



SHADOWSENSE PERFORMANCE
REPORT: DEAD LEDS



DOCUMENT REVISION HISTORY

Revision	Date	Author	Comments
1.1	Nov\17\2015	John La	Re-formatted for release
1.0	Nov\3\2015	Jason Tang-Yuk, Gurinder Singh, Avanindra Utukuri	Created the document

1.0 Objective

ShadowSense technology uses a number of LED emitters which emit an IR light curtain over the touch surface. When any object touches the screen, it casts a pattern of shadows which are detected by our proprietary Shadow Sensors and the position of the touch is triangulated. Over time, it is possible that LEDs in the system may fail. Certain LEDs will naturally degrade faster than others based on manufacturing variations resulting in random LEDs failing over the life time of the touch screen. Conversely, LEDs might fail or stop contributing to the system sequentially based on external contaminants such as gum. For example, it is conceivable that a user sticks gum on the bottom surface of the touch screen and all the LEDs in that area are obstructed and no light is seen from them by the Shadow Sensors.

The main objective of this experiment is to understand and characterize the performance degradation of the touch screen as LEDs fail. The first part of the testing will be used to evaluate the performance and accuracy of the Baanto ShadowSense touch frame as non-consecutive LEDs were randomly removed. The second part of the testing will evaluate the performance and accuracy of the ShadowSense touch frame as consecutive LEDs are removed.

1.1 Equipment

The equipment used during the entire test:

- Baanto SDW656 touch frame with firmware 7.30
- Baanto Dashboard software
- XYZ CNC machine
- MATLAB
- MATLAB test script

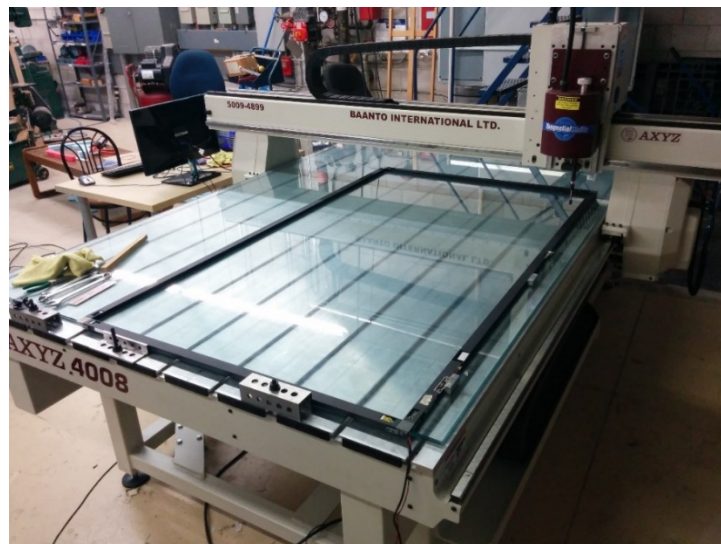


Figure 1: Fault tolerance testing set up on XYZ CNC machine

1.2 Setup

A Baanto ShadowSense SDW656W1 touch frame was assembled and tested to ensure that there were no defects with the unit. The configuration parameters were all reset to the default settings through Dashboard. The frame was then put into position for the test on the AXYZ CNC machine (*Figure 1*) and tested. The CNC machine is controlled via a MATLAB script that is able to move the CNC probe and test the touch screen over 1600 evenly spaced positions along the entire surface. The error is then measured as the difference between the true position of the robot and the position read from the ShadowSense touch frame. *Figure 2* shows the output of the test. The red dots represent the true position of the robot, while the blue line indicates the measured point. In addition there are two heat maps that are generated that show the error distribution across the entire touch area. One is generated to show the error in the X direction and one is generated to show the error in the Y direction.

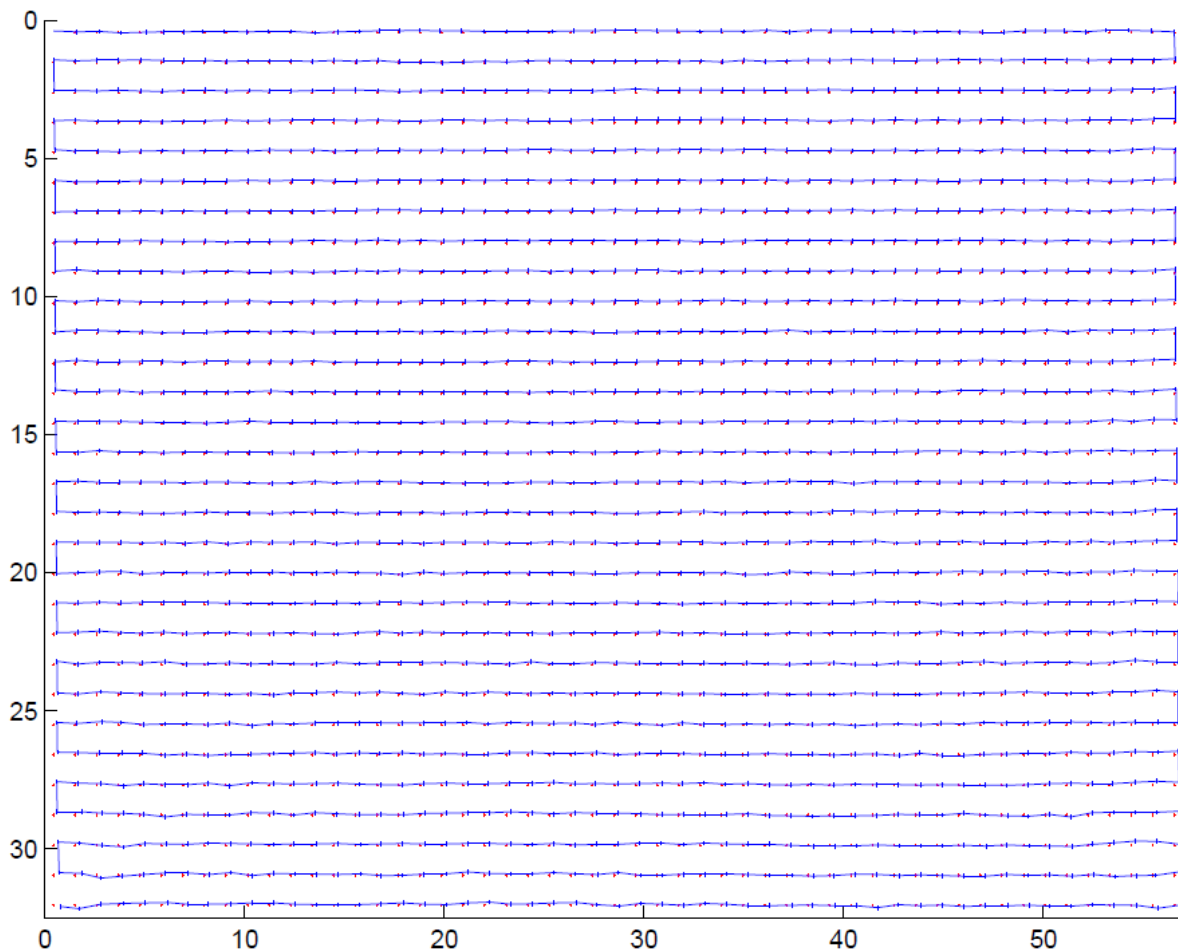


Figure 2: Test pattern for the AXYZ CNC machine for 1600 test points

1.3 Baseline vs. Dead LED Brightness

Figures 3 and Figure 4 below show the ShadowSense frame before and after LEDs were removed and the effect on the brightness values of the LEDs. When the LEDs were removed the brightness became zero, meaning the randomly selected LEDs were emitting no light.



