A New Music Keyboard with Continuous Key-position Sensing and High-speed Communication

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Abstract

We describe a new music keyboard with independent, continuous position sensing capable of communicating gestural nuance available on manual tracker organs, harpsichords and pianos. We explain how the additional functionality can be obtained at a lower cost than existing keyboard controllers and demonstrate a prototype to illustrate this analysis. Our new keyboard uses optical interruption sensing for each key and hybrid space and time multiplexing to achieve the requisite scan rates. Scanned data is assembled into packets using a single FPGA and formatted for a variety of readily available communication methods including embedded in SPDIF and ADAT audio streams and as Ethernet UDP packets.

1. Introduction and Motivation

Most electronic keyboards sense key-down velocity and a single instant at which the key is considered released. A few models support pressure or displacement sensing over the final few millimeters of key travel for "polyphonic aftertouch".

Although key-down velocity is the defining parameter for the initial loudness and timbre of a piano tone, release timbre is controlled by position. This is because the dampers are (unlike the hammers) directly and continuously coupled to the key. Articulation on manual tracker organs depends on continuous control of the air-jet velocity profile during the beginning and ending of each note. As with the piano the relevant gestures involve key position as well as velocity.

Since these facts about keyboard instruments have been widely known for decades, why has the electronic keyboard not evolved for 25 years? The primary reason is that the electronic keyboard is a victim of the general success of MIDI, which imposes a narrow velocity-based model of the keyboard (Moore, 1988). Another important factor is a consolidation of the industry producing electronic keyboards to a very small number of high volume manufacturers who are focusing on cost at the expense of functionality.

2. Keyboard Evolution

Although the basic design of the keyboard has not changed for a long time, networking, processing and sensing technologies have–to the stage that a highly responsive, position-sensing keyboard can be built at the same or lower cost than current keyboards.

2.1. Networking

Many viable alternatives to MIDI now exist for communicating gestural information. A continuous, position sensing keyboard controller requires a much higher bandwidth connection to other devices than MIDI allows. USB and Firewire comfortably handle this requirement and offer the cost and convenience advantage over MIDI of supplying power to the controller. Remote power is also possible using extensions of existing audio industry protocols such as AES/EBU (Freed, 1999).

2.2. Sensing and Processing

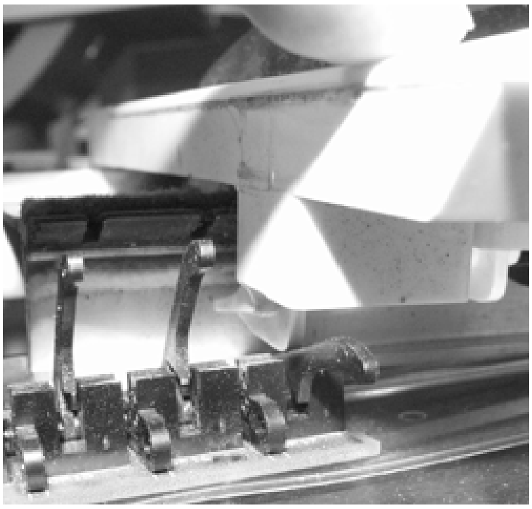
Advances in processing power allow for cheap, reliable, non-mechanical RF-based position sensing as typified by Wacom graphics tablets, already being applied to musical applications (Wright, et al., 1997). Such systems can be self-calibrating because the rest and depressed positions of each key are easily determined as the keyboard is played. This lowers manufacturing costs and maintains quality for the user over a long product life.

Traditional approaches to implementing keyboard controllers involve embedding a microprocessor to handle the complex subtleties of the MIDI standard. By adopting a much more straightforward gesture based representation (Freed and Wessel, 1998) we have shown how the processing can be integrated into very small, cheap ASIC.

3. Demonstration System

We describe here a prototype keyboard we have developed to illustrate the potential of new technologies to expand the gestural vocabulary of the keyboard player.

We have adapted a patented keyboard-position-sensing technology developed by Gulbranson. The system uses a spring-loaded lever for each key. The lever operates a specially shaped vane that progressively obscures light being transmitted between an led source and phototransistor sensor.



To simplify wiring the Gulbranson engineers ingeniously connect all the phototransistors together in parallel (2 wires) and scan each key's sensor by sequentially illuminating each light source in turn using a set of serially connected shift registers (another wire). Simplifying the wiring of 88 sensors is a key issue but response time limitations of the sensors result in a low sample rate which in turn results in unacceptably high jitter in the gesture timing. We have solved this problem by breaking the keyboard into smaller 17-note segments that are concurrently time-multiplexed. The moderate increase in wiring costs (6 wires) is a small price to pay for a more temporally accurate sensing system.

The sensed output from each scan group is converted from analog to digital by a multi-channel A/D convertor. The results are serially communicated to an FPGA which generates the timing for the entire system and formats the data in any of a a variety of readily available communication methods including: SPDIF, ADAT audio streams and as Ethernet UDP packets. This FPGA is part of a scalable connectivity processor described more fully in another paper in these proceedings (Freed, et al., 2000).

4. Acknowledgements

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