A Programmable MIDI Instrument Controller Emulating a Hammer Dulcimer

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ABSTRACT

Real-time digital music system design involves the translation of formal music notation or human gestures by some input device to Musical Instrument Digital Interface (MIDI) commands which are then transmitted to an electronic music synthesizer. This paper describes the design and implementation of a microprocessor controlled input device that maps analog signals to MIDI commands and transmits them to a digital synthesizer in real-time. The controller emulates a traditional acoustic folk instrument known as the hammer dulcimer. The hammer dulcimer is the forerunner of the keyboard family of instruments and incorporates features found in percussion and keyboard instruments. As with any acoustic instrument, its tone is a composite of several partial tones. The controller, in emulation mode, calculates these partial tones and outputs them within the just intonable difference (JID) tolerances described in psychoacoustic research. This MIDI controller also provides features such as on-demand re-tuning which allows the musician to play in any tonal pattern without changing hand positions. Standard MIDI features such as pitch bend, program change, and sustain are implemented by the controller. The prototype instrument yields a two octave range from an eight by eight inch sensor grid. Additional grid cells may be added to increase the range of the instrument.

1. INTRODUCTION

The separation of the gestural tones from the sound generating module creates the potential for designing instruments based on families other than the keyboard family. Keyboard controller design has been well documented in literature for the past fifteen years. The design of non-keyboard controller interfaces is a relatively new area of research. Microprocessor evolution allows unique gestural controller interfaces to be designed and tested. This flexibility gives the instrument designer the ability to build an instrument that is limited only by those imposed by hardware and the dexterity of the human hand" [Aikin, I].

Other researchers have built non-traditional instrument controllers such as the Video Harp [Rubiec, et al. 6] and the H'ANDS [Waineez, 9], the RoKy [Johnstone, 4], the Bio-MusikKnapp, et al. 3, the Buchla Thunder [Rich, 7]. These instrument controllers, while outside the mainstream of "traditional" instrument design, were able to interpret what the musician does and transmit this information to the actual sound producing modules of a musical instrument. In some cases, they did not allow the musician to play notes on a real-time basis. Rather, the musicians could only play a predefined set of notes.

The hammer dulcimer is a member of one of the most ancient families of instruments in the world. It is the forerunner of modern keyboard instruments such as the piano, harpsichord, clavichord, and clavechord. Almost every culture in the world can claim possession of an instrument in this family. It is known by various names such as the cymbalom (Hungary, Romania), hackett (Germany), Qiang-chu (China), pitabiero (Mexico), santur (Greece) and santar (Peru). Modern instruments are trapezoidal in shape with 40 to 150 strings. The instrument is played by striking the strings with wooden hammers or plucked by the musician's fingers. The instrument has a wide dynamic range and the sound can be modified by altering the surface of the hammers. A loud, sharp tone can be gotten from bare wood hammers. Conversely, a light, soft, harp-like tone can be gotten from felt-tipped hammers. It is this wide degree of flexibility that makes the instrument a prime candidate for emulation.

The hammer dulcimer is a classic example of a 'trigger timbre' style of instrument. 'Trigger timbre' is defined to be an 'action where a musician performs a gesture and a machine/vibrating body produces the sound in a fixed pre-arranged manner' [Chabot,2]. Because the musician can vary factors such as impact speed, size and weight of the hammers, and or beams, no two sounds on the instrument have the exact same timbre.
The No Strings Attached Hammer Dulcimer is a persuasive controller interface that emulates a hammer dulcimer. This controller senses the following information:

1. Note information based on an x-y grid,
2. Touch sensitivity information on the note (how hard it was hit),
3. Sustain information on the note,
4. Control information such as voice switching, pitch bending, and dynamic returning.

The controller converts this input information to valid MIDI control messages and transmits them to a digital synthesizer in real-time.

This project presents a highly economical method of constructing a fairly powerful MIDI instrument controller. The No Strings Attached Dulcimer uses piezo sensors known as Kynar (Kentec) arranged in a 4 by 4 grid. This single grid of the prototype instrument provides enough information to generate musical notes in a two octave range. Figure 1 shows a typical sensor to note mapping. Additional grids can be added to increase the range of the instrument. Synthesizer control information can be sent by activating additional sensor strips on the controller.

