Synchronizing High Speed Image and Data Acquisition

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The purpose of this project is to develop the capability to match high speed imagery with high speed data. This would improve on the current data and imaging acquisition systems. The project studies how visual information captured by digital high speed cameras are synchronized with information captured with data acquisition systems. The computer software that is used by data acquisition systems at the UAH Propulsion Research Center is LabView. The time stamps recorded by the LabView program would be compared the time stamps recorded by the high speed camera. The high speed camera used in this research was a Vision Research Phantom Miro-4. The time stamp difference was calculated and a series of experiments were conducted to ensure good results. The results yielded a 9.21% random uncertainty in time delay measurements between the two independent systems.

Nomenclature

$UAH = University\ of\ Alabama\ in\ Huntsville$
$DAQ = Data\ Acquisition$
$PRC = UAHuntsville\ Propulsion\ Research\ Center$
$FPS = Frames\ Per\ Second$
$LCD = Liquid\ Crystal\ Display$
$LED = Light\ Emitting\ Diode$
$\Delta t = Time\ Difference$
$Hz = Hertz$
$V = Volts$
$StDev = Standard\ Deviation$
$Rnd\ Uncertainty = Random\ Uncertainty$
$Sec = Seconds$
$\mu s = Micro\ Seconds$

I. Introduction

In recent months, there has been interest in trying to synchronize high speed imagery with high speed data. The UAHuntsville Propulsion Research Center currently works on research projects that use both systems to gather data from an experiment. The reason for this type of experiment is to be able to capture an image to match a discrete characteristic event and its signal. This would provide more accurate results for better documentation. The main idea of this research is to find the Δt between the time stamps of two independent systems in order to find correlating data points and images. This can be seen in Figure 1. Synchronization methods are an important step in better preserving

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phase relationships between periodic events and their signals. The computer program that will be used in this study is LabView. The high speed DAQ will be connected to the computer interface as will the high speed camera. The high speed camera used in this study will be the Vision Research Phantom Miro-4.

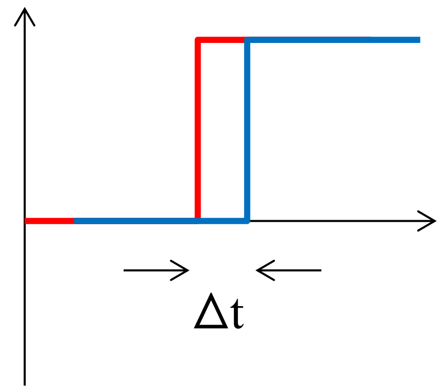

Figure 1: Time Delay

II. Experimental Approach

A. First Cut

The initial time stamp difference between the computer and camera was calculated using a first cut experiment (Figure 2). The experimental set-up called for the high speed camera, a Vision Research Phantom Miro-4, placed in front of a laptop computer with LabView programming. The camera was placed two feet in front of the computer screen. The high speed camera settings were set to record at a rate of 25,400 FPS at a 128 x 128 resolution. The shutter speed during this test was set to 1μs. A time string was added to the coding of the program in order to display the computer clock time in nanoseconds (Figure 3).

Figure 2: First Cut Experiment Setup

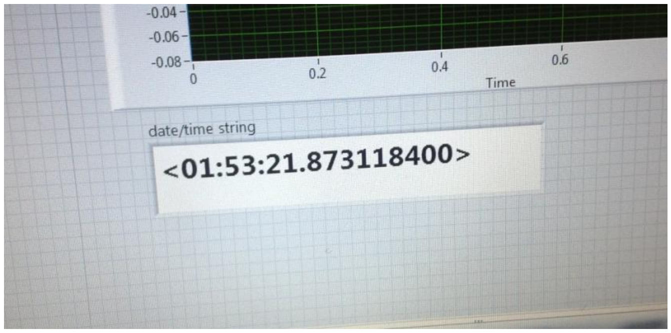

Figure 3: Computer Clock Time in LabView

The high speed camera was positioned to show the computer clock, displayed in LabView, on the LCD monitor of the Miro-4 Camera (Figure 4). The high speed camera has an internal buffer that will continuously save and delete images until it is triggered to record. Once triggered the Phantom Research PCC software will save the file for playback in the software interface. These images could then be analyzed to acquire data and results of the experiment.