Figure 3: Graph representing LED values while on baseline testing (0 dead LEDs)

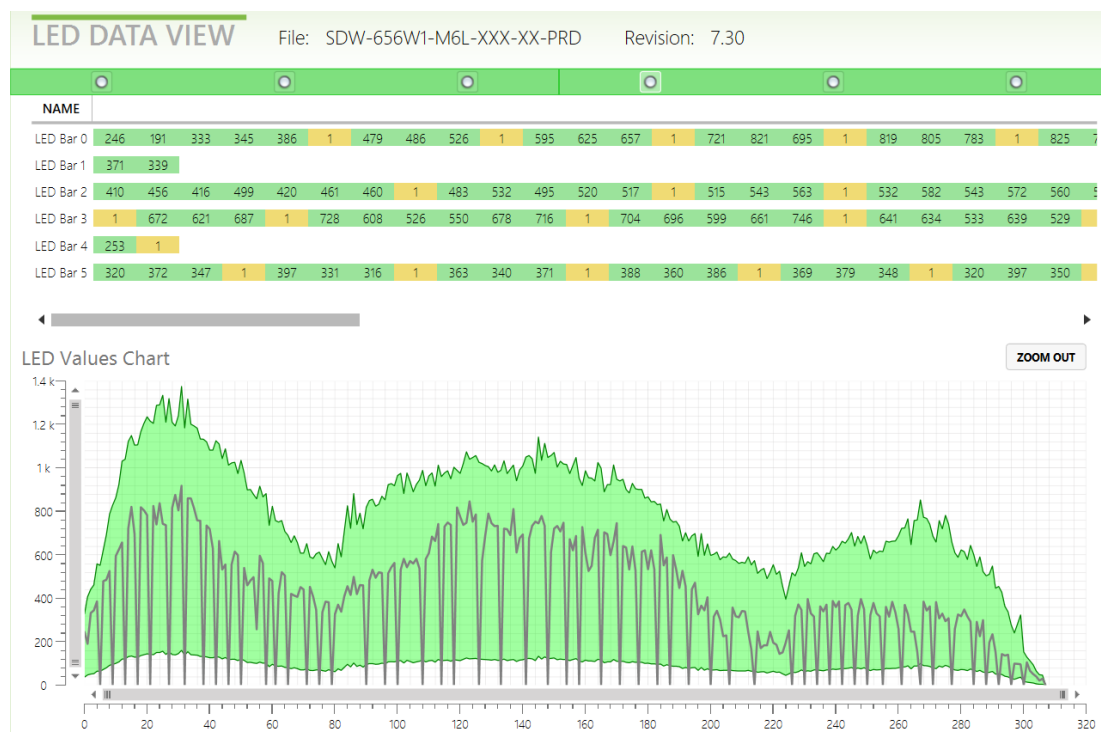


Figure 4: Graph representing LED values, 55 dead LEDs

2.0 Method 1 – Pseudo-Random Dead LEDs

Once the frame was tested and put into place, the MATLAB script could be executed. The first series of tests were performed to evaluate the fault tolerance of non-consecutive dead LEDs in the ShadowSense touch frame. The testing was performed using the SDW656 unit previously tested. This was done in order to establish baseline data for performance and accuracy of the ShadowSense touch frame. The accuracy was measured through the use of an automated robotic system performing the test pattern shown in *Figure 2*. After the initial baseline test was completed, 3 LEDs were removed, from both side light bars as well as the bottom light bar. Multiple tests were run while removing 3 additional LEDs each time from the respective light bars, as shown in *Figure 5*. Due to the bottom light bar containing significantly more LEDs compared to the side light bars, additional LEDs were removed from the bottom light bar during the proceeding tests. This allowed for a more even distribution of dead LEDs throughout the ShadowSense frame.

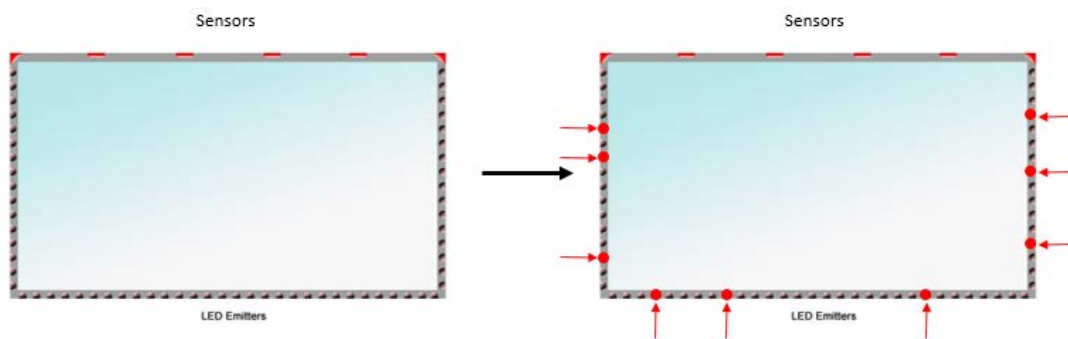
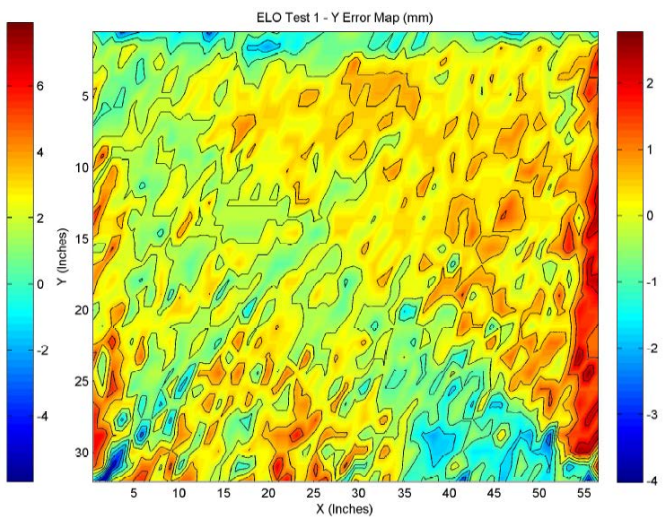
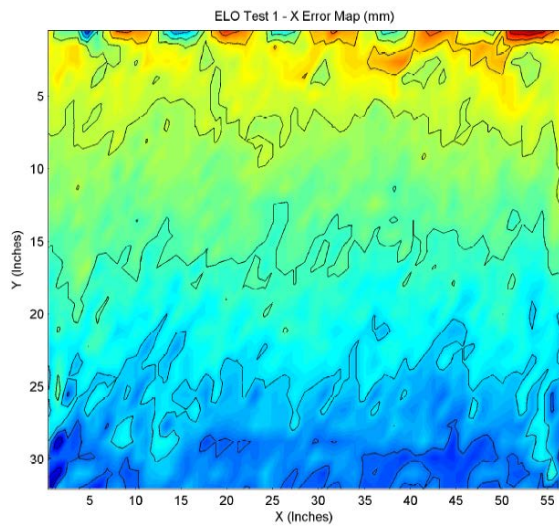
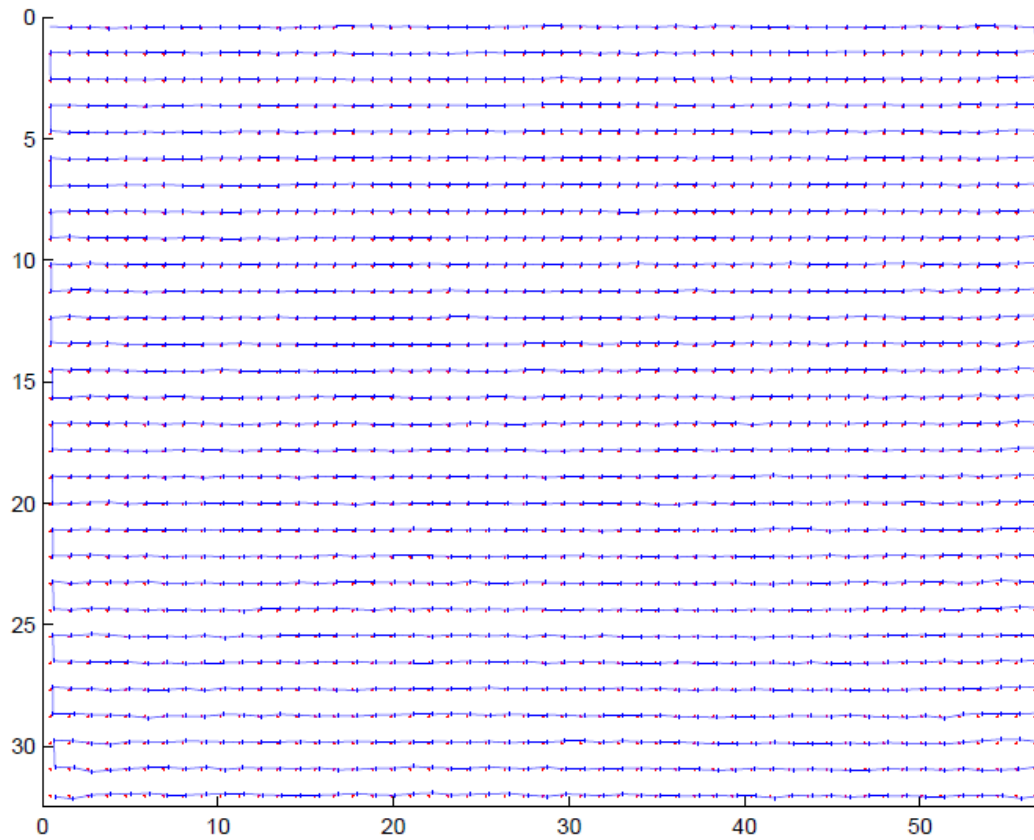


Figure 5: Removing 3 non-consecutive IR LEDs each test from the respective light bars

The following set of trials show a sub-set of results that were taken during the tests. Certain test results have been omitted because they did not show any significant deviation from the norm and also for the sake of brevity.