2. HARDWARE SYSTEM DESIGN

The hardware system is divided into 3 subsystems: the 8751 microprocessor, the piezo-electric sensor circuitry, and the A/D circuitry. The No Strings Attached Dulcimer uses an INTEL 8751 microprocessor to drive the MIDI controller circuitry. Musical input is transmitted to the microprocessor via a piezo-electric sensor subsystem that provides sensor coordinate and magnitude information to the 8751. This sensor information is converted to MIDI command messages and sent to the MIDI output port. The Intel 8751 microprocessor was chosen as the driver of the system for its 1) fast execution time - using a 12 MHz crystal, most 8751 instructions will execute in 1 usec, 2) priority interrupt structure - the 8751 has 2 external interrupt control lines that can be prioritized under software control, 3) system completeness - the 8751 chip has 4K of EPROM memory, 4 bidirectional I/O ports, a serial transmit/receive port and 2 internal timers, and low cost.

The sensor subsystem consists of a 4 by 4 grid of piezo-electric strips made out of a polyvinylidene fluoride (PVDF) sensor material. The film is approximately 22 x 165 mm in size and resembles a piece of tape. The sensor is a thin sheet with a film of metal on each side to act as the electrical connection. When the strip is pressed in one direction, it generates a positive or negative DC voltage spike which corresponds to the magnitude of the movement of the strip. Voltage in one polarity generates movement in the opposite. The more the strip is moved, the greater the voltage spike. This allows for measuring how hard a strip was hit. However, this voltage spike is generated only by the change in position and does not give a static level. Once the material stops moving, the spike returns to zero. The output of the sensor strips is filtered by a resistor-capacitor circuit and amplified by a noninverting operational amplifier circuit.

3. SOFTWARE SYSTEM DESIGN

3.1 Design Goals

The No Strings Attached Dulcimer software was designed to accomplish the following goals:
1) derive note and intensity information from the Kynar sensor circuitry. 2) send proper control signals to the Analog-to-Digital (A/D) converter chips and read the A/D data. 3) interpret control information such as pitch bends, modulation and sustain. 4) translate this information to MIDI data and output it thru the MIDI interface.

3.2 General Software Description

The No Strings MIDI dulcimer software is an INTEL 8751 assembler program that is divided into 5 sections. They are: 1) initialization - this section initializes the timer, interrupt vector at-
Figure 1. Kynar Sensor Grid Musical Note Mapping

3.3 Overall System Flow

The controller software was designed to perform all of the necessary functions such as A/D conversions, table look-ups, MIDI note transmission, and reset functions within 5 msec. This is within the time range that two notes played at different onset times are still perceived to occur simultaneously. The software remains in an "IDLE" state until a hit is detected on a vertical Kynar strip. The software then moves to the "START CONVERSION" state. The four A/D converters are activated to read the values of the horizontal Kynar strips. When the conversions are complete, the driver moves to the "PROCEISS DATA" state. The maximum A/D data value is used to indicate which horizontal strip was hit. We assume that although all four strips will generate positive values, but only the one that was actually struck will generate the maximum value. This maximum value is used as an index into a lookup table for the correct MIDI note. Once the flags are set for MIDI note transmission, the driver moves to the "DISCHARGE" state.

The driver sends a DISCHARGE signal to the peak detector circuits in order to prepare to read the next data value. Once this is done, the driver returns to the "IDLE" state.

3.4 MIDI TRANSMITTER ROUTINE

The MIDI transmitter uses the information collected by the two ISRs to determine which musical note to send to the synthesizer. The vertical strip ISR provides the x coordinate and the horizontal strip ISR provides the y coordinate information used in the table lookup.

The routine then inserts the MIDI note value, and the key velocity value into a preformatted MIDI note message and sends it out the serial port to a synthesizer. The soft-
ware delays 3.8 msec and sends out a MIDI "note off" message. After re-reading the RAM data values, the routine returns to the main loop.

4.0 FUTURE ENHANCEMENTS

The No Strings Attached Dulcimer presents acoustic hammer dulcimer builders with a wide variety of options to include in their acoustic models. The author is currently working with his hammer dulcimer builder on a sensor arrangement that can be fitted to an acoustic dulcimer. This arrangement allows the performer to use the acoustic and MIDI features separately or in combination during a performance. The sensor subsystem is not restricted to the Kynar style sensors. The overall hardware system was designed in a modular fashion in order to provide the experimenter with a flexible tool for investigating different sensor technologies.

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