The Development of a Piano Player
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Abstract
This paper describes the development of a piano player. This device consists of a moving coil actuator to produce a swing-stroke on each key, a pedal actuator for a pedal, and a computer system for the control of the actuators which is hierarchically structured into three levels with 90 micro-processors. With regard to the processing, to play back faithfully from the data of a score, the process is based on every key in the knowledge-base, including analytic data of the motion of the key and the hammer.
As a result, this piano player is able to obtain high quality playback.

1. Introduction
A piano player has been invented since about the 19th century. In recent years, a superior one has been put on the market by several companies. But the capacity of such a piano is not enough relative to the stable playback of the smallest tone volume and the repetition of movement by the same key.
The purpose of this study is to develop a piano player which solves some of the problems described above.
In what follows, the components of this Piano Player are described.

2. Actuator for a swing-stroke and a pedal
First, with regard to the actuator for the swing-stroke as shown in Fig.1 [Hayashi et al., 1993], to obtain the desired tone volume, the swing system is operated by a follow-up control which uses a signal wave-form to produce the motion of a swing-stroke. The actuator has a torque of 1.33Nm/A, a thrust of 13.3N/A at the swing-stroke point, and frequency response up to 60Hz. As a result of the experiments which use constant velocities for the signal wave-form, the actuator is able to generate enough force to attain saturation of the movement of a piano's action, and to control a wide range of hammer's struck-string velocities down to the smallest tone volume. Also, the optimum signal wave-form is found by analyzing the motion of the key and the hammer. The actuator is found to produce a stable tone down to the smallest tone volume and to perform the repetition of the same key in the sound pressure range of about 18 dB at 15 Hz.
Second, with regard to the actuator for the pedal as shown in Fig.2 [Hayashi et al., 1991], because a piano's pedal needs a fair force when performing a pedaling and keeping a pedal's position, the mechanism is used worm gear and worm wheel, and DC motor for a driving force. And the present actuator is installed in the non-contact position measurement mechanism. The servo system used is the same one as therefore the actuator for a swing-stroke.

Fig.1 Schematic of the actuator for a swing-stroke
Fig.2 Schematic of the actuator for a pedal
3. Synthesis of the computer system

With regard to the synthesis of the computer system, it has to maintain efficient control of a total of 90 actuators. In addition, it is most important to determine the swing-stroke and pedaling wave-form to play back faithfully from the data of a score and the playing of a pianist. Therefore, as shown in Fig. 3, the computer system for the actuator's control system is hierarchically structured into three levels with 90 micro-processors. The top level processes the piano score information. It is processed for every key, and from the data of a score and the playing of a pianist, it computes the swing-stroke wave-form data for the actuator. Then, to play back faithfully, the process is based on every key in the knowledge-base, including analytic data of the motion of the key and the hammer. The middle level, which uses a real time control, sends the swing-stroke wave-form data for the key, which is the time for the beginning of the swing-stroke, to the bottom level. At the bottom level, a single chip micro-computer is allotted to every key and pedals, and the process creates the wave-form from the swing-stroke wave-form data, and this is sent to the actuator's servo system. By using this computer system, 90 actuators are capable of being controlled efficiently.

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<thead>
<tr>
<th>32 bit CPU</th>
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<td>Amplifier</td>
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<td>Actuator</td>
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Fig. 3 Synthesis of the computer system

4. Knowledge-base

The knowledge-base described above consists of the time of the analytic data identified as * in Fig. 4, which shows the motion of the key and the hammer by the experimental movement of the swing-stroke, and volume. In addition, to create the wave-form efficiently in the process, and to play back faithfully, the start and the end position of the swing-stroke is prepared for 3 positions where the key lifts the damper. And, to make uniform the sound pressure of every key, the piano's sound pressure template method [Hayashi et al., 1992] was used.

Fig. 4 Construct of data in the knowledge-base

5. Summary

As a result, this piano player can play such pieces as Liszt's La Campanella and Ravel's Alborada Del Graciorno, which are difficult even for a pianist, and in the process of playing data from pianists, it is able to obtain high-quality playback.

References


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