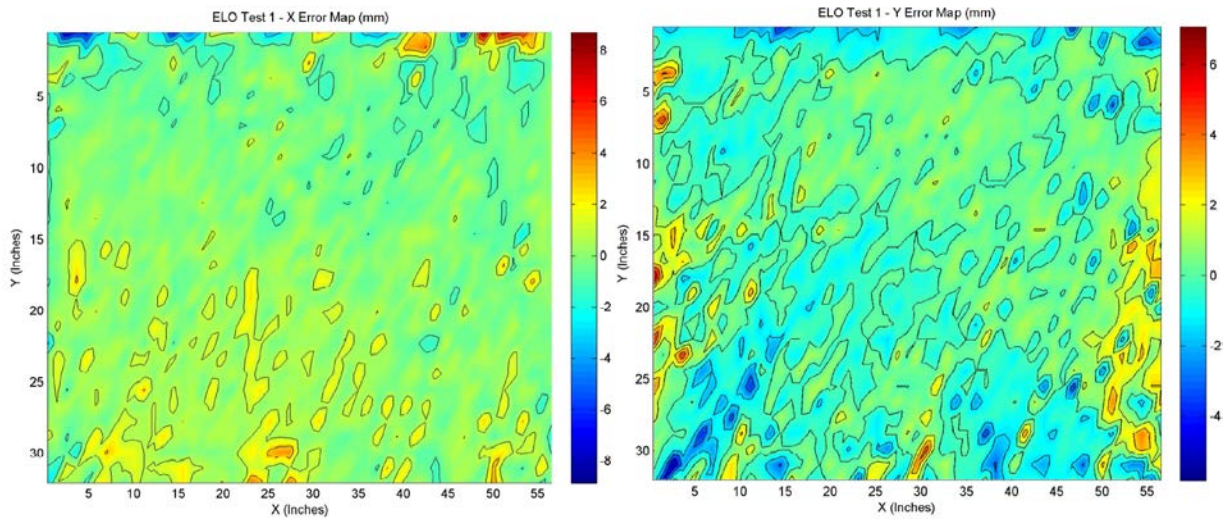
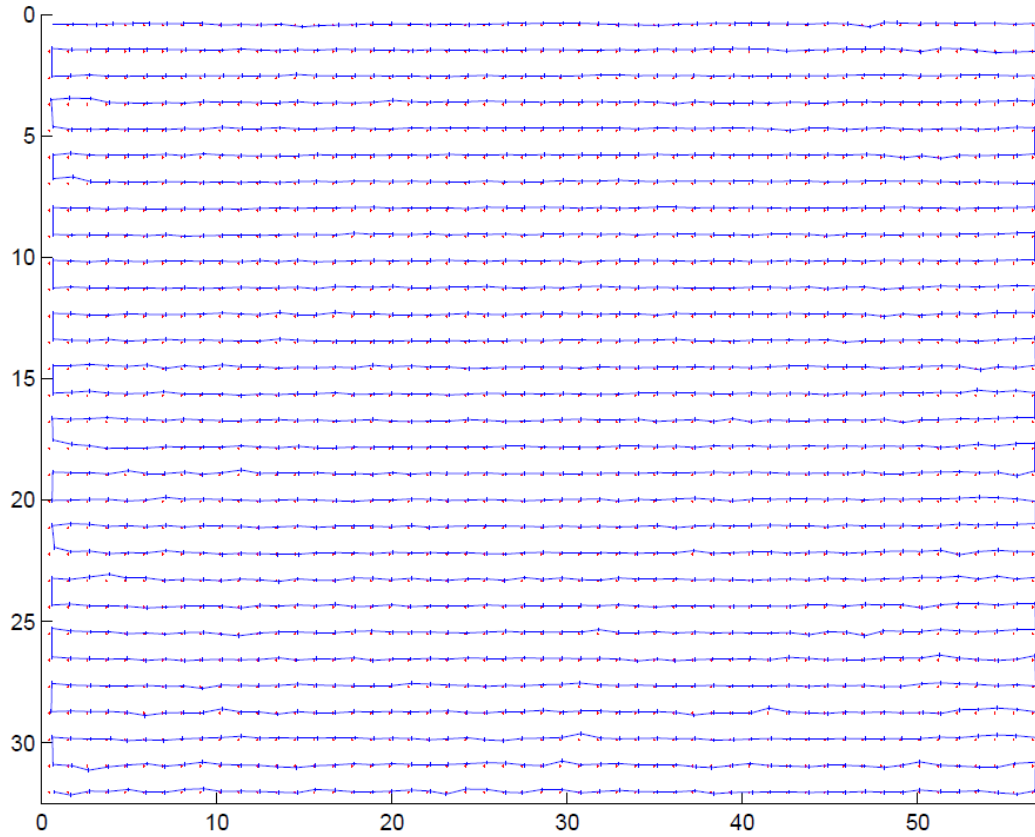
Trial-1 -- Baseline Test: 0 Dead LEDs:

Error at 90: 1.599mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 0.8815mm
Mean X Error: 0.5194mm
Mean X Error without Nulls: 0.5194mm
Mean Y Error: 0.599mm
Mean Y Error without Nulls: 0.599mm



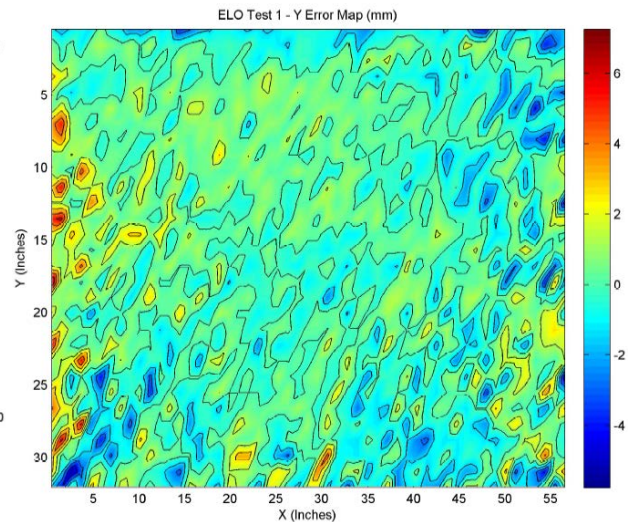
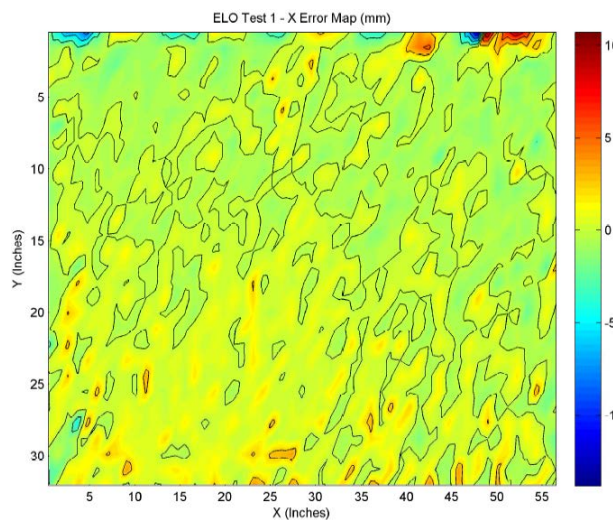
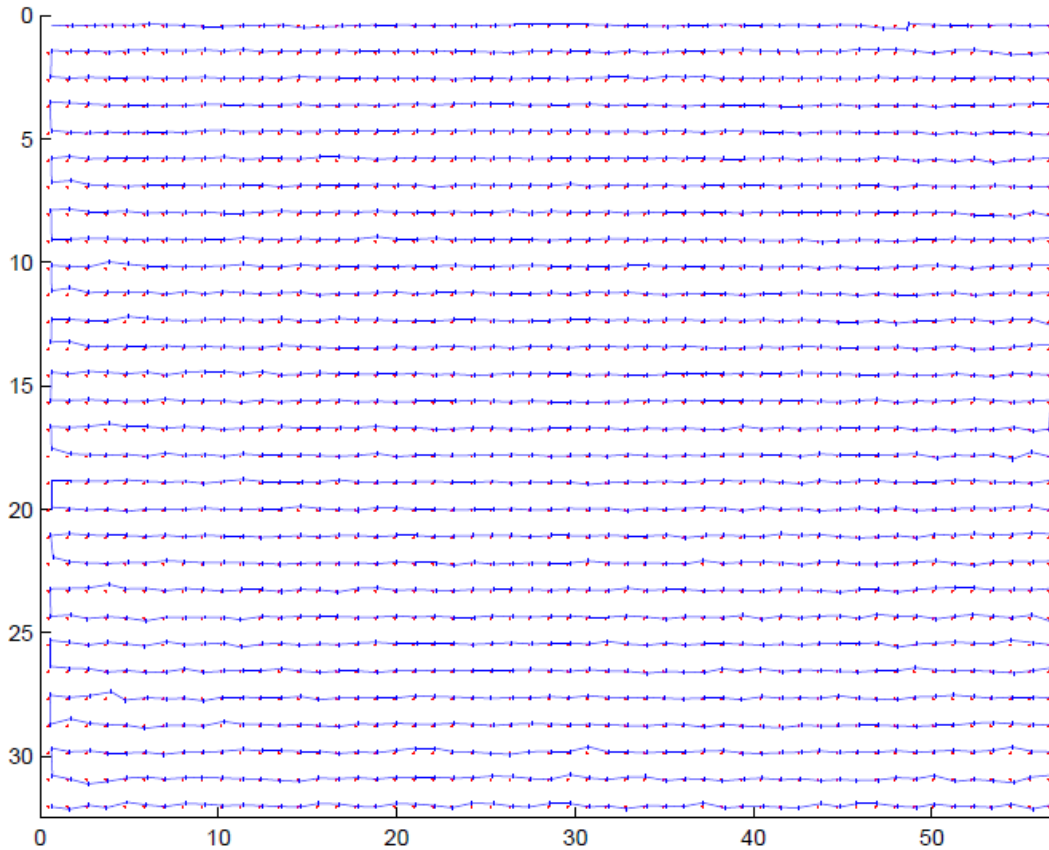
Trial-3 – 6 dead LEDs in each light bar:

