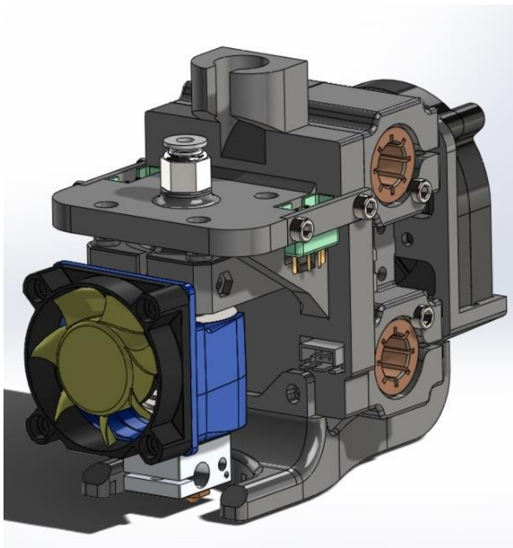
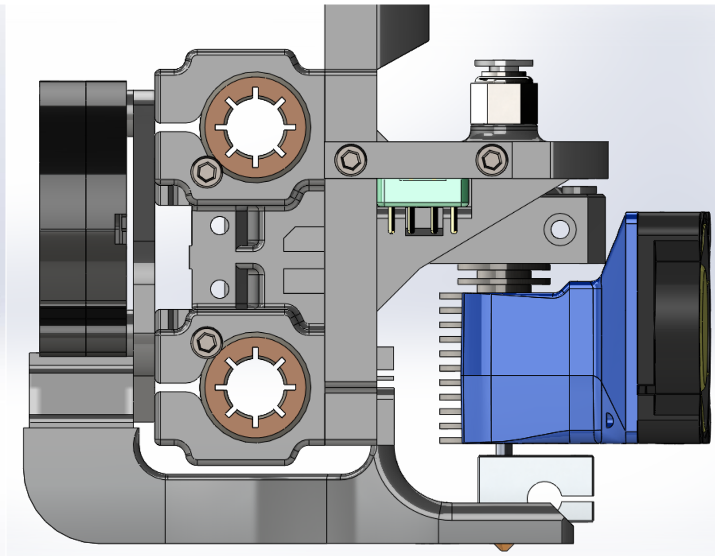
Hypercube Evolution Precision Piezo Orion Hotend Assembly Mount Test Results - 20181010

vergienc





This mount is designed for the Hypercube Evolution printer by SCOTT3D to accommodate a Precision Piezo Orion sensor disk for the hotend sensor system. There are two extruder mount options for either an embedded Bowden connector (shown above) or the typical clones with a PC4-01 (Thread Diameter: 9.729mm). In addition, there are two options for mounting the heatsink. The files can be found here: https://www.thingiverse.com/thing:2617424

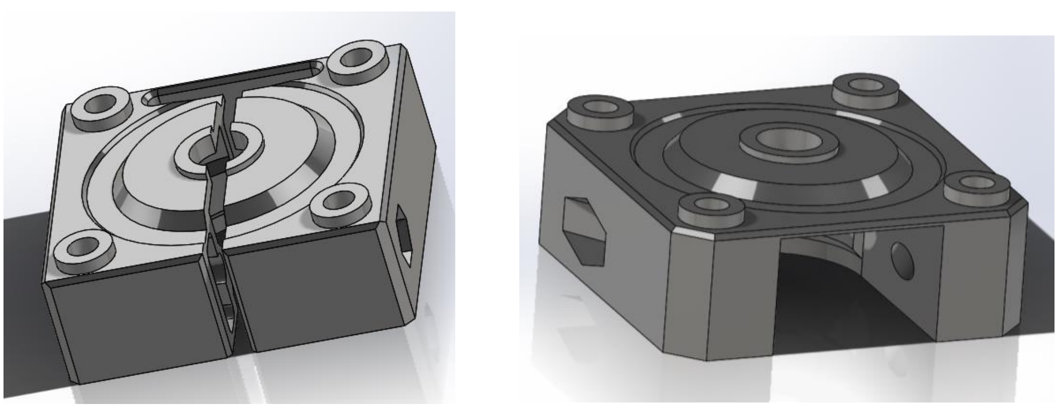


Image 1: Two mounting options for the Precision Piezo Orion sensor

The part on the left is designed to match the original mount designed by the Precision Piezo team; however, the requirement to use brass inserts is removed. The part on the right is the same dimensions, but the clamp in the front allows for a more permanent mounting of the circuit board whereby the hotend heatsink can be swapped out, yet the sensor would require little to no adjustment.

