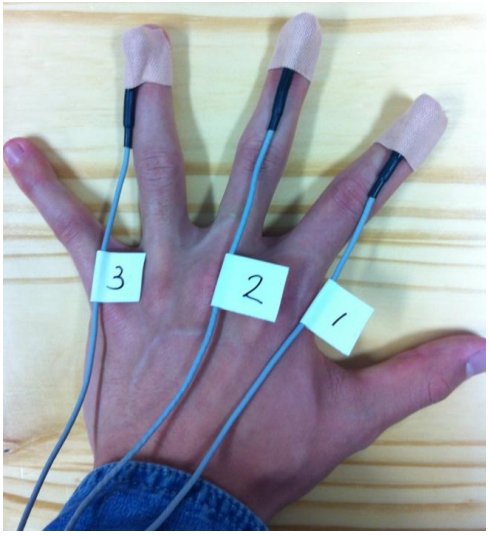

Figure 10. Left hand equipped with receivers of LIBERTY

3.3 Pitches Evaluation

This item evaluates whether or not subjects improved a skill for playing accurate pitches by the finger position skill. Figure 11 shows a tuner. It is electronic equipment for tuning instruments and it visualizes input pitches. We evaluate differences between subjects' pitches and accurate pitches by the tuner.

Figure 11. The tuner

3.4 Evaluation by Questionnaire Survey

We evaluated whether or not subjects acquired awareness of accurate finger positions and learned them efficiently by a questionnaire survey. The questionnaire is five levels evaluations by Likert scale. Table 1 shows contents of the common questionnaire. Table 2 shows contents of questionnaire only for the experimental group, which is needed to evaluate system usability and efficiency of each function. The five levels by Likert scale are as follows.

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

Table 1. Contents of the common questionnaire

Num	Content of questionnaire
1	You have found gaps from accurate finger positions and size of gaps.
2	You have learned efficiently.
3	You will learn finger position continuously in the future.
4	Sensors have interfered with your learning.

Table 2. Contents of questionnaire only for the experimental group

Num	Content of questionnaire
5	System is user-friendly.
6	It is useful to show your finger position and accurate finger position.
7	It is useful to diagnose finger position.
8	Advice is useful.

3.5 Experiment Image

Figure 12 shows a scene in the experiment.

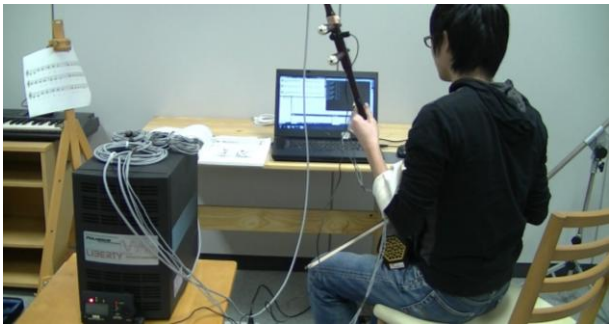

Figure 12. A scene in the experiment

3.6 Result of Experiment

We have found gaps between subjects' finger positions and accurate finger position. We have also found gaps between subjects' pitches of sounds and accurate pitches in accordance with finger position gaps. Then, we have calculated improvement values which are available by subtracting post-test values from pre-test values. Table 3 shows the improvement values about finger position and Table 4 shows the improvement values about pitches. The larger a value in the Table 3 or Table 4 is, the more improvement the subject achieved. The experimental group has achieved larger improvement than the control group about finger positions and pitches. This result shows significant differences because p value of finger positions and pitches are 0.011 and 0.006, respectively.

We have found that novices can acquire accurate finger position skill by using the system, because average of improvement values about finger positions is larger in the experimental group than the control group and this result indicates significant differences. We have also found that novices can improve playing accurate pitches skill by acquiring accurate finger position skill, because average of improvement values about pitches is larger in the experimental group than the control group and this result also indicates significant differences.

Table 3. Improvement values about finger positions

Experimental group	Improvement values[in]	Control group	Improvement value[in]
A	0.173	K	0.043
B	0.012	L	0.205
C	0.545	M	0.033
D	0.475	N	0.068
E	0.542	O	0.111
F	0.374	P	-0.141
G	0.135	Q	0.425
H	1.016	R	0.008
I	-0.146	S	-0.193
J	0.271	T	-0.181
Mean	0.340	Mean	0.038

Table 4. Improvement values about pitches

Experimental group	Improvement values[cent]	Control group	Improvement value[cent]
A	26	K	3
B	7	L	6
C	27	M	1
D	29	N	5
E	29	O	8
F	35	P	-10
G	7	Q	28
H	78	R	1
I	-7	S	-11
J	17	T	-12
Mean	25	Mean	2

On the other hand, we have found medians and modes about each item in questionnaire survey which was taken after post-test by Likert scale five levels evaluation. Table 5 shows the result of questionnaire survey. Numbers in Table 5 match numbers in Table 1 and Table 2 and the numbers represent contents of questionnaire. So, the control group is not included from Num 5 to Num 8 in Table 5. Median and Mode values in Table 5 show the five levels value in section 3.4.

In case of questionnaire number 1, median and mode are 4 in the experimental group and they are 2 in the control group as shown in Table 5. This result shows novices can find gaps from accurate finger position and size of gaps by using system. It is difficult by using conventional method. In case of questionnaire number 2, median and mode are 4 and 5 in the experimental group and they are 2 in the control group as Table 5. This result shows novices can learn more efficiently by using the system than conventional method. In case of questionnaire number 3, median and mode are 5 in the experimental group and they are 3 and 2 in the control group as Table 5. This result shows novices can learn continuously in the future by using system. It is difficult by using conventional method. In case of questionnaire number 4, median and mode are 4 and 5 in Table 5. This result indicates sensors did not interfere with novices' learning. In case of questionnaire number from 5 to 8, median and mode values indicate that the system is useful. However, there is still room for improvement in this system.

Table 5. Result of questionnaire survey

	Experimental group		Control group	
Num	Median	Mode	Median	Mode
1	4	4	2	2
2	4	5	2	2
3	5	5	3	2
4	4, 5	5	4	5
5	4	4	-	-
6	5	5	-	-
7	5	5	-	-
8	3	3	-	-

3.7 Future Prospects

We found that there is still room for improvement in this system. So, we will improve the system based on the points of improvement by free description about the system in the questionnaire and result of experiment for aiming more useful system.

In addition, there are many free descriptions about right hand motions. Not only left hand but also right hand motion is important for playing erhu. So, we found that novices need diagnosis and advice about right hand motion. Sensors do not interfere with users' learning according to the result of questionnaire number 4. Therefore, we will add diagnosis and advice about right hand to the system for aiming more efficient system.

In this paper, we have not developed a function for showing a learner an accurate sound. If there is this function in system, users will find gaps between playing sounds and accurate sounds by listening sounds. Then, users learn more efficiently.

4. CONCLUSION

In this paper, we aim to design and develop a learning environment for a novice erhu learner to acquire an accurate finger position skill, which diagnoses finger position by using magnetic position sensors and gives the learner advice. The system has three windows, finger position window for visualization of finger position, score window for diagnosing finger position along score and command prompt window for showing states of the system and advice. In addition, we evaluated the system by an experiment. Twenty novices about playing erhu who are students in their early twenties are divided into an experimental group who use system and a control group who use conventional learning support method by watching DVDs. Regarding the results, improvement values about finger positions and about pitches of sounds in the experimental group are larger than the control group. These results show significant differences. We also evaluated system by Likert scale questionnaire survey. The result of questionnaire indicates that the system is useful. Therefore, we have achieved the aim.

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