Event Synchronization of EEG data using the Lab Streaming Layer (LSL)

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Event Synchronization of EEG data using the LSL

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In this document we describe the integration of the Lab Streaming Layer into NIC. This allows for millisecond jitter network synchronization of events generated by third party programs such as *Presentation* with NE EEG data streams.

In this test, two triggers were generated by Presentation on a computer and recorded by NIC on a second computer on the same local network (connected by the LAN). A hardware trigger here is a pulse generated by the parallel port and recorded using one of the Enobio electrodes connected to a NE **testboard**. The software triggers are generated by sending markers through an LSL Outlet following typical LSL examples.

NIC was thus used to record both the trigger signals from the electrodes and the received local area network markers. A Matlab script measured the relative separation between the software and hardware triggers (in milliseconds).

We can consider three factors affecting the relative syntonization of events. One is the latency of bluetooth transmission from the EEG NECBOX[1] to the computer file (created by NIC). It can be characterized by a constant bias. The second one by a bias and jitter in the received network triggers, which are controlled by the LSL protocol to millisecond level. Lastly, there is an intrinsic difference in the frequencies of the computer clock (used for time stamping of triggers) and the NECBOX clock used to timestamp the EEG samples.

NE's test-board provides an electrical interface for simulation of EEG impedances and signals. Shown here attached to a

All in all, we can relate the trigger event time *t* and EEG file timestamp *t'* by

$$t' = \alpha t + b + \hat{\eta}$$

where α is a scaling factor reflecting frequency differences in computer and NECBOX clocks, *b* a time bias, and η a zero mean stochastic process (with variance of the order of a few ms).

NIC estimates the time dilation α factor by evaluating the nominal EEG sampling rate in computer time. the LSL network protocol controls network delays - only an overall bias due to the bluetooth latency for the initial EEG sample remains.

As can be seen in the figures below, we conclude that aside from an overall bias which can be of the order of 50 ms, **when using the LSL protocol trigger jitter is of the order of 2 ms (**using simple TCP/IP triggering leads to jitter of the order of 12 ms).

For more information please visit our Wiki.

[1] Recall that the NECBOX is the wearable device which contains the EEG amplifiers and which communicates with a computer running the NIC software via Bluetooth.