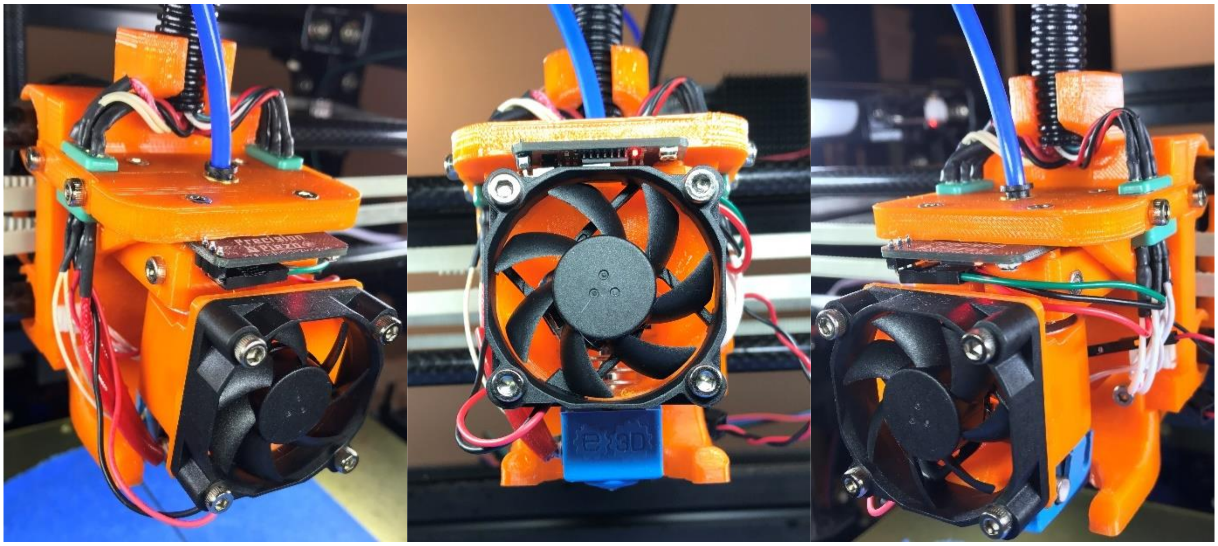


Image 2: Hotend assembly mounted on Hypercube Evolution printer (300 mm × 300 mm × 300 mm). The mount will bolt directly on the original x-carriage designed by SCOTT3D. There are other options for x-carriages in the files section of the Thingiverse page.

The mount was designed, installed and tested under typical operating conditions of 3d printers using this style sensor; therefore, it was not adjusted to get the maximum precision possible. The sensitivity of the sensor can be further adjusted to achieve better results. The Orion kit supplied by Precision Piezo will include printed parts; however, these are not necessary as the only parts you will need are the Orion sensor board, wires to connect the sensor, and Bowden embedded coupling if using the embedded type mount. If you are considering this mount, you can save £10.00 by buying just the Orion board. The assembly can be referenced here (https://youtu.be/aENNRXDgR98), but again keep in mind as you watch the video that their printed parts are not required for this mount. The Orion sensor was adjusted as shown here: https://youtu.be/L4OCfqMVTWk and recommended to watch.

Once the mount was installed with the Precision Piezo Orion sensor, several tests were performed to validate the operation and accuracy of the sensor. The first test was to use bilinear bed leveling to create a bed mesh. The chosen mesh was 5 × 5, which created 25 points on the bed.

