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Implementation of a time-warping AER mapper.
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number of events over the time-delay position in the FIFO, that in the worst case will be *N*.

Therefore we have implemented a version of the delay-mapper with reduced capabilities. We apply a 15-bit fixed delay (programmed through USB commands) for all the incoming events that have to be delayed (0 to 0,65s, in 10us steps). In this case the order of the incoming events that have to be delayed is not modified.

The block diagram of this implementation (Figure 2-bottom) is similar to the previous one, but differs in that the FIFO is outside the FPGA, the state machine managing the FIFO does not take care about the correct order in time-delays, and a resource sharing controller is needed between the first and second state machines in order to coordinate the access to the SRAM for mapping table read accesses and for FIFO read and write accesses. Used resources in the FPGA are at 15%, which implies no temporal restrictions after routing the firmware, so no wait states are needed. The time to dispatch an output event is 320ns. The time to insert an event in the FIFO is 60ns. The SRAM access time is 12 ns.

IV. Elementary Motion Detection

In this section we present a simple experiment where we implement an elementary motion detector (EMD) that requires temporal mapping [15]. The hardware setup consists of a silicon retina [1] which is connected to the delay-mapper. The mapper is configured to map one row (32) of the retina to two different output rows, one of them with no delay (row 32) and the second one with a fixed delay (row 40) for all the events (see Figure 3-top). The output of the delay-mapper is connected to the USBAERmini2 [12] board for monitoring events using the jAER[14] open-source software. Under jAER an EMD filter has been implemented to characterize the polarity of the events when a motion has been detected depending on the direction of the motion (left or right).

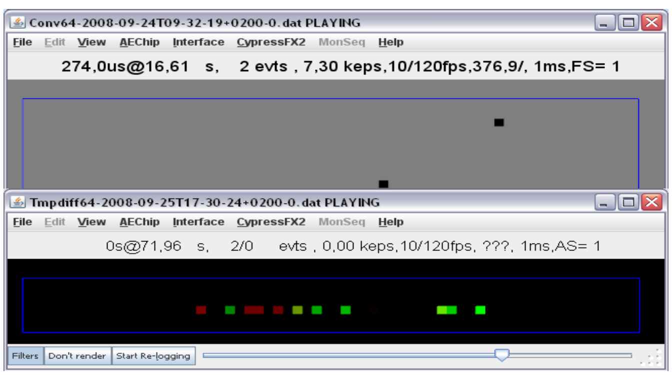

Figure 3. Top: Mapper-delay output for a right to left motion. Bottom: EMD output for a right to left (red) followed by a left to right (green) motion.

An EMD cell correlates the activity of one pixel with the delayed activity of a different spatial pixel. The output of the multiplier is non-zero when there is activity at both pixels. By coding two EMD cells with opposite direction preferences for the two pixels it is possible to distinguish the direction of the motion. The implemented jAER filter processes a packet of monitored AE that come from the delay-mapper. If *d* is the delay applied by the mapper, and if both pixels (32, y) and pixel (40, y-n) have an event, it means that an object presently at column y, was already present at column y-n *d* ms ago. So this object is moving in the decreasing direction of the y axis. Figure 3 top shows the output of the delayed and not delayed events. And Figure 3 bottom shows the jAER output of an EMD filter which looks for a right to left motion (red pixels) followed immediately by a left to right motion detection (green pixels). The more recent events are lighter and the older ones are darker. The delay was set to 50ms for all the events, with a 16Kev FIFO in the SRAM of the USB-AER, and EMD detection using 3 pixels between the delayed and no delayed ones for both directions.

V. Conclusions

This paper presents two implementations of a time-warping mapper firmware for the USB-AER tool. We discuss pros and cons of minimizing resources or minimizing mapping time in the implementations. An example of the use of the mapper is also presented with the evaluation in jAER open-source software of an EMD model based on spikes.

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