A META-ACTION FOR THE GRAND PIANO

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Abstract: This paper outlines a portable high performance computer controlled action for the grand piano. It was designed to be installed in a variety of instruments and, in effect, temporarily replaces the removable hammer and keyboard assembly. It can be controlled from different computer systems operating in either a performer/machine interactive or computer only context. The principle features are a high degree of independence between the hammers and dampers, and their operational speed. Performance sophistication lies in the ability to control these components; a control that has hitherto not been accessible in either traditional instruments or any player piano system.

Origins

The concept of a portable computer controlled action for the grand piano grew out of work with upright pianos which commenced in 1981. Through a series of customized instruments developed around the now defunct PianoOrder system, I was able to frame the idea of what a grand piano action, operating under computer control, should be capable of doing from both an aesthetic and performance perspective. Attention was specifically directed towards the site of the Grand Piano as superior instrument in both sound and functional design.

While inspiration initially came from the music of Conlon Nancarrow, the idea was essentially founded upon a desire to investigate computing technology as a means to achieve greater control and performance nuance. For example, allowing a greater sense of human performance interpretation in compositions that are otherwise impossible to play. Nancarrow’s instruments had some technical limitations but more importantly they were not conceived in the age of computer control and performance/machine interaction. Yet his music reflects a state of performance that is potentially accessible to a performer through a collaboration with machines. Such complex, musical structures as those found in his Study #25 might give rise to an interesting piano technique, not to mention compositional direction.

The construction of the action was undertaken through a grant from the Australia Council’s Special Projects Unit and the work carried out in the engineering workshop of the Physics Department at La Trobe University in Melbourne between June 1987 and August 1989. It was designed and constructed by Marshall MacIntosh and the author. Investigation into the operational aspects of the traditional piano action were undertaken between June 1987 and March 1988. Research is continuing in the areas of software development and composition in the Music Department at Princeton University.

Structural Organization and Functional Design

Two particular requirements strongly influenced the design of the action. Given that the keyboard and action chamber in most grand pianos is a complex space, the new action aimed to accommodate critical geometric variations. Furthermore, since portability was an important factor, it also had to be made of convenient subsections for both installation and transportation.

Functionally, the action consists of approximately 160 solenoids, one per hammer and one per damper, mounted on 2 parallel but different shaped rails. Both rails are assembled from 3 sections.

ICOMC GLASGOW 1990 PROCEEDINGS 365
into a seamless unit where all components can slide freely along a continuous surface. The rails are mounted on 5 support brackets which have adjustable feet. These brackets can be moved into any position along the unit rails themselves and the first can tilt the action forward or backwards a few degrees off the vertical and also raise it slightly. The action frame was machined from aluminium which gives it an assembled weight of 55 kg.

On the forward rail, which faces into the instrument, are mounted the hammer solenoids as two staggered rows. The length of the rail can be varied to suit different action widths and the height is adjustable from either the action feet or the individual hammers themselves. The actual hammer is a single moving part consisting of the solenoid ‘plug’ or ‘core’ at one end and the hammer head at the other end of a threaded rod. They are capable of operating very rapidly. The hammer tips have a base of aluminium and although vary in size are smaller than conventional hammers. They can be covered in a variety of materials to produce different ‘voices’. The hammer travels approximately 18 mm and weighs slightly more than the corresponding conventional hammer.

The hammer solenoids receive power for very brief periods of time, ranging from approximately 10 to 20 milliseconds. This range determines the dynamics. It is approximately between the points where the hammer just reaches the string and where it is in contact with the string for a duration that results in interference from waves returning along the string.

On both sides of the rail which appears towards the front of the instrument are mounted the solenoids that lift the dampers. A damper is raised via a lever which passes under the hammer rail. At once, the hammer/damper assembly consists of 3 moving parts: the solenoid core, the lever and the damper itself. The damper solenoid moves approximately 5 mm and there is considerable adjustment possible at either end of the lever. Hammer and damper pairs can operate either synchronously or asynchronously. Each solenoid is connected to a driver board which is responsible for switching through the power upon receipt of the appropriate signal. The driver boards are in turn connected to a central processor. The hammer solenoids operate at approximately 170 volts while the damper solenoids operate at a significantly lower voltage since they have to remain on for indefinite periods of time.
Control and Performance

It was envisioned that the action should remain interactive, i.e. operate through performer/machine interaction. Whichever way this might be achieved — perhaps performer information from a commercially available controller is sent to a powerful computer, interwoven, redefined and then the output information passed to the action — performer/machine interaction is currently felt to be one of the most challenging directions in computer music.

In meeting the real-time demands of such an interactive system, the delegation of action control to a Secondary Processing System (SPS) appeared necessary. Two strategies are currently under consideration. The first, involves 2 (or more) main alone processors, accessed by a serial communications link. The second, requires a memory mapped I/O coprocessor. Communication is via shared memory with the main processor. Either approach should permit complex combinations of hammer/damper operations, e.g. the ability to raise dampers on strings that are not currently being struck or leave them lowered while striking the strings. Also, the careful application of delaying strategies, where the dampers can be removed after the attack or raised and lowered during the natural decay of the sound, has powerful compositional and performance implications.

Control of the action is divided on a function basis, since hammer and damper operations are not only quite distinct but vary in control complexity. The former is complicated by the receipt of asynchronous data while managing internal clock-time critical events. The later, being less time critical, benefits from being in operation slightly earlier than the onset of the hammer. Thus the dampers can be manipulated freely without impeding any simultaneous hammer operations. If the dampers could not be raised early enough the system would have a severely restricted function.

Two communications protocols expedite data transfer through the system. One between the performer and the main computer (MIDI), and the other between the SPS and the action (proprietary). Since the SPS can be remotely reprogrammed, various protocols could be loaded for different compositions and performances. At this moment, the SPS outputs a 16 bit word to the driver boards. The 16 bits actually map to 16 signal control lines which select decoders, their specific output combinations, and in turn, the actual solenoids.

One area of concern is response time through the system. This is easily appreciated as an unwarranted delay between initial action and response but what might be a result of the input should be taken into consideration. The system might, for example, have an acceptable response time for a "one-to-one" event mapping but a "one-to-many" mapping has more disturbing performance ramifications. The very nature of such complex temporal structures implies that they will require their own time in which to exist. Certainly, there is a point when the performer should no longer feel in control of the instrument. However, an interesting question is whether performers can learn to manage a sense of drifting in and out of control of their instrument and indeed, could that become part of the performer/machine interactive experience.

From the above discussion, it is obvious that the action was not designed to necessarily produce a traditional piano sound, nor in fact, to be necessarily played in a conventional manner. For the most part, the piano provides a convenient, abundant and aurally entrenched musical vehicle upon which to expound ideas about humans, machines and art.

References