Error at 90: 2.442mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.19mm
Mean X Error: 0.7007mm
Mean X Error without Nulls: 0.7007mm
Mean Y Error: 0.8079mm
Mean Y Error without Nulls: 0.8079mm



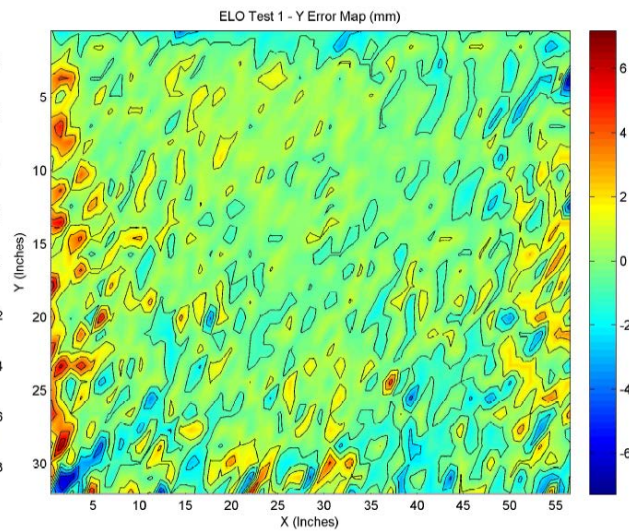
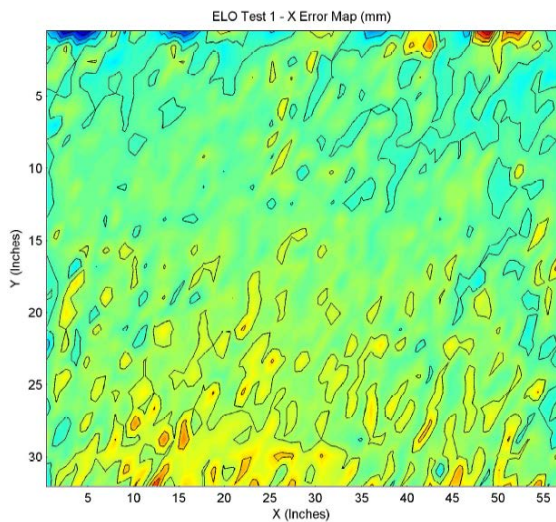
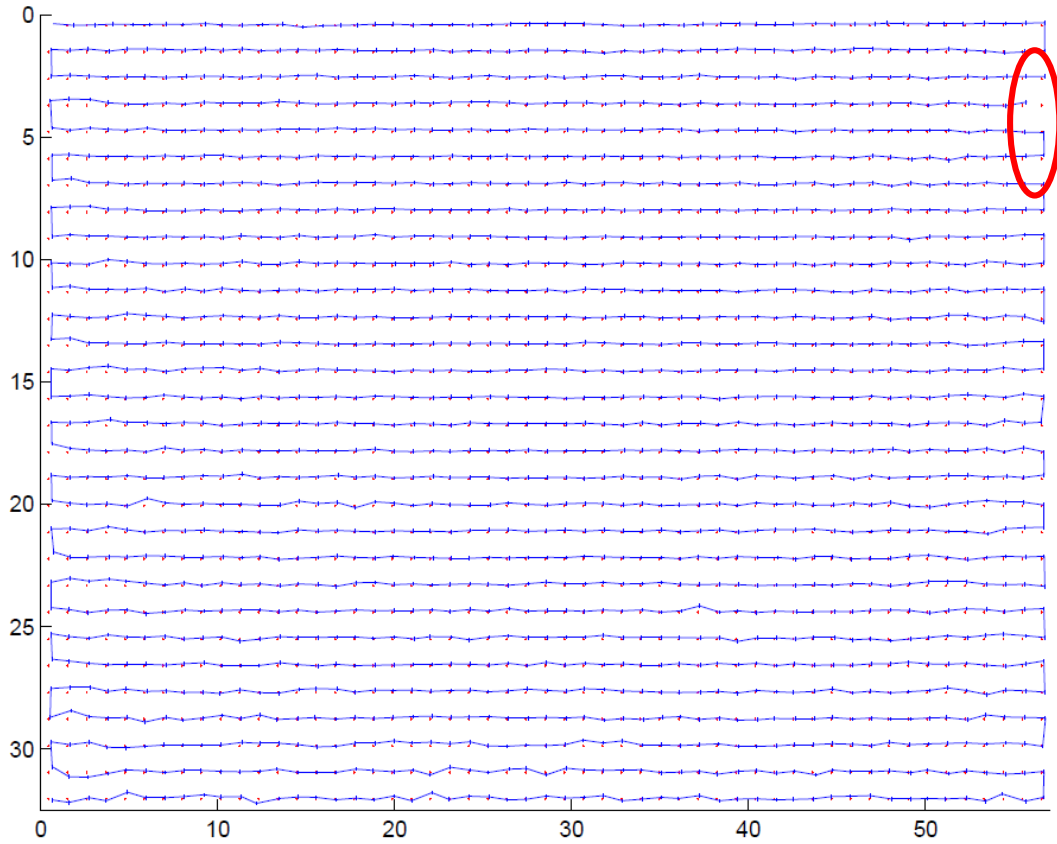
Trial-5 – 13 dead LEDs in each light bar:

Error at 90: 2.656mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 1.361mm
Mean X Error: 0.7878mm
Mean X Error without Nulls: 0.7878mm
Mean Y Error: 0.9318mm
Mean Y Error without Nulls: 0.9318mm



Trial-7 -- 21 LEDs dead in bottom light bar and 17 dead in both side light bars:

Error at 90: 2.934mm
Missed Data Points in x: 1
Missed Data Points in y: 1
Mean Total Error: 1.528mm
Mean X Error: 0.932mm
Mean X Error without Nulls: 0.9294mm
Mean Y Error: 1.006mm
Mean Y Error without Nulls: 1.003mm



2.1 Method 1 – Results

All of the testing that was executed using the XYZ CNC machine has error associated with it from slight variations of the experimental setup as well as the error associated with the CNC machine. As can be seen in *Table 1* and *Figure 6* below the error between the actual position of the touch point and the position being read by the ShadowSense touch frame slightly increases as additional LEDs are removed. Each test consisted of an accuracy test performed by the automated XYZ CNC machine. Even after a total of 55 LEDs were removed, the ShadowSense touch frame continued to perform well, with only one touch point missing. This is highlighted in the XY-Plot of trial 7.

