

## ***Accurate Point Cloud Generation for 3D Machine Vision Applications using DLP® Technology and Industrial Camera***

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### **About Test Results**

The DLP Structured Light Software Development Kit (SDK) offers a complete software solution for 3D scanning and point cloud generation. The point cloud data below was generated using the DLP Structured Light SDK with a DLP® LightCrafter™ 4500 and Point Grey Flea3 USB camera. The generated point cloud data was visualized using MeshLab.

### **Related Documentation From Texas Instruments**

- DLPC350 Data Sheet: DLP Digital Controller for Portable Advanced Light Control, TI literature number [DLPS029](#)
- DLP4500 Data Sheet: DLP 0.45 WXGA Visible DMD, TI literature number [DLPS028](#)
- DLP4500NIR Data Sheet: DLP 0.45 WXGA Near-Infrared DMD, TI literature number [DLPS032](#)
- User's Guide: DLPC350 Programmer's Guide, TI literature number [DLPU010](#)
- Application Note: Using DLP® Development Kits for 3D Optical Metrology Systems, TI literature number [DLPA026](#)
- Application Note: Using DLP® LightCrafter™ 4500 Triggers to Synchronize Cameras to Patterns, TI literature number [DLPA036](#)

### **If You Need Assistance**

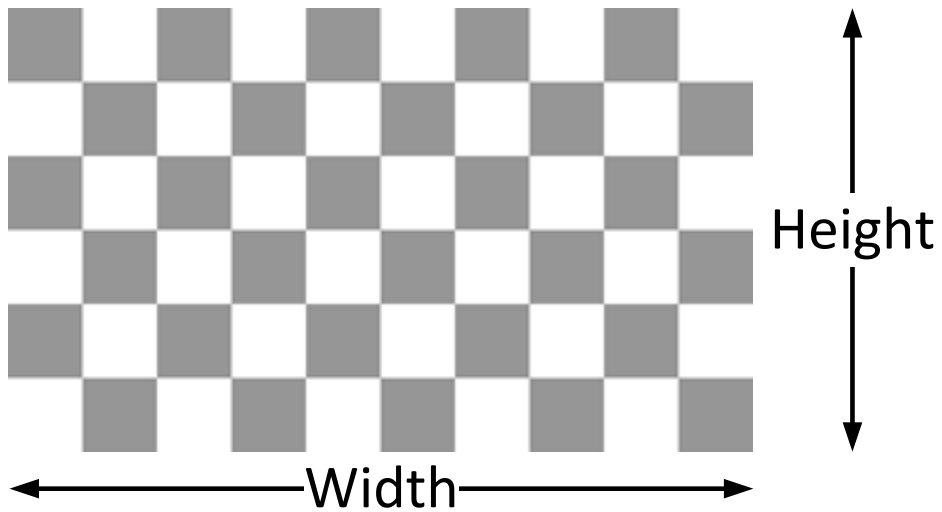
Refer to the [DLP and MEMS TI E2E Community support forums](#)

### **Calibration Results**

This chapter provides test data from the DLP Structured Light SDK for camera and projector calibration module. When the camera and projector calibration parameters are found, the output is used to generate the system optical rays which ultimately allow line intersections to be calculated for point cloud generation.

To calibrate the system, the following procedure is used:

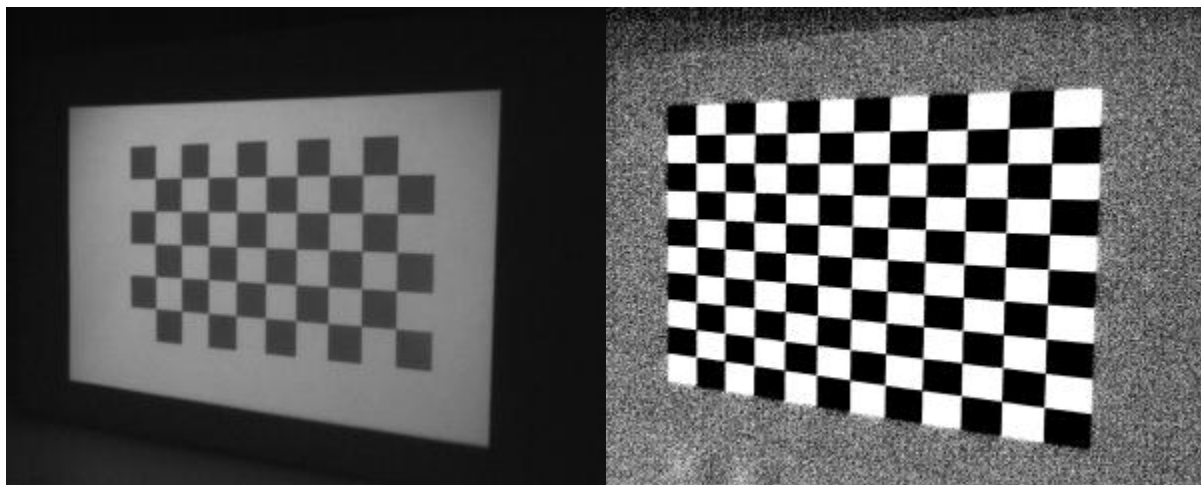
1. From main menu of software, select “1: Generate camera calibration board and enter feature measurements” and follow instructions
  - a. Note: Measure the height and width of the printed calibration board in the desired units of the point cloud



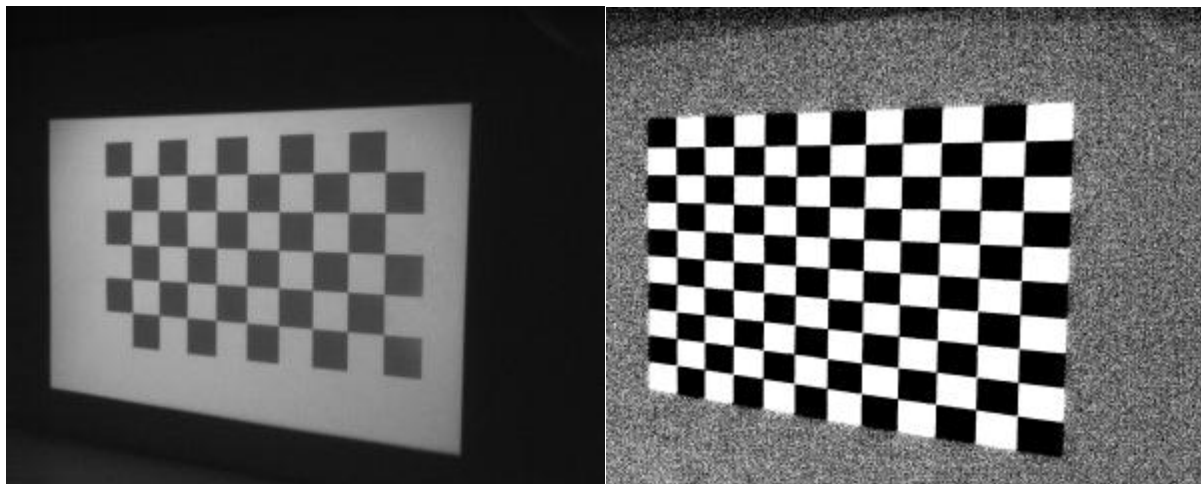
**Figure 1** Camera calibration board measurement

2. From main menu of software, select "2: Calibrate camera (all camera data and project white pattern)" and follow instructions
3. From main menu of software, select "3: Calibrate system (update camera extrinsics and all projector data)"