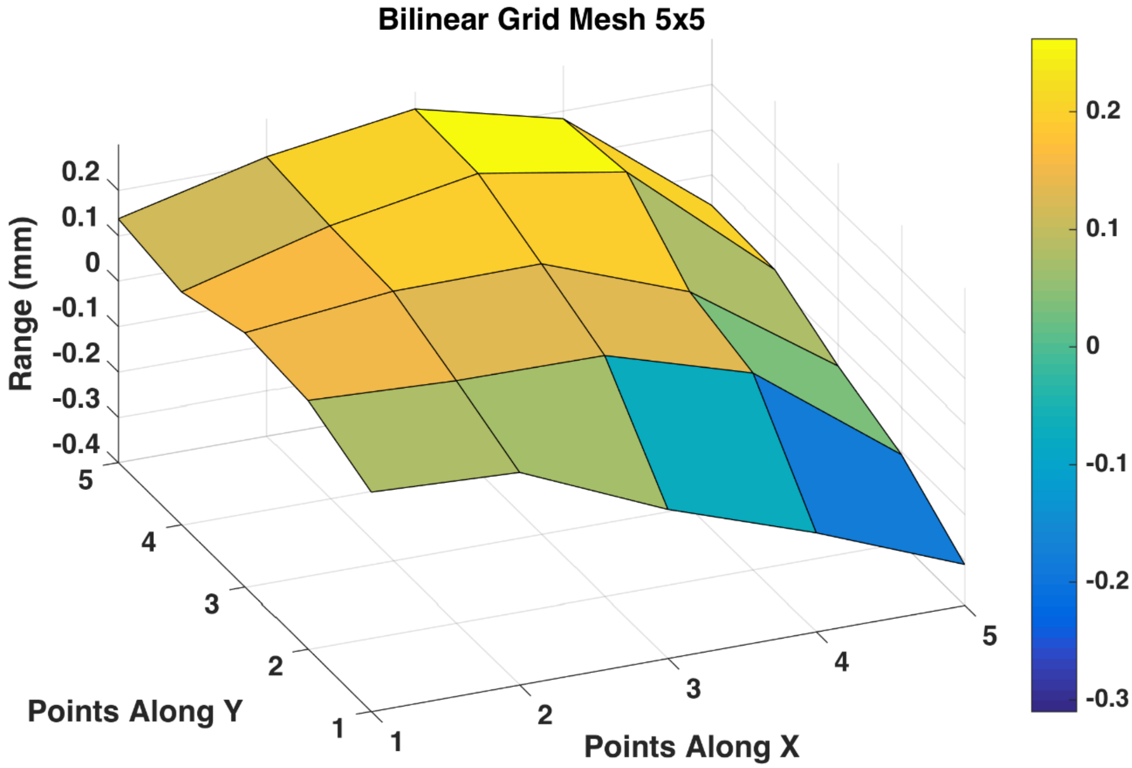


Figure 1 – Mesh profile using the Orion sensor on a 300 mm × 300 mm × 8 mm Aluminum bed with a 0.762 mm PEI sheet attached.

The first data set was to obtain a profile of the bed and use those numbers to create a surface plot that shows the surface profile of the bed. Although the data in Fig. 1 suggests a skew in the bed to one corner, keep in mind the range on the color bar to the right of the plot. The entire range is 0.1 mm; therefore, it could be adjusted slightly, but typically, this is well within the error of our 3d printer mechanics.

The mesh was generated 25 times, which allowed enough statistical data to demonstrate the range or accuracy and standard deviation between each point. The command that was executed in Marlin 1.1.9 was G29. The entire data set was collated, calculated, and plotted using MATLAB to show the performance of the Orion sensor with the mount.