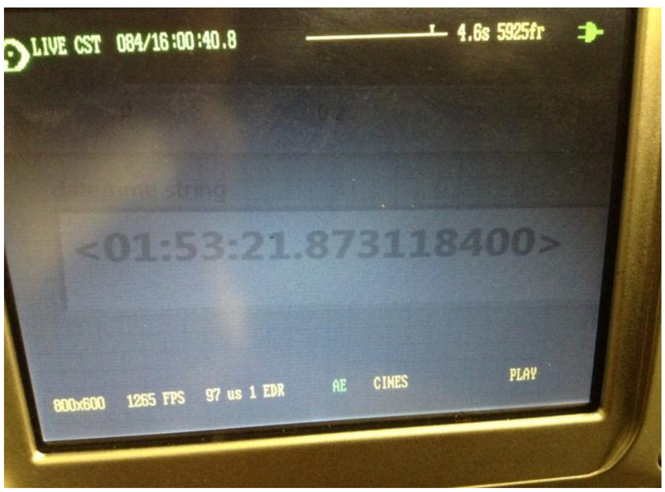

Figure 4: Computer Clock Time seen on High Speed Camera

B. Second Edition

A series of periodic LED experiment were conducted to in order to determine the accuracy of the triggering system used by the High Speed DAQ and Camera. In this test set-up (Figure 5), the Miro-4 camera was placed two feet from an LED circuit with a green high-intensity LED. The purpose of this test was to determine the time difference between the time stamp of the first data point recorded by the DAQ and the time stamp of the image when the LED first turned on. The data acquired by the high speed DAQ would be used to determine the baseline minimum and maximum voltages seen by the LED circuit. Finally, a trigger voltage would be found using this information.