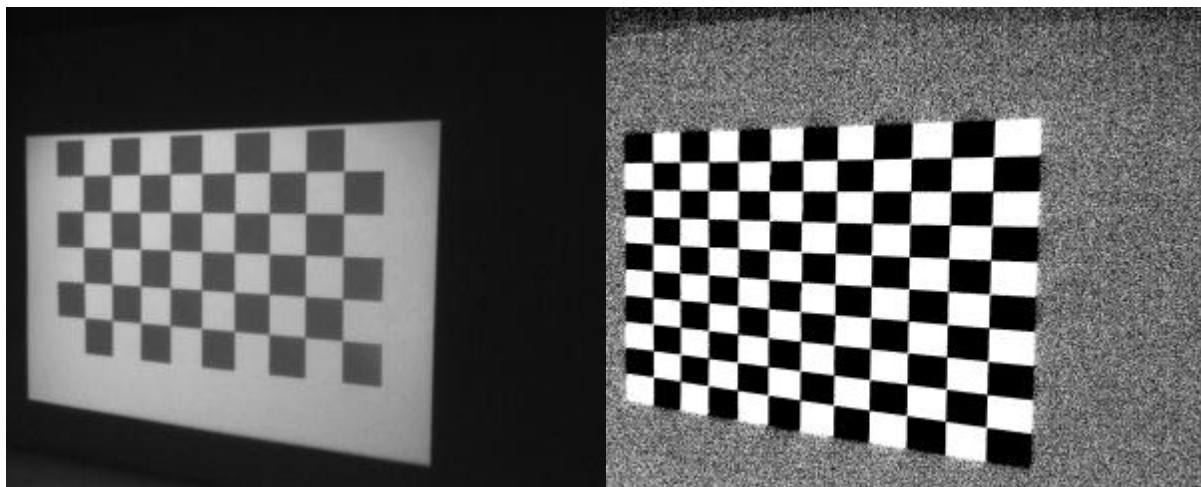
The following images show the camera captures of the printed calibration board and projected calibration board after removing the printed calibration board from the projected.



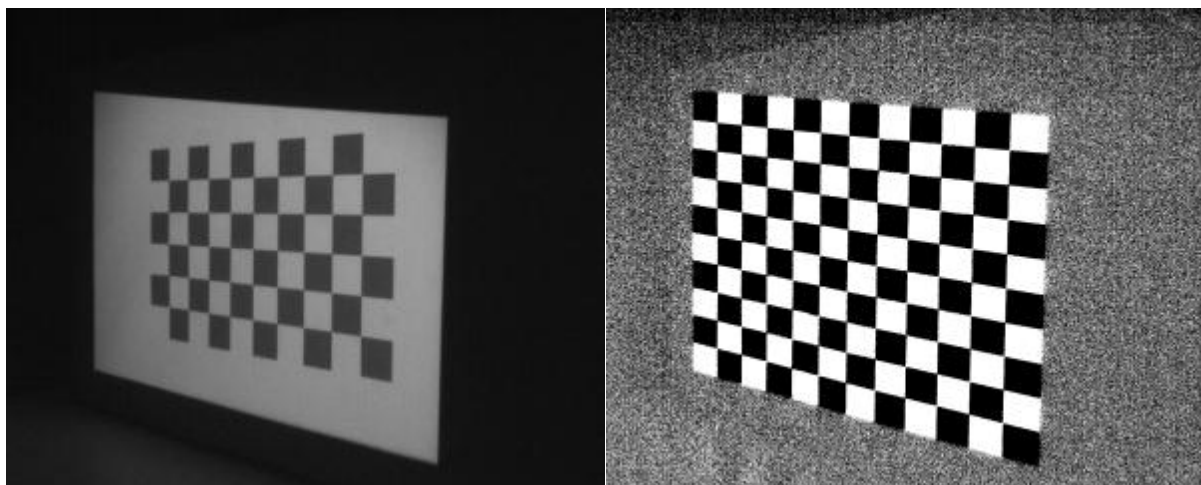
**Figure 2** Printed calibration board and projected calibration board position 1



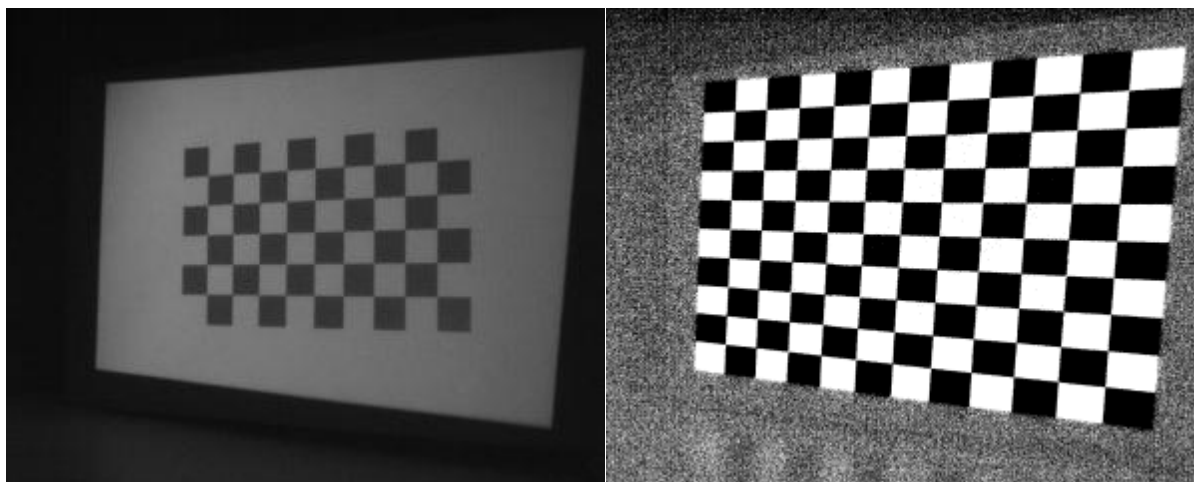
**Figure 3** Printed calibration board and projected calibration board position 2