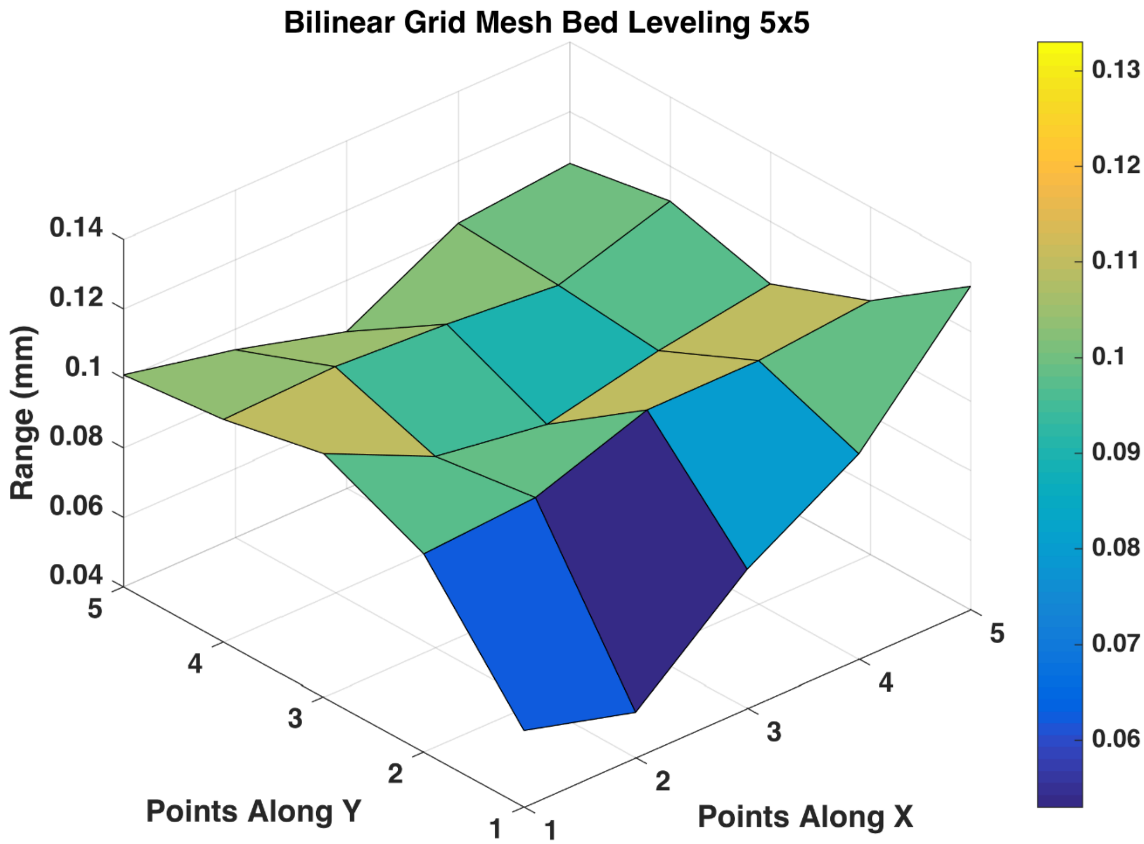


Figure 2 – A surface plot displaying the range of 25 Bilinear grid mesh bed leveling sets with a 5×5 grid that generated 25 points for each mesh set.

As a reminder, the range (accuracy) of a set of data is the difference between the min and max values; therefore, within the 25 sets of data, the range was calculated for each mesh location point and the mean is displayed in Figure 2. It is clear the Precision Piezo hot end assembly varied slightly at each point, but considering these are 25 independent full grid measurements with the hot end moving around each time, this system is quite robust and accurate for 3d printer bed leveling. Despite this variation and considering a typical layer height of at least 0.2 mm, the variation shown in Figure 1 is approximately a factor of 2 better at the visual midrange of 0.1 mm in Figure 3.