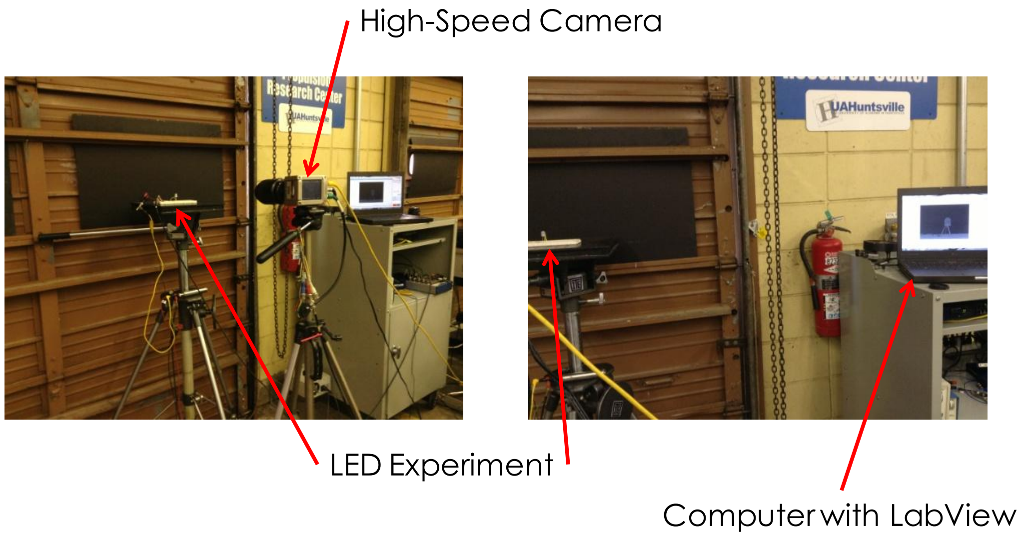

Figure 5: LED Experiment Set-up

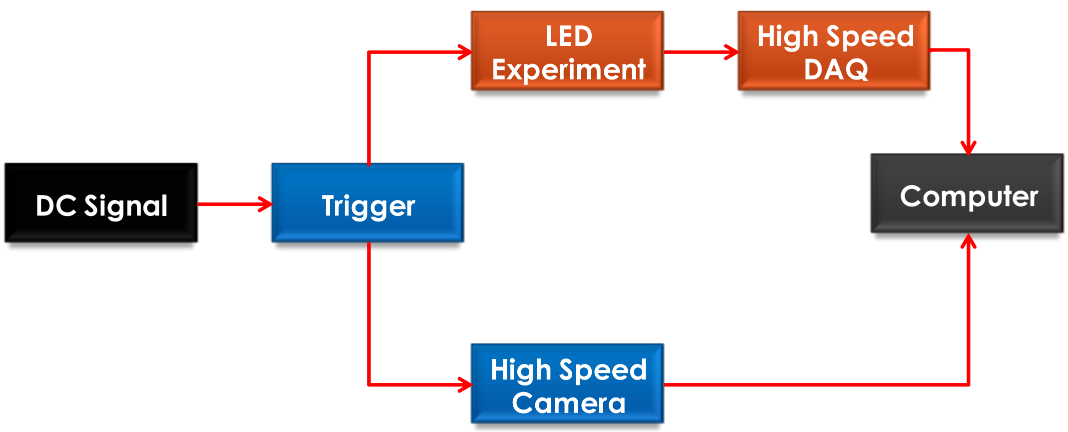

Figure 6: Period LED experiment schematic

Figure 6, above, shows the direction of the DC signal in the period LED experiment. A DC signal is inputted in the system via power connection to wall outlet. This signal is transferred through the camera to the manual hand trigger being used by the operator. The trigger is placed in series with the high speed camera and the LED circuit. Next, the triggered signal is sent to both the camera and LED experiment simultaneously. After the signal leaves the LED experiment it passes through the high speed DAQ, which receives voltage measurements. The LabView program and the Phantom Research software both collect and save the recorded data for post experiment analysis.

III. Results and Discussion

A. First Cut Results

The first experiment to compare the computer clock time to the time stamp of the camera yielded 43 images out of 3000 that could be used to properly identify time differences. Figure 7 shows an example of three images that were acquired from the high speed camera software. The image of the computer clock time was compared to the camera time stamp in the bottom left corner of the image to find the Δt between the two independent systems.

