Report on low latency video capture and display

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Introduction

The following are some notes on the exploration of low latency digital camera-to-display systems. The aim was to identify replacements to existing analog camera/displays using more modern digital hardware, secondary consideration was to identify options for stereoscopic 3D video recording and display.

The first test was with standard commodity hardware, a Panasonic 3D camera (Panasonic AG-3DP1 3D video camera) and consumer 3D TV display (Samsung 46inch, UA46C7000WF). The display is driven "directly" from the camera over HDMI 1.4a (stereoscopic support). There was typically 300+ms latency! This has been largely attributed to staging in the HDMI 1.4a pipeline.

A range of subsequent tests with both analog and digital web-cam style cameras and a mixture of displays and projectors did not yield any latency below 150ms. The explanation of this is along these lines: for a PAL (25Hz) camera there is a fixed frame/field time of 40ms (1 frame made up of 2 fields for interleaved). During this time, the current image is being exposed, while the previous image is being read out to the grabber, while the next to previous image is being written to the display by the computers OS. If we start from exposure beginning, the total latency is 80ms for a full frame to arrive into PC memory via the DMA from grabber. Then there is typically an OS overhead to the display of about one frame time, so total minimum latency is about 120ms.

vDisplay

The vDisplay from Pleora and a machine vision camera (Imperx camera IGV-B0610C) were recommended by Atlantek.

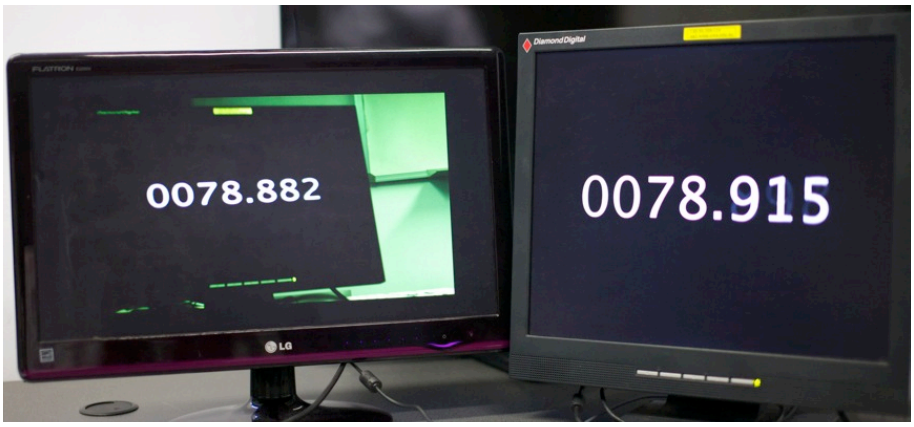
http://atlantek.com.au

http://www.pleora.com/our-products/vdisplay-video-receivers/vdisplay-hdi-pro

The key piece of hardware is the vDisplay that accepts GigE signal from the camera (over Cat6 cable) and outputs an HDMI signal. The vDisplay has a streaming mode with at most a single frame buffer stage. Quoting from the manual "*Using the single buffer means that images are displayed as packets are received. This mode provides the lowest latency, but pixels from different video frames can appear on the same screen as the image is updated. Therefore, using a single buffer is only recommended where the absolute lowest latency is required.*"

While the camera tested was only 800x600, there are a range of cameras available of different resolutions and frame rates. It should also be noted that these cameras have a standard lens mount (called C-Mount) and therefore lenses can be chosen to meet particular experimental requirements.

The tests were performed with a counter running at 1ms intervals, this was created as a simple Quartz Composer composition running on a low persistence display (right hand display in the photos below). The display with the counter and the display with the output from the camera are photographed together with an SLR camera using a fast shutter speed, at least 1/1000 of a second in the cases presented here.



In all cases less than 35ms was measured. The camera and display were operating at 60Hz so the assumption is there are two frames being buffered, one in the camera/vDisplay and one in the LCD panel resulting in a latency of 2/60 (33ms). It is not expected at this stage that one is going to be able to do better than this with current digital hardware running at 60Hz refresh rates (see comments in the section on future work for 120Hz capable displays). For example it would appear that all displays buffer at least one frame (accumulating a whole frame from the digital interface before being able to display it), and some displays seem to buffer multiple frames.

