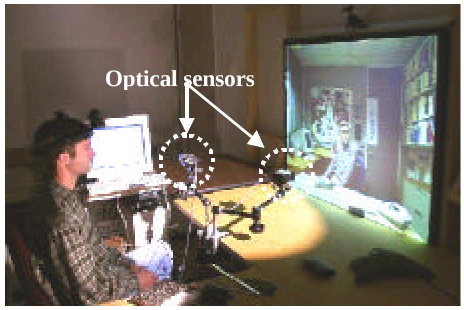
Latency Meter:

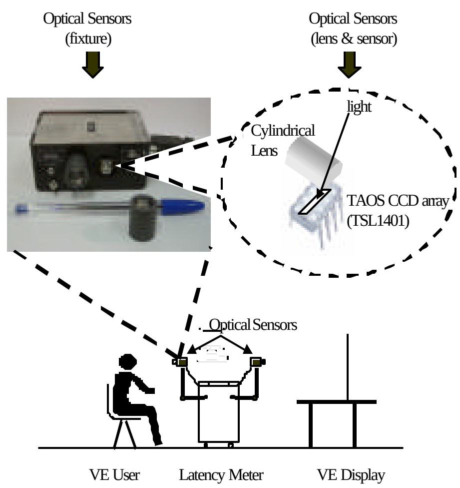
A device for easily monitoring VE delay

The Problem

Despite dramatic advances in virtually all the components of VE systems – renderers, displays, trackers – the overall performance of such systems is still hard to measure. Even with careful continuous monitoring of frame rate, for instance, a system from one day to the next "appears" to perform less well. All too often the change is some trivial detail whose effect the system doesn't measure and whose overall impact only the most experienced developers will understand: a change in the buffering behavior between tracker and host computer, for instance. An experienced user may realize that "something is wrong", but has no way to demonstrate or confirm that some deleterious change has occurred.

The most serious sites perform latency measurements on their systems from time to time for quality control, but these exercises are difficult and time consuming and their validity doesn't extend much beyond the isolated situations measured at the time of the experiment. The following day, for example, a small change in the system –– the orientation of the user with respect to the simulated or real environment — may change the execution-time behavior of the system. We have encountered this problem for years but existing methods for latency measurement were too invasive for everyday use.





Our Approach

We are developing a standalone instrument that quickly estimates end-to-end latency without requiring electrical connections or changes to the VE software. We believe that a method for easily monitoring latency will change the way programmers and users work. Instead of making occasional measurements and hoping for the best in between, both programmers and users will have an objective measure of this critical factor.

Latency meter in use is shown top left picture. User is on the left. Projected output is on the right. The optical sensors of the latency meter are circled.

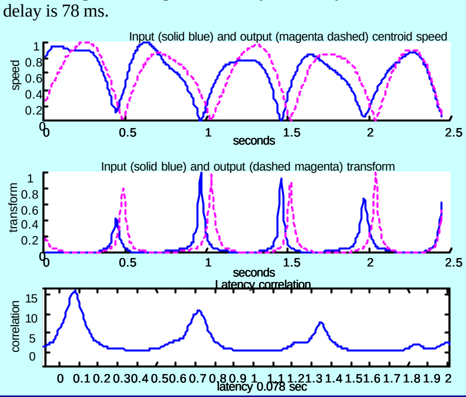
Our latency meter works by observing the user's motion and the display's response using high-speed optical sensors (see bottom left picture). When the user rocks back and forth, the display exhibits a similar but delayed rocking of objects in the user's field of vision. We process the signals from the optical sensors to extract the times of very slow image change corresponding to the times when the user is nearly stopped (just before reversing direction). By correlating a sequence of these turn-around points in the two signals we can accurately estimate the end-to-end system delay.

Capture motion

User motion results in corresponding motion in the VE display. The user and display motion are shown in the first and second row respectively. Without restricting the application too much, we can assume that when the user is **not** moving the motion from his sensor will change relatively little. Further when the user is **not** moving, the VE display (for static VE scenes) should not change. Thus, by detecting stops (times of little motion) in the user sequence and relating them to the corresponding stops in the VE sequence we can estimate the system delay.

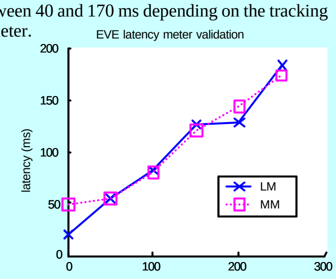
Calculate latency

The VE system latency is calculated by processing the data of the optical sensors. *Graph (A)* shows the motion data corresponding to the user and VE scene. The speed of change in motion is plotted against time. *Graph (B)* shows motion data after the stop-function is applied. The spikes represent times of stopped motion; the spikes of the VE display motion lag the spikes of the user motion. *Graph (C)* is a correlation of the user and VE display motion. The time of the correlation peak corresponds to the system delay. In this case the delay is 78 ms.



Results

The latency of the Tele-immersion (TI) and other systems can be measured. The latency results, for example, of the EVE system are shown in the graph below. The latency meter and Mine method measure the TI system. The Mine method is an independent experiment to validate the latency meter measurements. The tracking software of the TI has a controllable filter parameter, which when increased also increases system delay. The measured system delay is plotted against the delay value set in the tracking system. The overlapping plots of the latency meter (LM) and Mine method (MM) confirm that the two independent techniques obtain the same end-to-end latency measurement. The EVE latency is between 40 and 170 ms depending on the tracking parameter.



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