Table 1: Trial results from the accuracy robot plots

Trial	Dead LEDs (Total)	Mean Total Error (mm)
1 - Baseline	0	1.599282
2	9	2.096270
3	18	2.442010
4	27	2.538296
5	39	2.656375
6	45	2.859639
7	55	2.934073

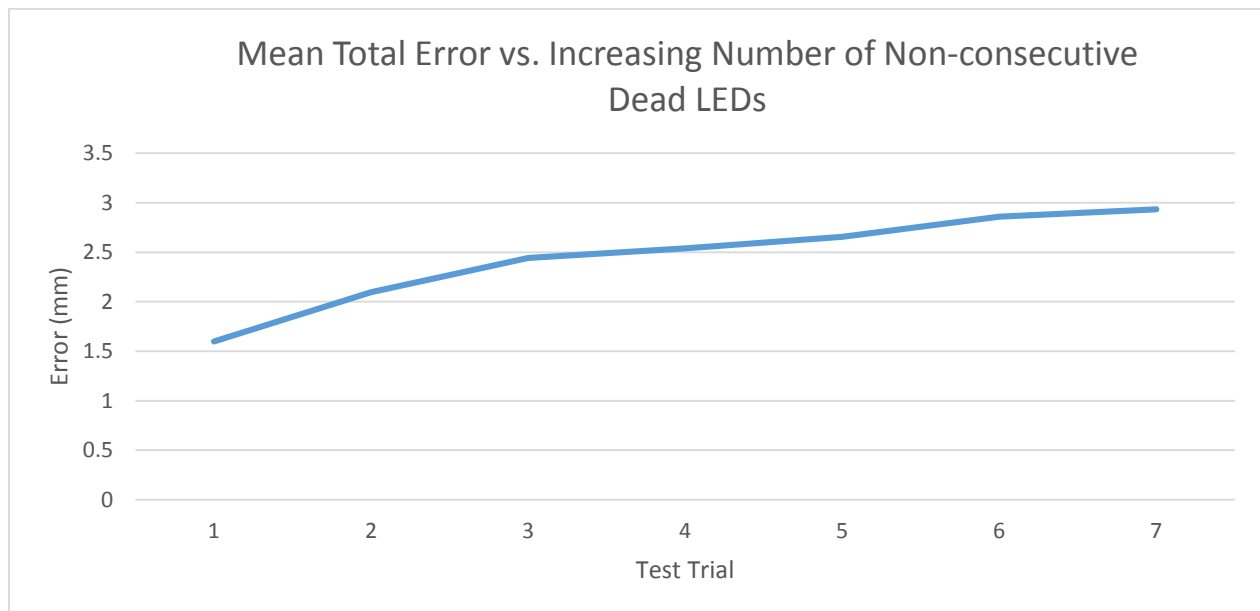


Figure 6: Graph of relationship between error and number of failed non-consecutive LEDs

3.0 Method 2 – Consecutive Dead LEDs

The second series of tests were performed to evaluate the fault tolerance of the ShadowSense touch frame with regards to consecutive dead LEDs. The test was performed in the exact same manner as the previous test except this time instead of removing 3 additional LEDs from each light bar, 3 LEDs were removed from the same light bar each time (from left light bar). This allows for more in depth analysis of how the ShadowSense touch frame responds to consecutive dead LEDs and the relationship between the location of the dead LEDs and the corresponding accuracy and performance.

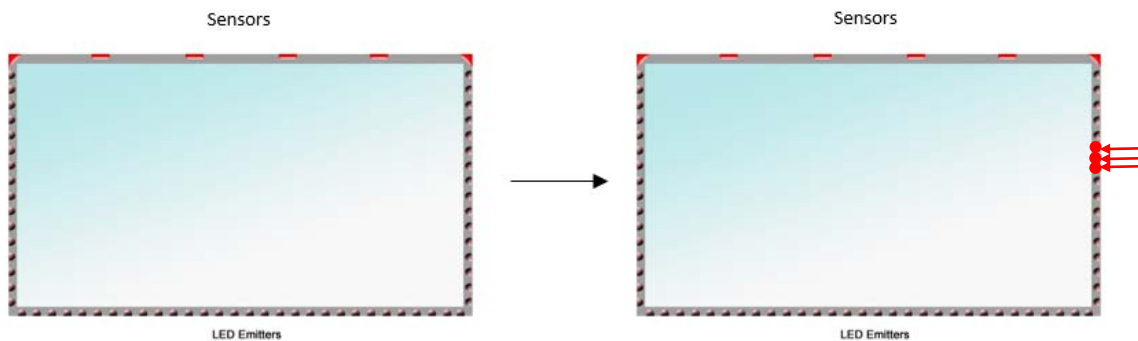
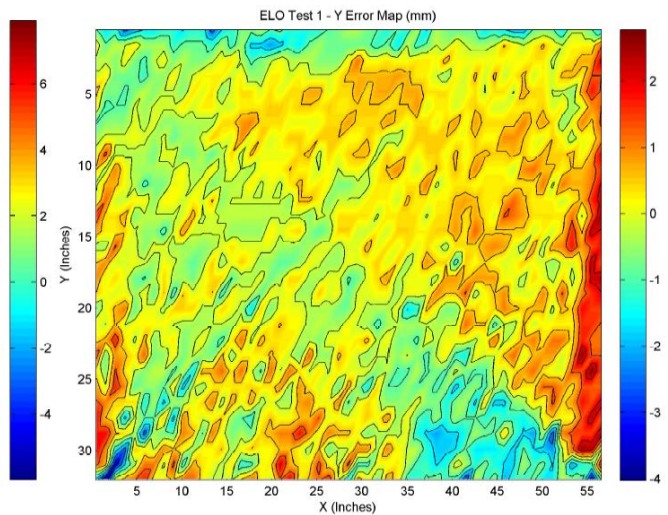
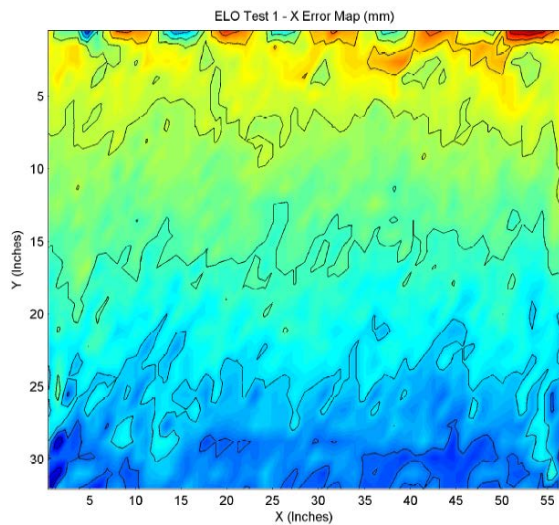
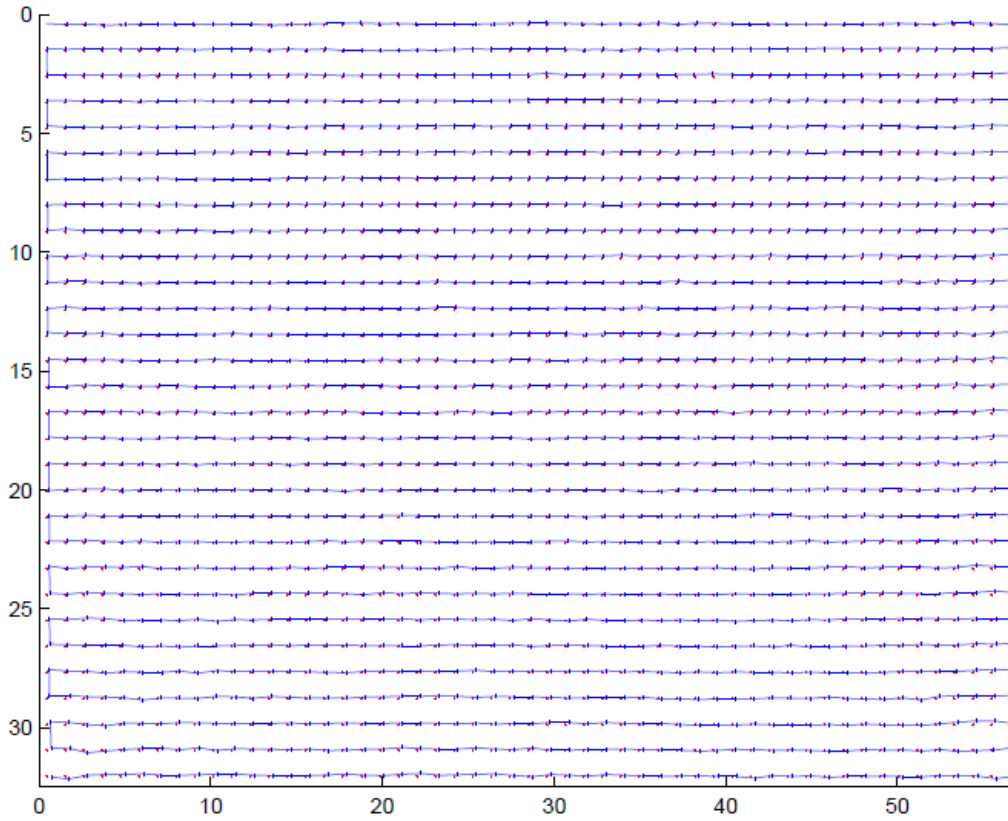