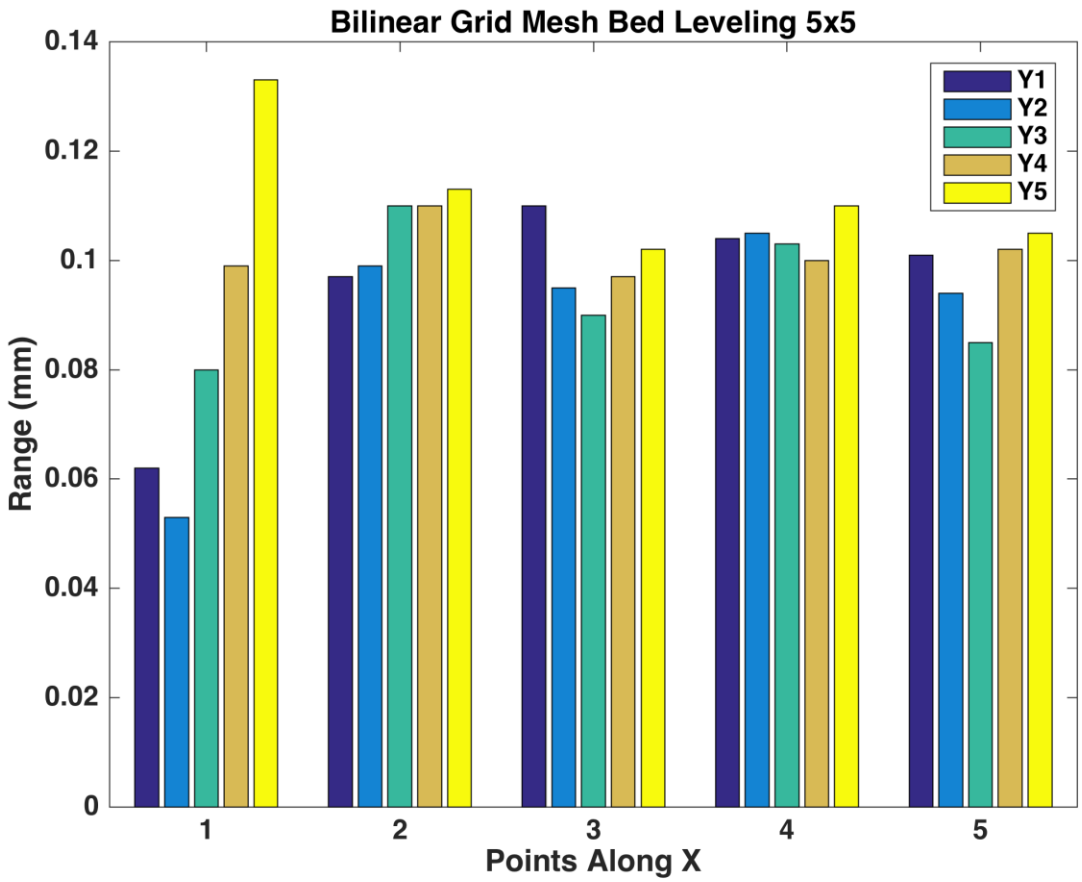


Figure 3 – The range (accuracy) of 25 Bilinear grid mesh bed leveling sets with a 5 × 5 grid to generate 25 points for each set. There are 5 points along the x-axis and the 5 points along the y-axis shown by Y1, Y2, Y3, Y4, and Y5. Upon visual inspection of the plot, the average range was between 0.085 mm – 0.113 mm.

Figure 2 and 3 also shows a greater variation along the X1 locations on the bed. This was caused by the tolerance of the carbon fiber rods and bearings used in the setup. Since the location is along the edge of the bed, it does not cause much issues, but can be noticed here. Furthermore, even this variation of 0.06 mm (X1 locations only) or at the extreme (X1, Y1 – 0.135 mm) is acceptable and still falls within the range of 0.2 mm for a typical layer height. It might not seem like much, but when sensors of this caliber are utilized, small variations can be realized. Moreover, there also can be variations induced into the measurements from the nozzle temperature, bed temperature, and the printer's mechanics.

To further understand the repeatability of the piezo disk, a surface plot of the standard deviation (amount of variation of a set of values) is noteworthy. The standard deviation or dispersion of the mesh grid data set gives an indication of how close to the mean or expected value of the data set. This can also be thought of as the confidence in the statistical representation of the data set. Here, as with the above plots, the data set plotted is obtained from each point location on the bed with 25 points for each location and 25 locations on the bed. Thus, there are 625 data points total in the entire data set.