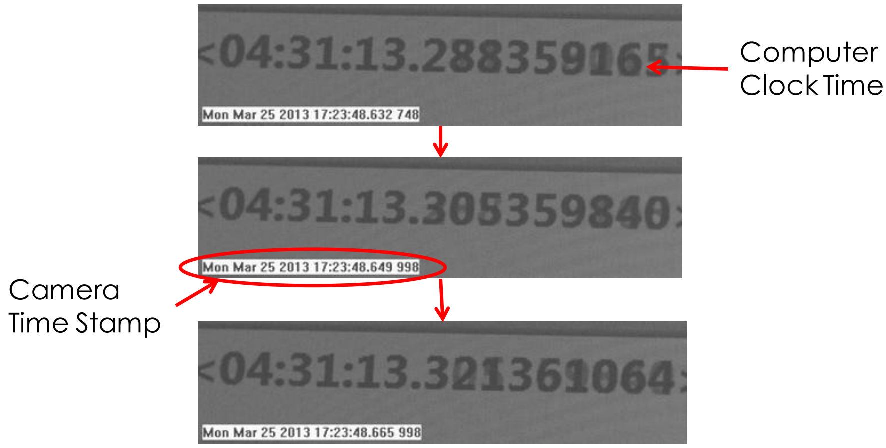

Figure 7: Imaging Results from First Cut experiment

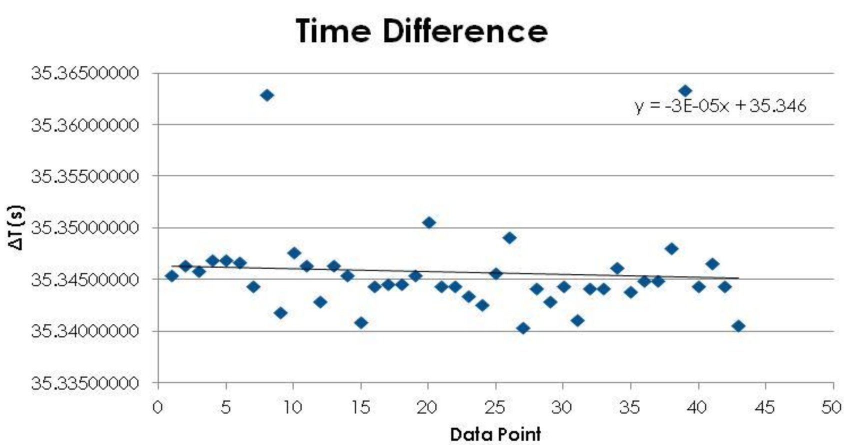

Figure 8: Time difference of seconds

Figure 8 shows the resulting time stamp differences, of seconds, between the high speed camera and DAQ. By performing simple analysis it was calculated that the overall time stamp difference was 0:52:35.34568449. This Δt must be either added or subtracted from one system in order to find the correlating image or data point. The standard deviation of this measurement was 0.00444607 (Figure 9). It is to be noted that the major source of uncertainty in this analysis is human error. Another source of error is attributed to the limitation of the high speed camera's frame speed. Observation of the images (Figure 7) shows that the camera was unable to clearly show the clock time. Many digits in the images were blurred. This caused error in identifying images that could be used for analysis.

Time Delay of Seconds

Average	35.34568449
StDev	0.00444607

Figure 9: Time Delay of Seconds

B. Baseline Data

Also assessed was the baseline voltages when the LED was on and off during the LED experiments. These baseline values would be used to calculate the trigger voltage for the high speed camera and DAQ. The minimum value would be subtracted from the maximum value to find the trigger voltage. Figure 10 shows the measured voltages for a single LED experiment. The DAQ sampling rate was set to 50,000 Hz.

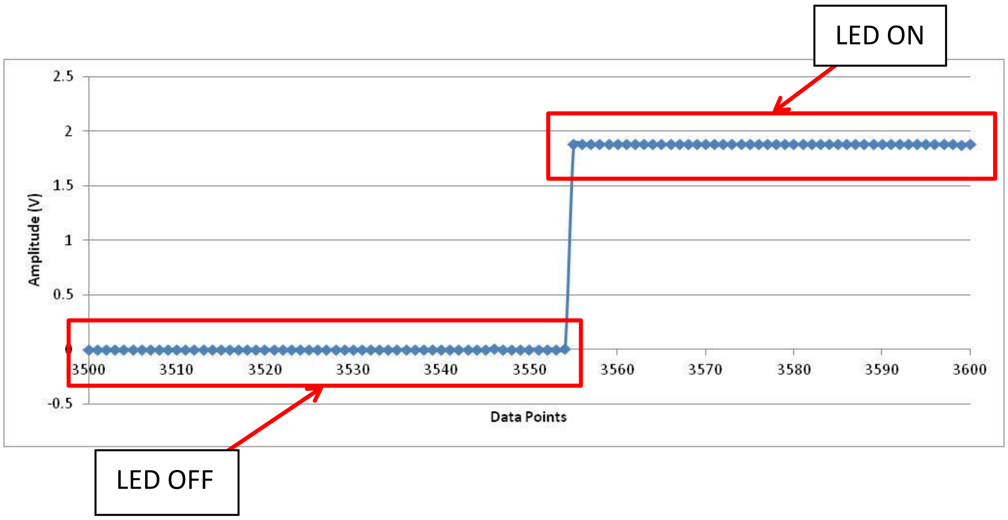

Figure 10: Baseline Voltage Data

The average value of the voltage measurements when the LED was off and on can be seen in Figure 11 and Figure 12, respectively. The average voltage when the LED was off came out to be -0.00215297 V with a standard deviation of 0.000703867 V. It was measured that the average voltage when the LED was on came out to be 1.880665562 V with a standard deviation of 0.000440478 V. The results showed that the average values were accurate and could be used to calculate a trigger voltage for the DAQ to record.