Figure 7: Removing consecutive IR LEDs from the light bars each test. (Red arrow and dot represent a dead LED)

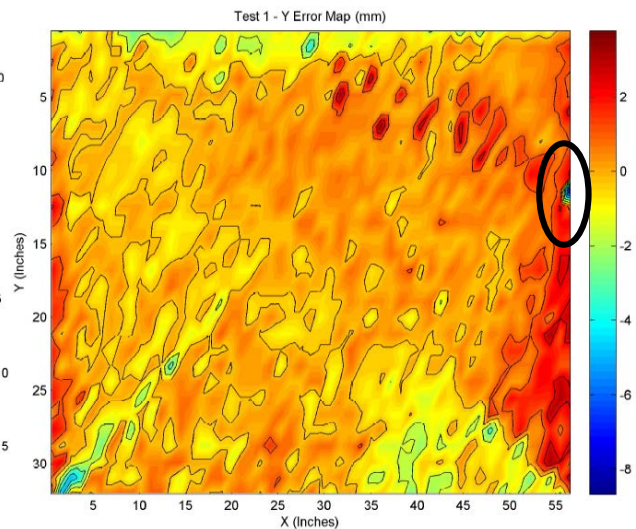
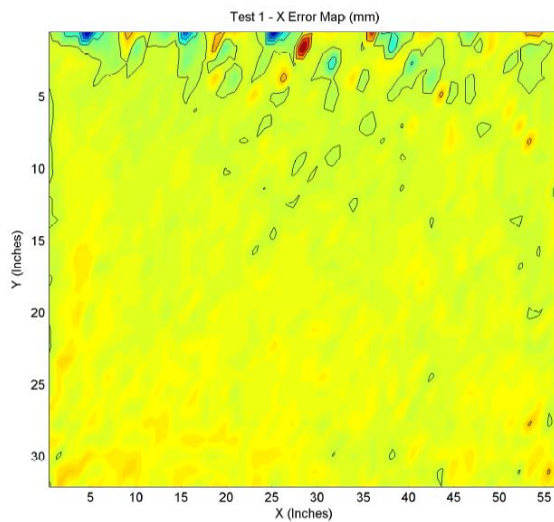
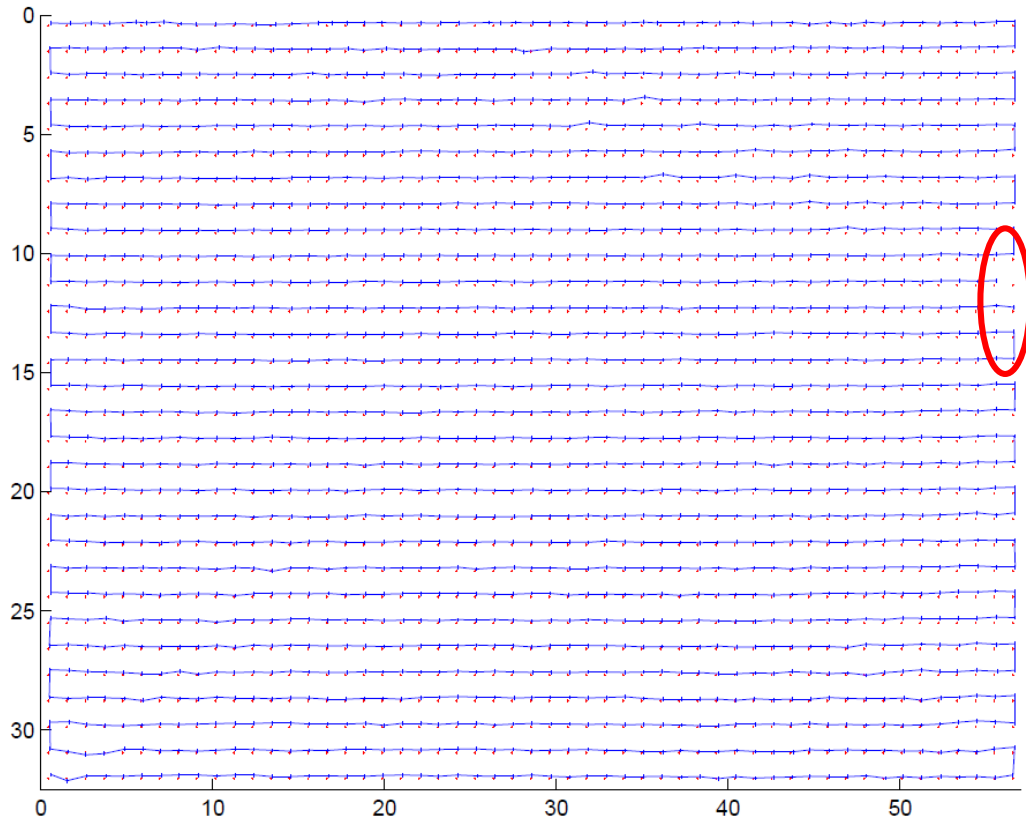
Trial-1 -- Baseline test 0 LEDs dead:

Error at 90: 1.599mm
Missed Data Points in x: 0
Missed Data Points in y: 0
Mean Total Error: 0.8815mm
Mean X Error: 0.5194mm
Mean X Error without Nulls: 0.5194mm
Mean Y Error: 0.599mm
Mean Y Error without Nulls: 0.599mm



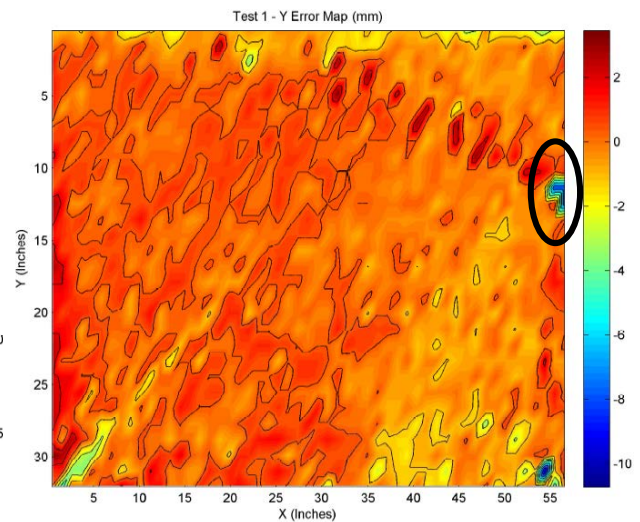
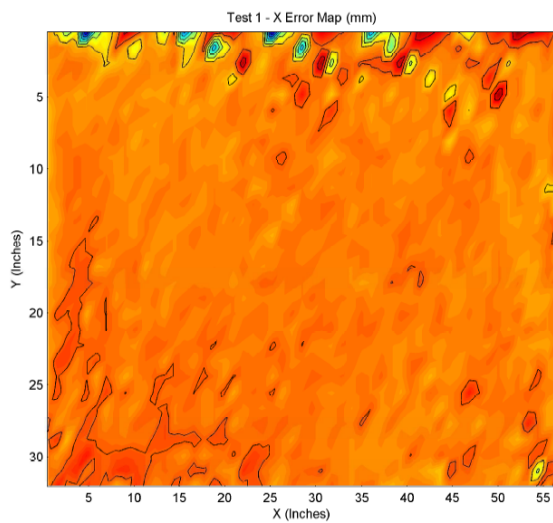
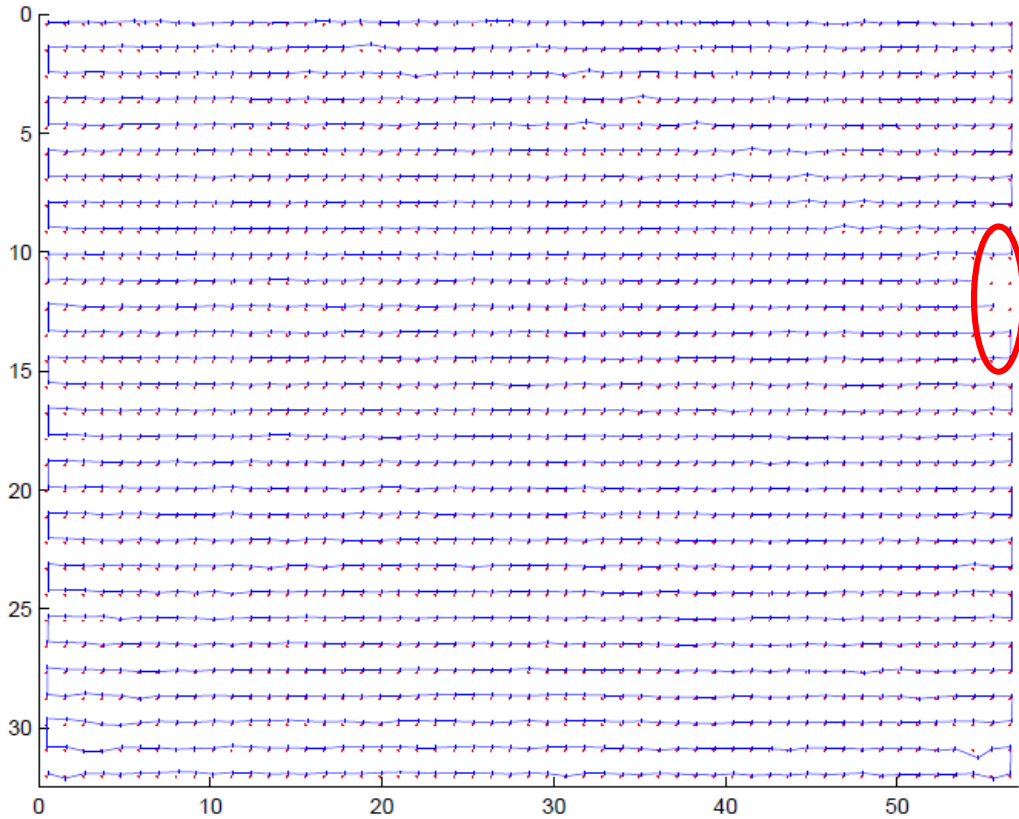
Trial-2 – 3 consecutive dead LEDs in the middle of left light bar:

Error at 90: 1.947mm
Missed Data Points in x: 1
Missed Data Points in y: 1
Mean Total Error: 1.02mm
Mean X Error: 0.6079mm
Mean X Error without Nulls: 0.6051mm
Mean Y Error: 0.6703mm
Mean Y Error without Nulls: 0.6675mm



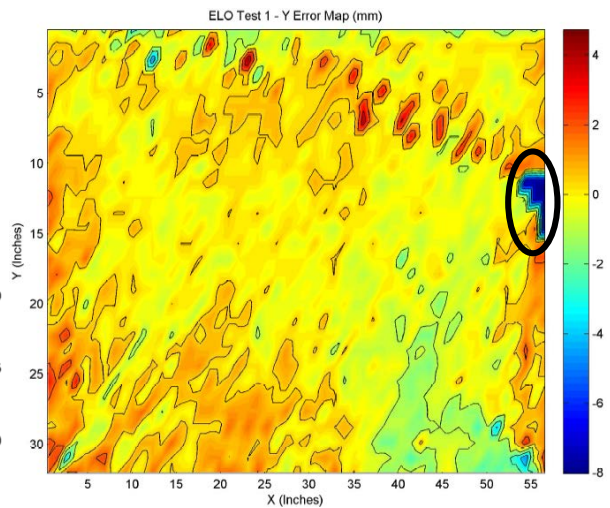
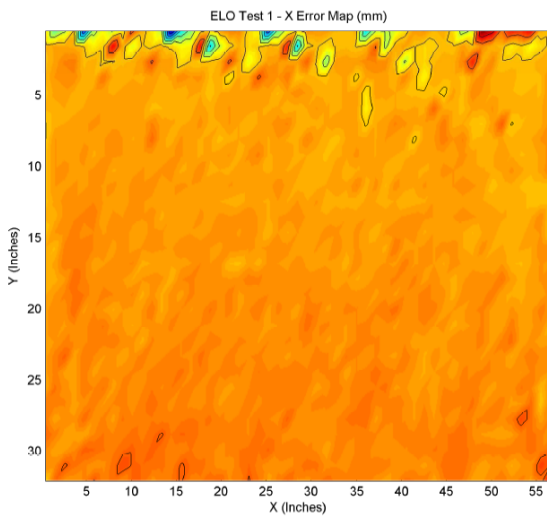
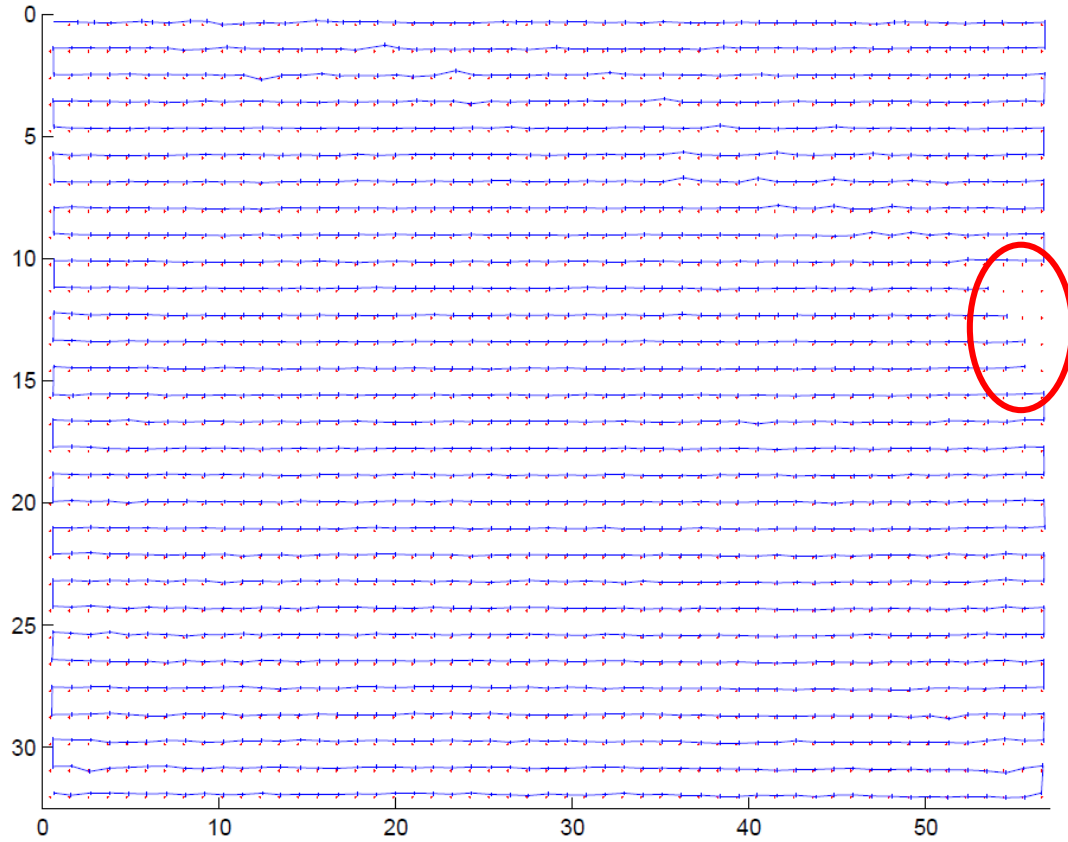
Trial-3 – 6 consecutive dead LEDs in the middle of left light bar:

Error at 90: 1.721mm
Missed Data Points in x: 3
Missed Data Points in y: 3
Mean Total Error: 0.9909mm
Mean X Error: 0.596mm
Mean X Error without Nulls: 0.5876mm
Mean Y Error: 0.6417mm
Mean Y Error without Nulls: 0.6333mm