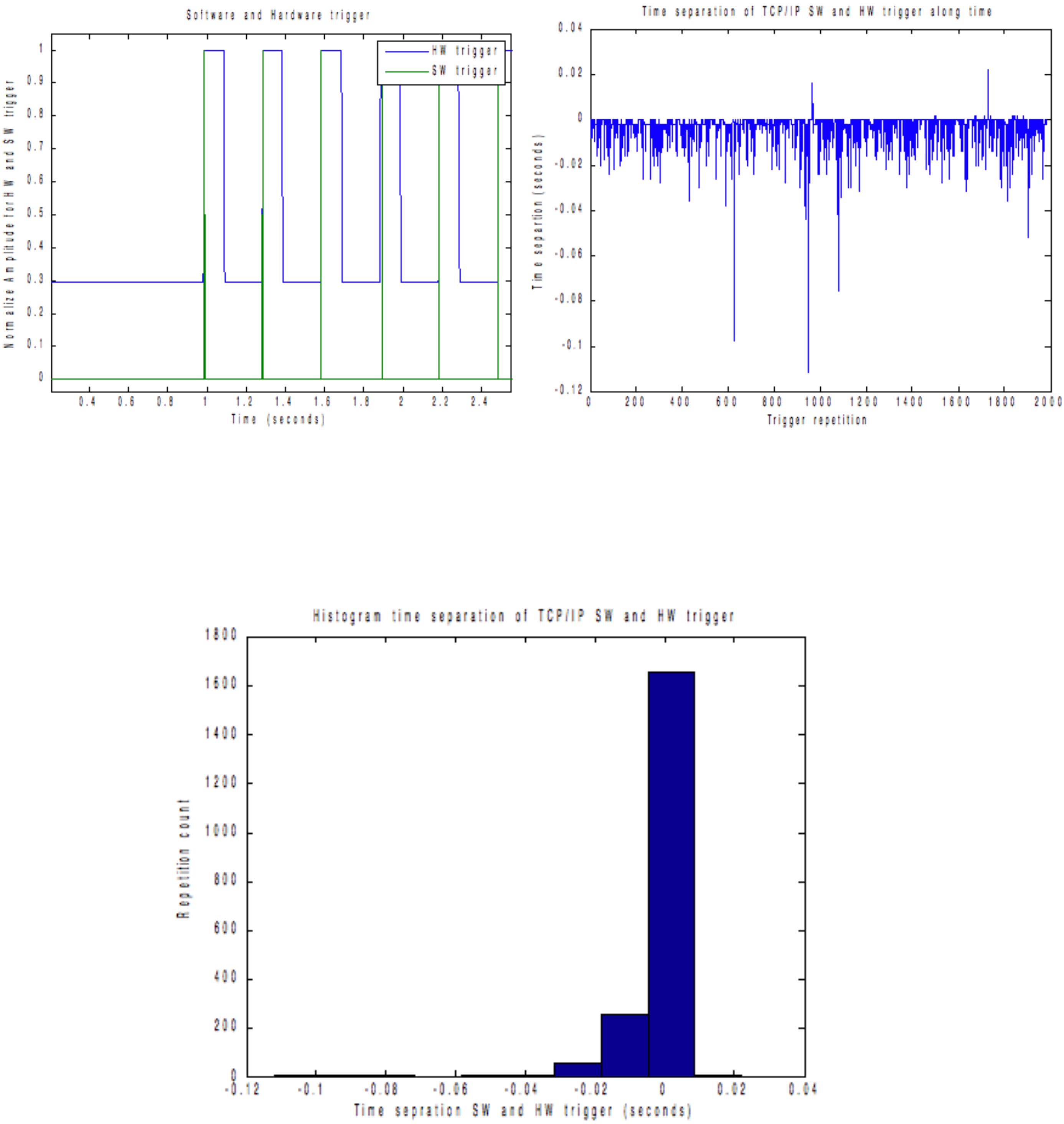

Figure 1: Sample data showing HW and TCP/IP SW triggers recorded using the testboard (top left), relative timing of the triggers (top right), and histogram of the delays (bottom). Using simple TCP/IP triggering leads to jitter of the order of 12 ms.

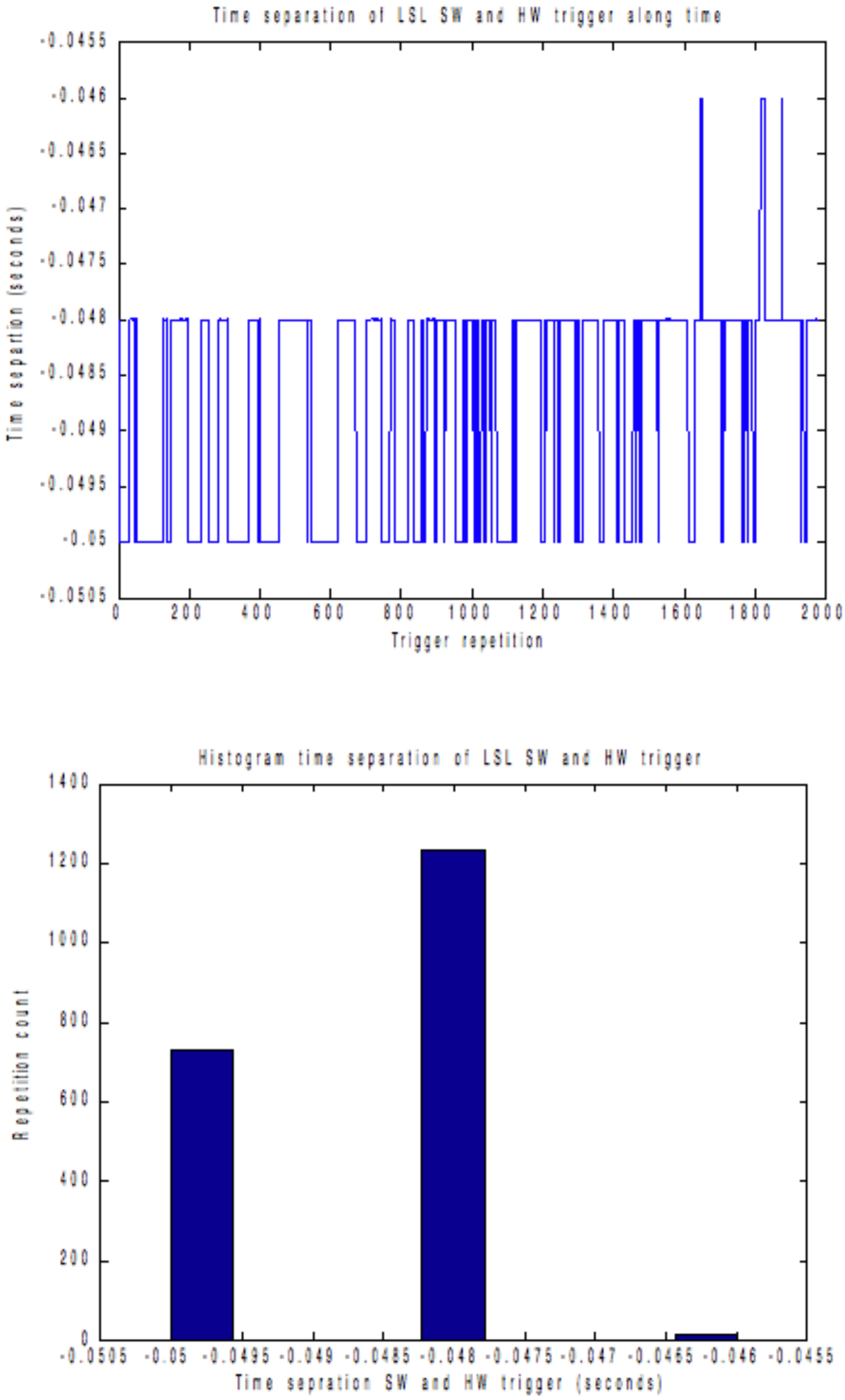

Figure 2: Sample data showing HW and LSL SW relative timing of the triggers (top), and histogram of the delays (bottom). Using LSL triggering leads to an overall bias of 48 ms with a 2 ms jitter.