Average	-0.00215297
StDev	0.000703867

Figure 11: Voltage when LED off

Average	1.880665562
StDev	0.000440478

Figure 12: Voltage when LED on

C. LED Experiments

Period LED experiments were conducted in order to determine the accuracy of the trigger voltage. By finding the difference of the average voltage values from Figure 11 and Figure 12 it was determined that the trigger voltage should be set to 1.8828V. However, when the trigger voltage was set to 1.88V it was seen in the image files that the LED would be on an average of three frames before the trigger frame. Twenty tests were conducted to find a more accurate measurement and to test repeatability of results. The conclusion that could be made from the results of the tests is that the LED comes on at a lower voltage before reaching maximum intensity at 1.88V. Also, the resolution of the images was lowered in order to reach a maximum frame rate of 25,400 FPS. This included another Δt into the calculations by having the LED on before the DAQ would register a trigger voltage. Figure 13 shows an example of the data collected by the experiments. The three images seen below are consecutive frames with time stamps. The first image shows the LED in the off position. The correlating data point is the last data point before the voltage increases. The second image shows the first frame in which the LED is on. The correlating data point is the first data point at the maximum triggered voltage. The third image is the second frame after the LED illuminates.

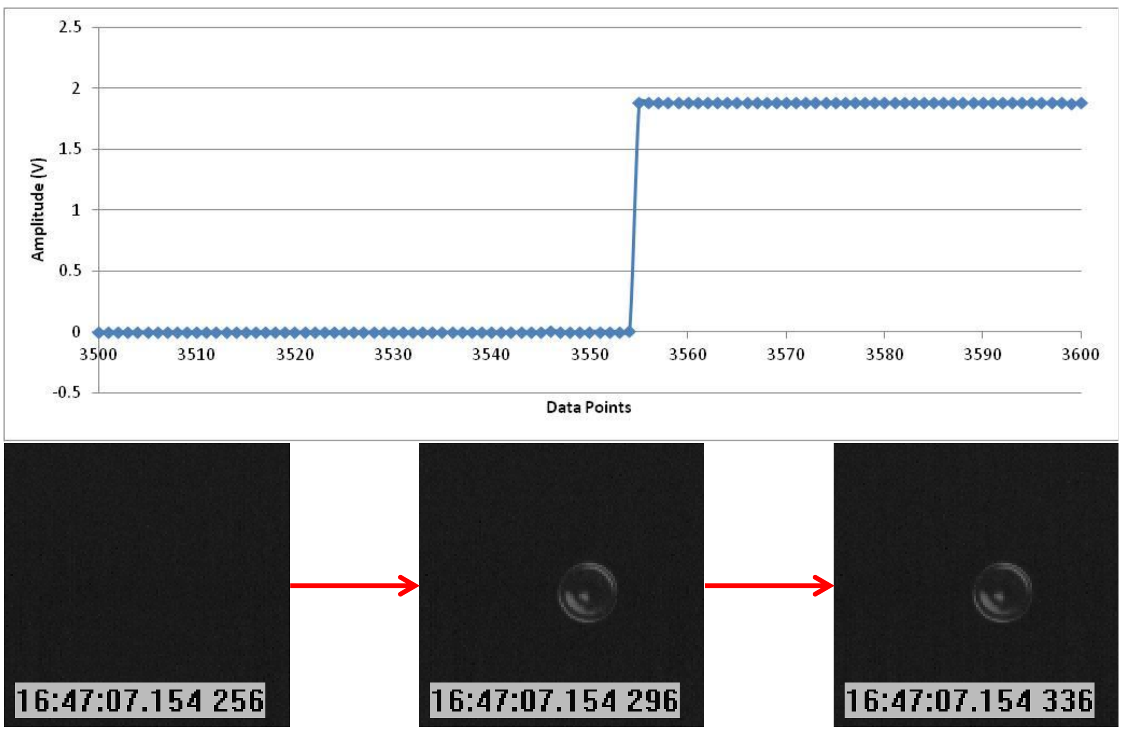

Figure 13: LED Experiment Results

Of the twenty LED tests conducted, seventeen tests yielded workable results. The time stamp, at the trigger point, of the second's position was tabulated for the computer and camera (Table 1). The Δt of these time stamps were calculated for each of the seventeen LED tests. The Average, StDev, and Rnd Uncertainty were calculated for the results of these experiments (Table 2). The average time delay of the second's position was 59.694922 sec with a stdev of 0.379551 sec. This resulted in an rnd uncertainty of 9.21%. It was also observed that during the triggering of the high speed camera that the LED illuminated before the trigger frame in the image series. The Δt of the LED "On" frame and the trigger frame (Table 1). The Average, StDev, and Rnd Uncertainty were calculated for this set of information and tabulated in Table 3. The average of the data was 0.00015 sec, the stdev was 0.00018 sec, with a rnd uncertainty 0.004%. The almost negligible uncertainty increased the confidence of the time delay between the LED "On" time and the trigger time.

Table 1: LED Experiment Time Data

Test	Computer Trigger Time (sec)	Camera Trigger Time (sec)	Δt of Time Stamps (sec)	LED "On" Time (sec)	Δt of LED and Trigger (sec)
Test 2	21.756019115	81.095884	59.339865	81.095764	0.00012
Test 3	26.820331573	86.087593	59.267261	86.087473	0.00012
Test 4	39.816938400	99.322463	59.505525	99.322343	0.00012
Test 5	2.814685821	62.389496	59.574810	62.389456	0.00004
Test 6	18.813032627	78.732362	59.919329	78.732282	0.00008
Test 7	14.813235759	74.484409	59.671173	74.484289	0.00012