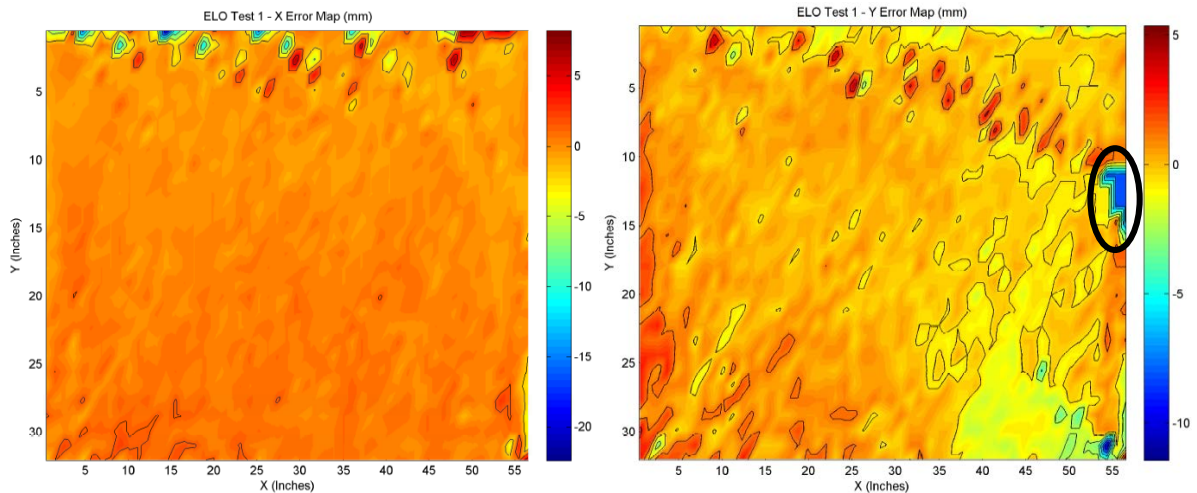
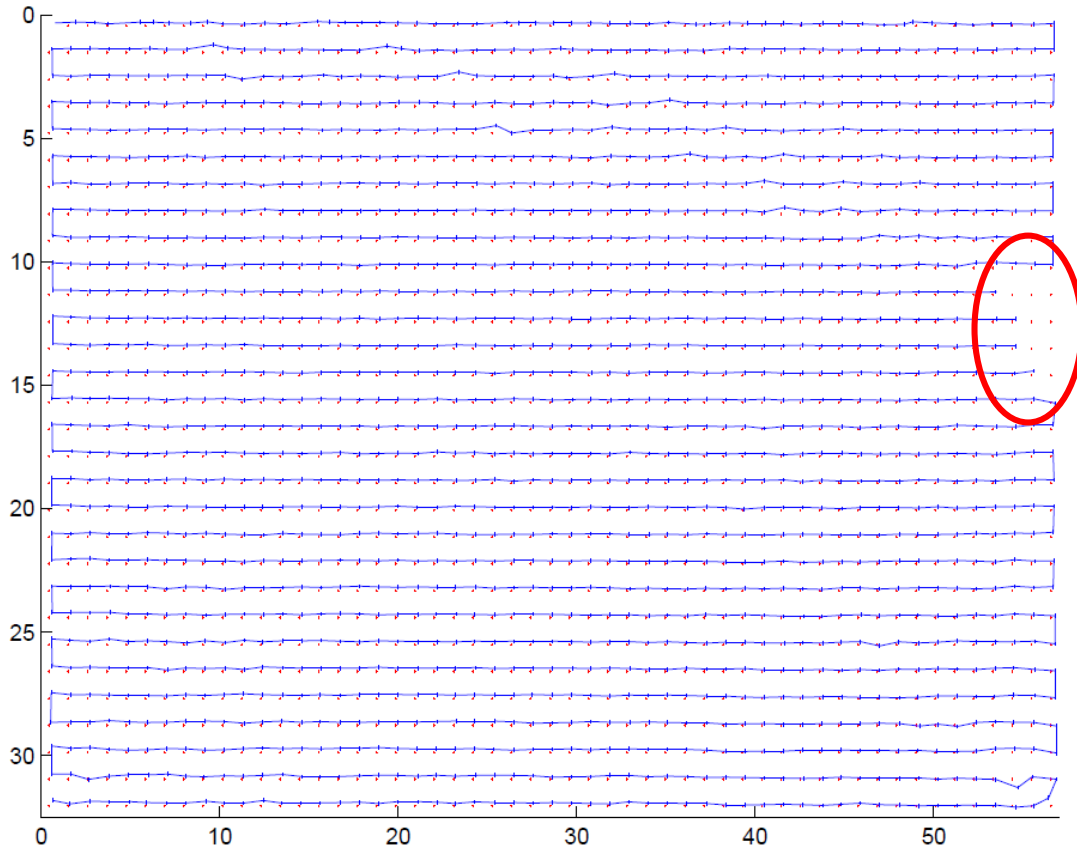
Trial-4 – 9 consecutive dead LEDs in the middle of left light bar:

Error at 90: 1.865mm
Missed Data Points in x: 7
Missed Data Points in y: 7
Mean Total Error: 1.094mm
Mean X Error: 0.7237mm
Mean X Error without Nulls: 0.7044mm
Mean Y Error: 0.6388mm
Mean Y Error without Nulls: 0.6192mm



Trial-5 – 12 consecutive dead LEDs in the middle of left light bar:

Error at 90: 1.998mm
Missed Data Points in x: 8
Missed Data Points in y: 8
Mean Total Error: 1.157mm
Mean X Error: 0.714mm
Mean X Error without Nulls: 0.6919mm
Mean Y Error: 0.7275mm
Mean Y Error without Nulls: 0.7055mm



3.1 Method 2 – Results

In this test the same AXYZ CNC machine was used to perform the accuracy testing. The only difference was in this series of tests consecutive LEDs were removed opposed to randomly selected non-consecutive LEDs. *Table 2* below shows three consecutive LEDs were able to be removed before a single touch point was missed by the robot accuracy testing machine. The ShadowSense frame was still able to perform at a high level with no problems tracking multiple touch points in the majority of the active touch area. The area that was affected was the area highlighted on the right of the above figures. As LEDs were removed the error between the true position and the position being read by the frame increased primarily in the location where LEDs were being removed and slightly throughout the rest of the touch screen. With 12 LEDs removed, the area that is affected and has increased error spans approximately the length of the failed LEDs and stretches approximately 6 inches towards the center of the screen.

Table 2: Trial results from the accuracy robot plots

Trial	De-rated LEDs (Total)	Mean Total Error (mm)
1 – Baseline	0	1.599282
2	3	1.946910
3	6	1.721477
4	9	1.864992
5	12	1.997661

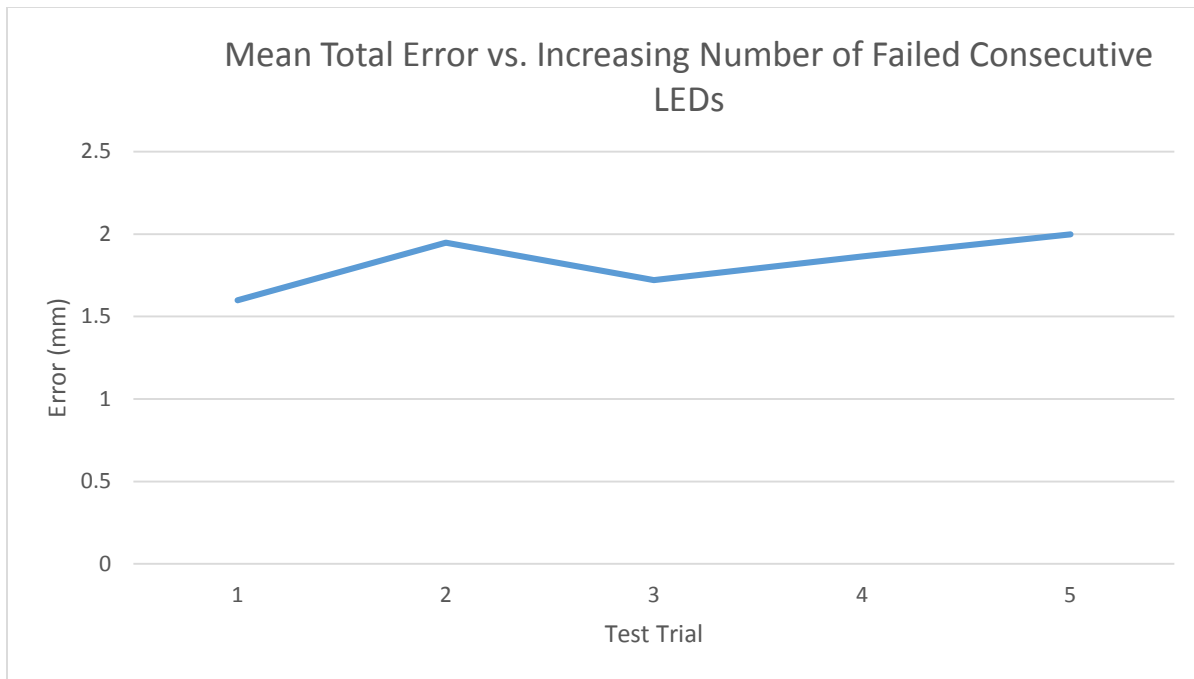


Figure 8: Graph of relationship between error and number of failed consecutive LEDs

4.0 Conclusion

The Baanto ShadowSense touch frame has a very redundant and robust design. The design allows for a large number of LEDs in the frame to fail before there is any degradation in the performance of the system. The effect of both consecutive dead LEDs and non-consecutive dead LEDs were investigated with respect to touch performance and accuracy. As shown above, approximately 18% of non-consecutive LEDs are able to fail with minimal variation in performance. The second portion of the testing showed that with consecutive dead LEDs, the localized area around the dead LEDs experiences performance issues but the rest of the touch screen continues performing at a high level.