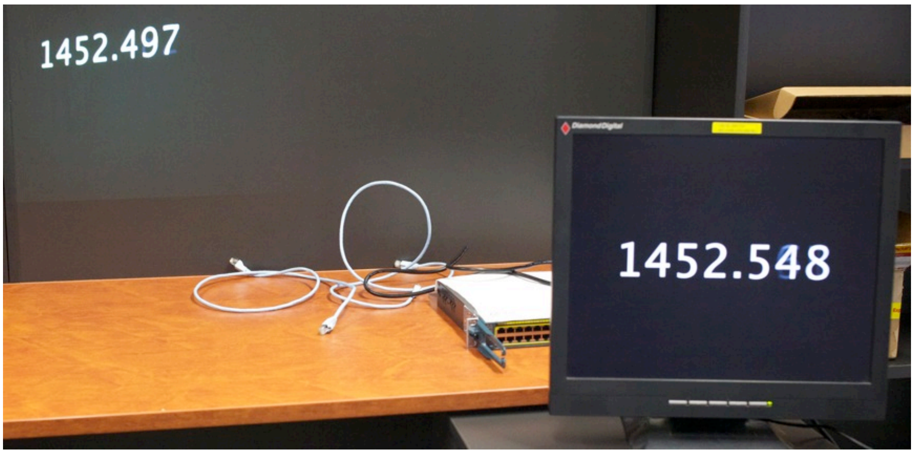
Stereoscopic display options

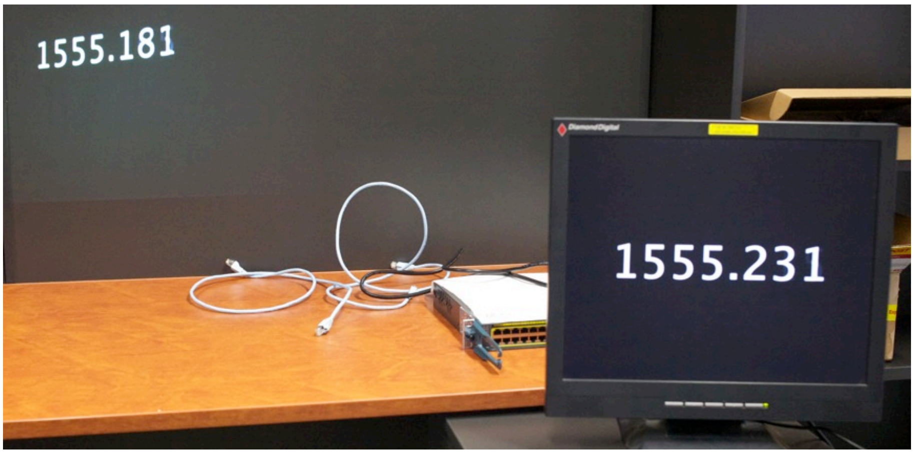
Based upon the machine vision style cameras here, any stereoscopic device needs to accept two images (separate stream for the left and right eye), as opposed to a frame multiplexed stereoscopic system (most modern 3D TVs and many 3D capable projectors). There are the following broad categories for 3D displays that accept independent left and right eye video streams.

1. Those based upon two display panels. An example of this is the True3Di (http://www.true3di.com). These consist of the light from two panels being polarized and a beamsplitter that bisects the angle between the two panels allowing the image from both of them to be seen.
2. A single 3D display panel capable of accepting dual video feeds.
3. Dual data projector displays. These would normally be polarisation based and would not require a beamsplitter.
4. Single 3D capable data projector. There are some 3D capable projectors that accept dual video feeds and combine those internally into a 120Hz frame sequential stereoscopic image. These would either use an IR transmitter for syncing or DLP-Link. An example of these is the AS3D projector products from Projection Design.

In terms of cost/availability options (1) and (4) exist commercially, (1) could possibly be built from panels of our choice while (4) would only ever be a commercial solution. The author is unaware of commercial products for (2). The easiest to build locally is (3), indeed the author has built a number of these over the years. Of course it would require testing of projectors to ensure models existed with the same 2 (or less) frames of buffering. Option (3) would also be the most cost effective since high brightness projectors would not be required. All solutions are suitable for mounting within a table with the viewer looking downwards.

An initial test was performed using a DLP data projector instead of a display, still driven using the HDMI from the vDisplay. Two representative outcomes from that experiment are shown below, in this case there was typically 50ms latency suggesting two frame buffering stages in the projector (3/60ms). As before the counter on the right is the input to the camera system, the counter on the left is the output from the data projector. It was only possible to test a single projector so no way of knowing if this is representative or not, or if there are differences between DLP and LCD projectors (noting that the later are more problematic for polaroid based stereoscopic installations). More professional grade projectors designed for simulation and training might be expected to have been designed with lower latency.





Future work

There are machine vision cameras (including the one tested here) along with the vDisplay unit that are capable of 120Hz. Unfortunately for the duration of the loan of the camera and vDisplay a 120Hz capable display was not available. Given the theory that 2 frames are being buffered then one might expect the currently measured latency could be halved to 16ms.

Further testing of data projectors is required in order to verify whether twin data projection style stereo3D presentation is an option.

There is another option but one that is considered to be more expensive and have a narrower range of supported/compatible devices. This is to use a HD-SDI interface from a camera to the display that accepts HD-SDI. Examples of camera and display in this space are given below

HD 1080: http://www.imperx.com/bobcat/isd-b1921

720: http://www.imperx.com/bobcat/isd-b1320

HD-SDI display: http://www.panasonic.com/business/provideo/BT-LH1710.asp

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