Test 8	21.812067508	81.028315	59.216247	81.028195	0.00012
Test 9	18.810328006	78.094567	59.284239	78.094487	0.00008
Test 10	41.808506965	101.636805	59.828298	101.636725	0.00008
Test 11	45.801894187	105.865956	60.064062	105.865836	0.00012
Test 12	12.068260192	72.649323	60.581063	72.649163	0.00016
Test 13	14.067806243	74.116426	60.048620	74.116346	0.00008
Test 14	10.068009376	69.952071	59.884062	69.951991	0.00008
Test 15	37.063985347	96.910456	59.846471	96.910416	0.00004
Test 16	16.051533222	76.031159	59.979626	76.030399	0.00076
Test 19	15.354516029	74.734606	59.380090	74.734166	0.00044
Test 20	55.353235721	114.606172	59.252936	114.606132	0.00004

Table 2: Summary of Time Delay of Clock Times

Average:	59.684922
StDev:	0.379551
Rnd Uncertainty:	9.21%

Table 3: Summary of Time Delay in LED Response Time

Average:	0.00015
StDev:	0.00018
Rnd Uncertainty:	0.004%

IV. Summary and Concluding Remarks

Complex problems and experiments require numerous small experiments to ensure good results. In this research finding a method for synchronization of data and images required many tests in order to reduce error and increase repeatability of results. The first cut experiment yielded a very consistent time difference with low standard deviation. By performing simple analysis, it was calculated that the overall time stamp difference was 0:52:35.34568449. Uncertainty was introduced through human error in the analysis of images when recording computer clock times. The clarity of the digits diminished since the high speed camera was unable to clearly capture computer clock times.

During the series of LED experiments a time difference was determined to be very close to that of the first experiment. The baseline data that was acquired from these experiments also provided information to set a trigger voltage in the high-speed DAQ. This trigger voltage, when registered by the DAQ, would start recording voltage data and also trigger the high speed camera simultaneously. The time difference between the two independent systems was calculated to have an rnd uncertainty of 9.21%. While this is within 10% it introduces an enormous amount of error relative to the high sampling rate of 50,000 Hz. It was also observed that the LED would illuminate before the triggered voltage was reached in the high speed DAQ. This presented another time difference that had to be taken into account during the analysis.

Synchronizing unique time stamp information from independent systems presents challenges that require many experiments to reduce error. This is a lessons learned during the testing process. Invaluable experience was gained through shadowing the work of a doctoral student researcher. Moving forward, additional tests should be performed to decrease the error and to develop a method in finding the phase differences in real time. This would limit the amount of testing and pre-test analysis. Modifying existing LabView programming is being evaluated for these goals.

V. Acknowledgements

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References

[1]http://www.visionresearch.com/Products/High-Speed-Cameras/Miro-eX4/