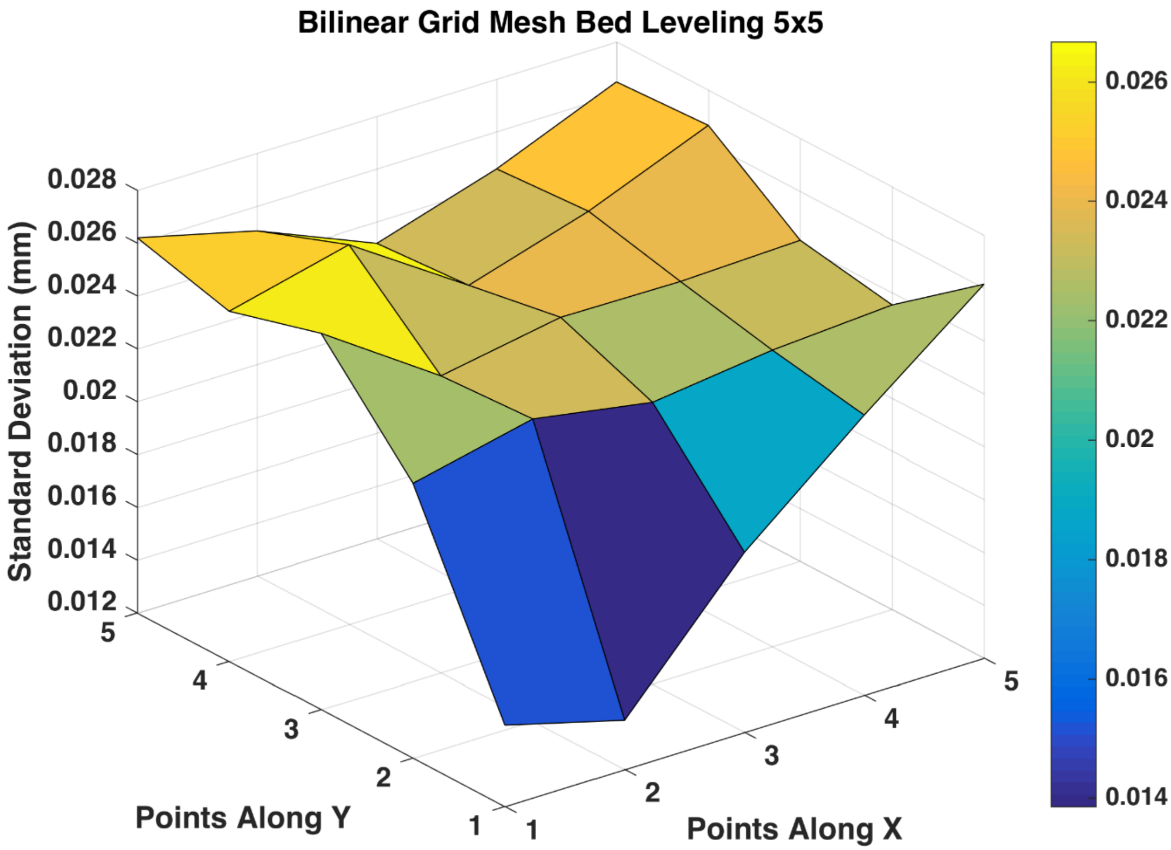


Figure 4 – The standard deviation of 25 Bilinear grid mesh bed leveling sets with a 5 × 5 grid that generated 25 points for each mesh set.

In spite of the bed variations shown in Figure 4, the results of the standard deviation from the 25 data points is approximately 0.024 mm by visually evaluating the bar plot in Figure 5. The information in Figure 4 is displayed alternatively in Figure 5 as a bar graph to clearly highlight the standard deviation at each of the 25 points for the 25 sets of mesh data collected.

The noticeable X1 variations propagated to the standard deviation results (Fig.4 and 5) since the same data set was used for all the calculations.