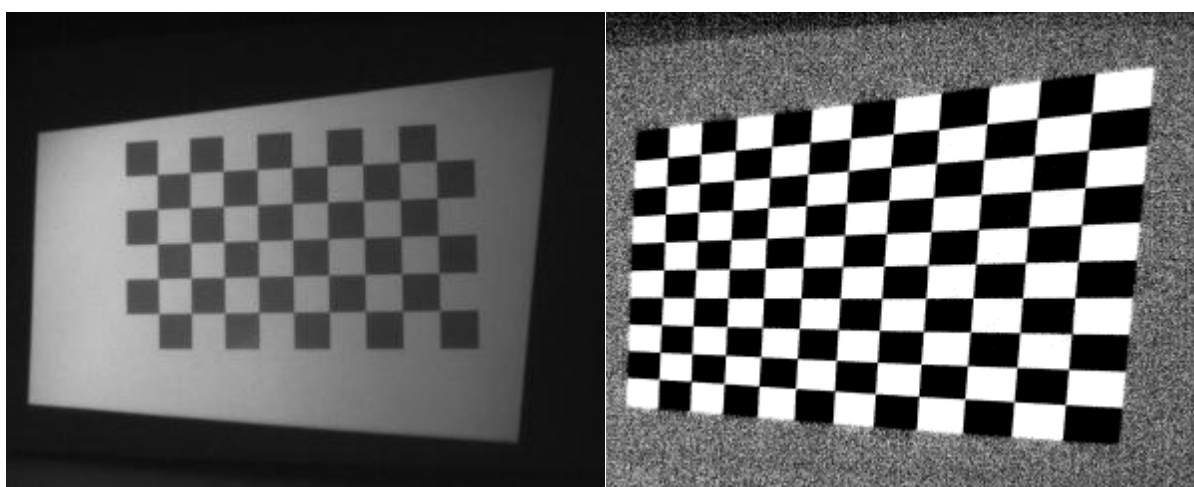
**Figure 4** Printed calibration board and projected calibration board position 3



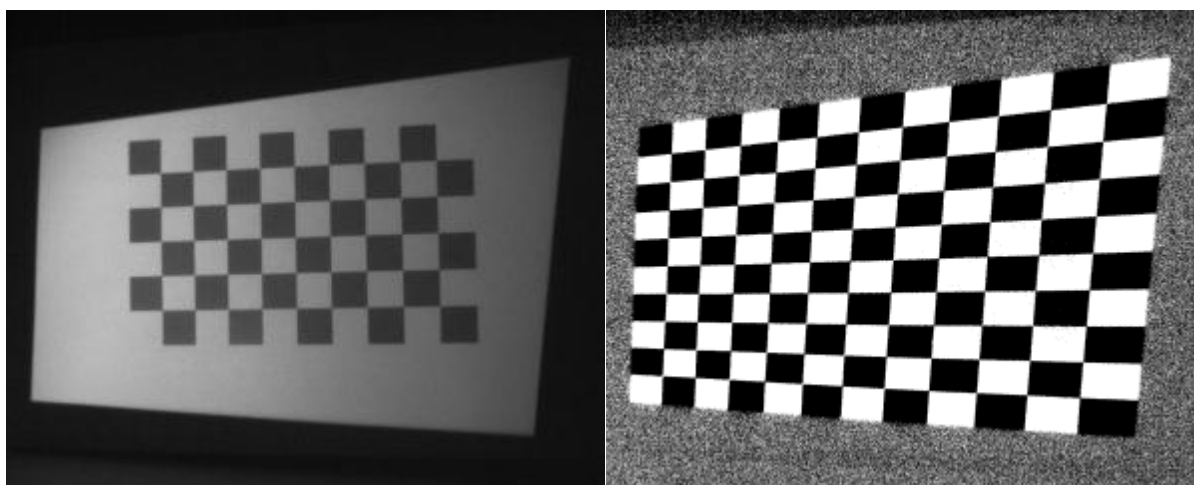
**Figure 5** Printed calibration board and projected calibration board position 4



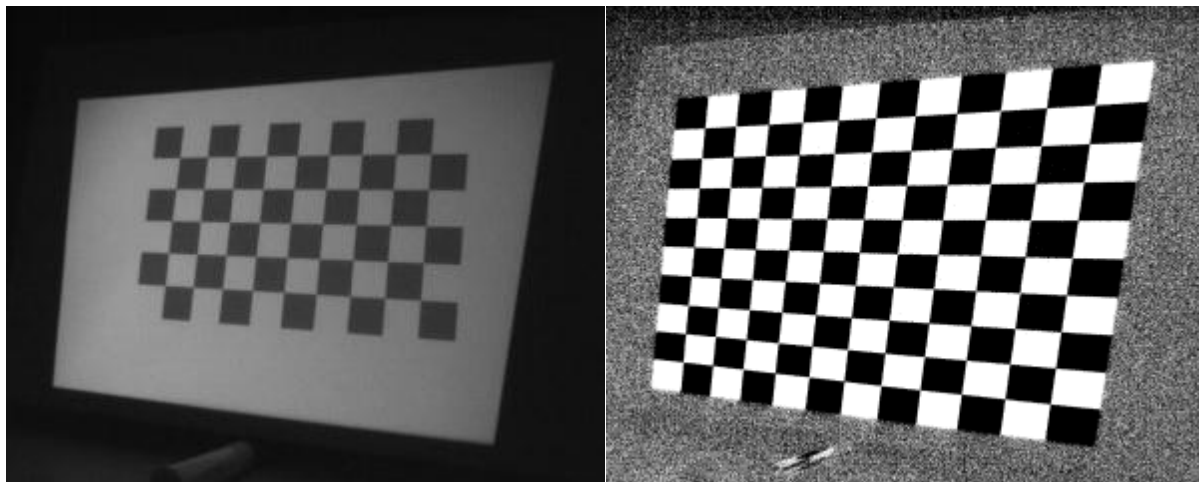
**Figure 6** Printed calibration board and projected calibration board position 5



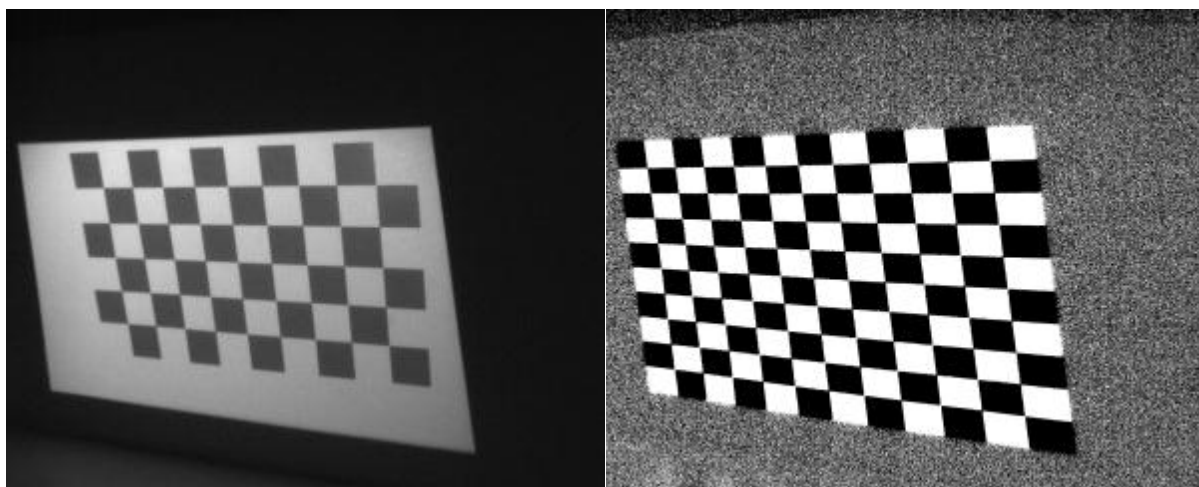
**Figure 7** Printed calibration board and projected calibration board position 6