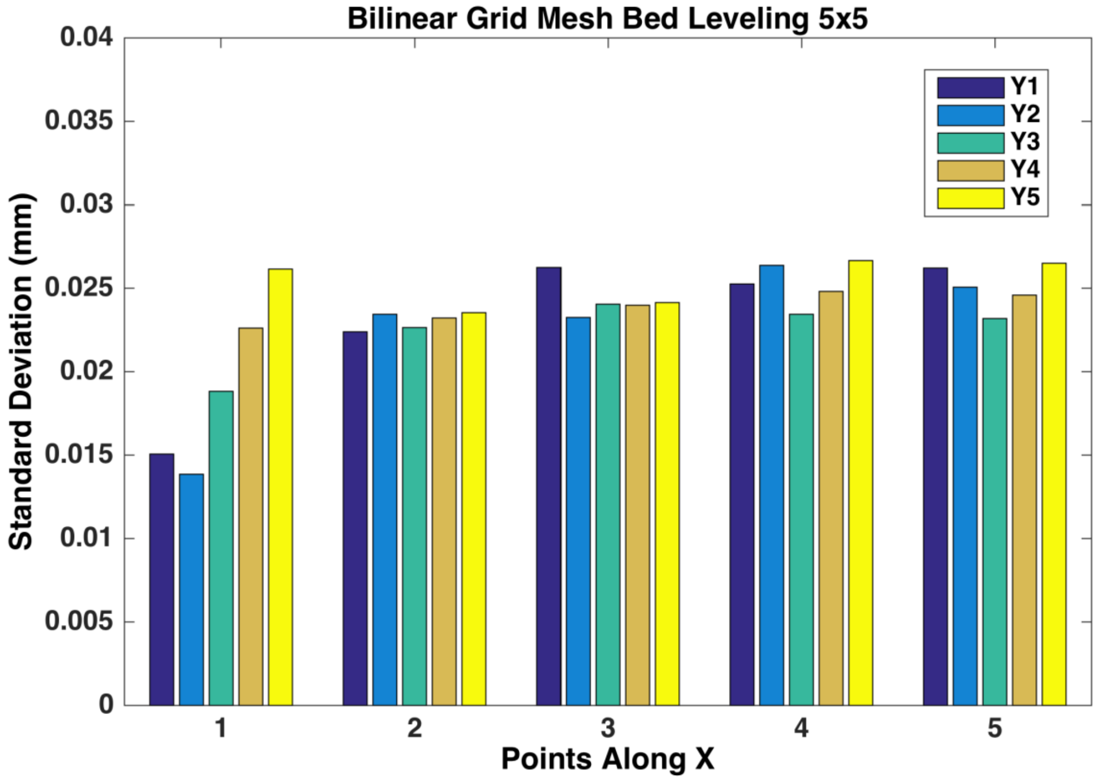


Figure 5 – The standard deviation of 25 Bilinear grid mesh bed leveling sets with a 5 × 5 grid that generated 25 points for each set. There are 5 points along the x-axis and the 5 points along the y-axis shown by Y1, Y2, Y3, Y4, and Y5. Upon visual inspection of the plot, the average value was between 0.022 mm – 0.026 mm.

Often repeatability tests are performed using the command M45 in the Marlin 1.1.9, but this was not accomplished for the Orion sensor. This approach of testing with the Hypercube Evolution printer can possibly provide a false expectation of the sensor's performance. In reality, the sensor will be traveling with the hotend, and while the repeatability tests are valid if you only move the z-axis, this is not the case for most situations using a 3d printer. Besides, in essence this was accomplished through the 25 mesh data sets.

In conclusion, the Hypercube Evolution Precision Piezo Orion hotend assembly performed well and within the manufactures design specifications. There is parity between the printed parts, piezo disk, and amplifier board where care must be taken during assembly and tuning. Yet, this sensor is much more robust than the Piezo20 sensor and can be removed, reassembled with no amplifier re-adjustments. This is the situation of the presented data in this work. Thus, it is a more realistic representation of what to expect when using the Orion sensor.

The Orion sensor and mount performance from generating 25 sets of bilinear grid mesh data achieved a calculated range (accuracy) of ~0.110 mm or ~110 μm and standard deviation of ~0.023 mm or ~23 μm. This test was most representative of results when executing a bed level prior to starting a print. The Orion sensor is more accurate than shown here; however, in almost all cases, the mount coupled with the Orion sensor is the appropriate way to consider the accuracy. Keep in mind, care must be taken to ensure the nozzle does not have any oozing plastic, or residual plastic on the nozzle since this will skew your results. Moreover, it is noteworthy to mention here that the kinematics of each machine will play a significant role in the grid mesh accuracy and because this machine has a z-axis driven by a trapezoidal leadscrew with the probe often striking nearly the same point, the results are quite repeatable. The limit is the x and y mechanics.

Finally, to place these numbers into perspective, a typical first layer height of 0.2 mm or 200 μm, which at the ~110 μm accuracy shown in Figure 2, there is still room for error. These results prove this mount performs to the design specifications of the Precision Piezo Orion System and well suited as an accurate bed leveling device for 3d printers.