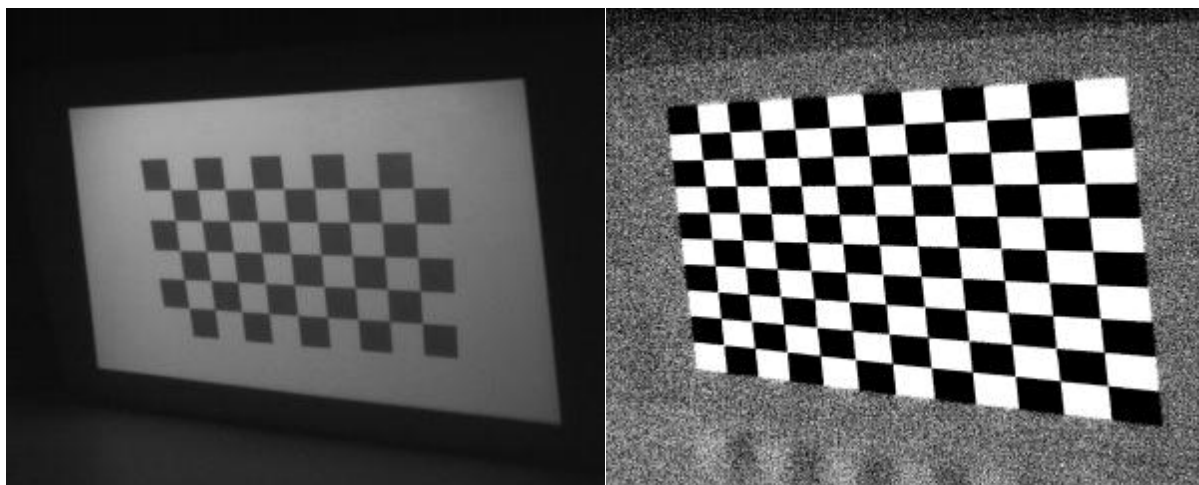
**Figure 8** Printed calibration board and projected calibration board position 7



**Figure 9** Printed calibration board and projected calibration board position 8

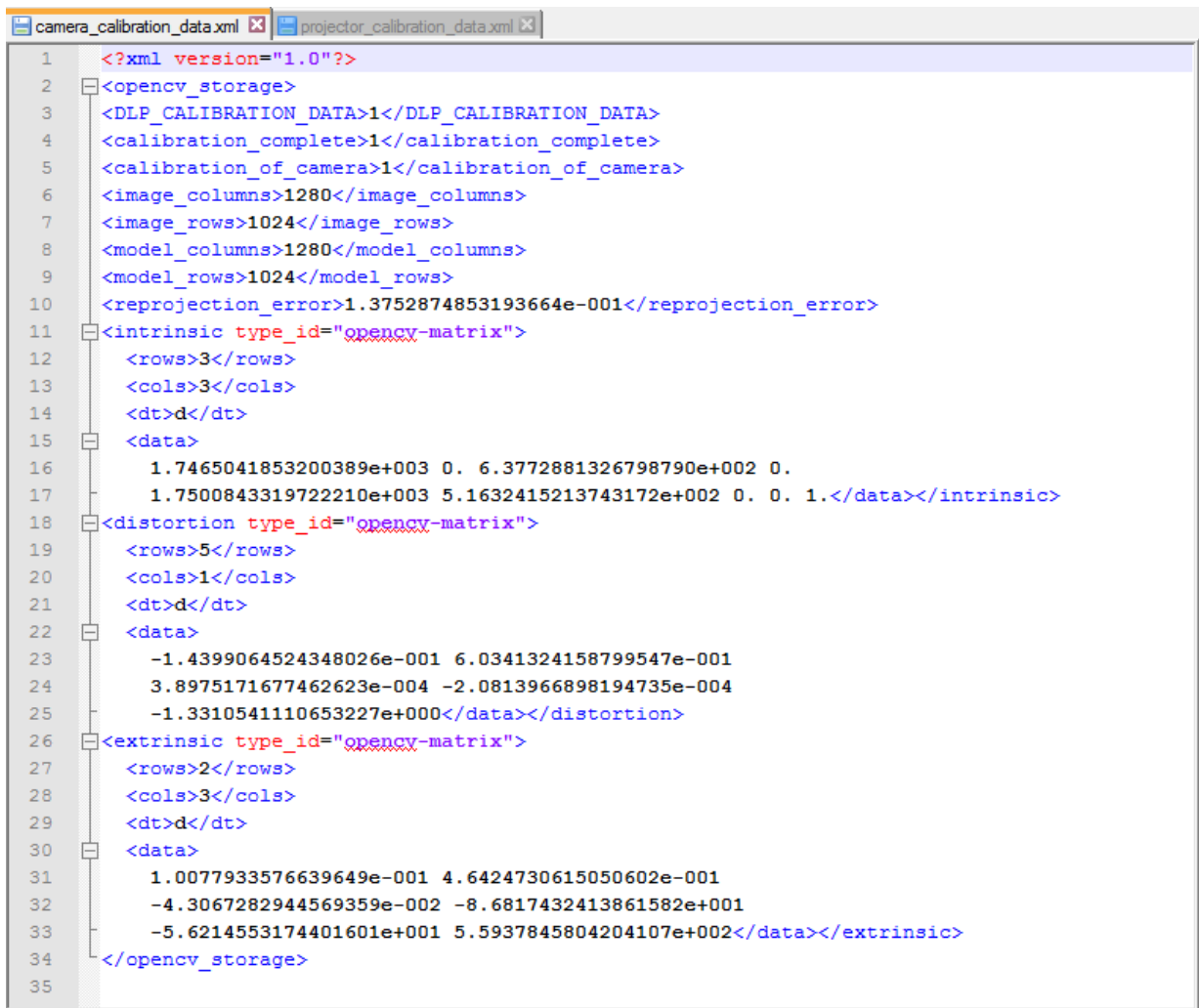


**Figure 10** Printed calibration board and projected calibration board position 9



**Figure 11** Printed calibration board and projected calibration board position 10

The following images should the calibration XML files generated for the camera and projector.



```
1  <?xml version="1.0"?>
2  <opencv_storage>
3  <DLP_CALIBRATION_DATA>1</DLP_CALIBRATION_DATA>
4  <calibration_complete>1</calibration_complete>
5  <calibration_of_camera>1</calibration_of_camera>
6  <image_columns>1280</image_columns>
7  <image_rows>1024</image_rows>
8  <model_columns>1280</model_columns>
9  <model_rows>1024</model_rows>
10 <reprojection_error>1.3752874853193664e-001</reprojection_error>
11 <intrinsic type_id="opencv-matrix">
12   <rows>3</rows>
13   <cols>3</cols>
14   <dt>d</dt>
15   <data>
16     1.7465041853200389e+003 0. 6.3772881326798790e+002 0.
17     1.7500843319722210e+003 5.1632415213743172e+002 0. 0. 1.</data></intrinsic>
18 <distortion type_id="opencv-matrix">
19   <rows>5</rows>
20   <cols>1</cols>
21   <dt>d</dt>
22   <data>
23     -1.4399064524348026e-001 6.0341324158799547e-001
24     3.8975171677462623e-004 -2.0813966898194735e-004
25     -1.3310541110653227e+000</data></distortion>
26 <extrinsic type_id="opencv-matrix">
27   <rows>2</rows>
28   <cols>3</cols>
29   <dt>d</dt>
30   <data>
31     1.0077933576639649e-001 4.6424730615050602e-001
32     -4.3067282944569359e-002 -8.6817432413861582e+001
33     -5.6214553174401601e+001 5.5937845804204107e+002</data></extrinsic>
34 </opencv_storage>
35
```

Figure 12 Camera calibration XML output file

```

1  <?xml version="1.0"?>
2  <opencv_storage>
3  <DLP_CALIBRATION_DATA>1</DLP_CALIBRATION_DATA>
4  <calibration_complete>1</calibration_complete>
5  <calibration_of_camera>0</calibration_of_camera>
6  <image_columns>1280</image_columns>
7  <image_rows>1024</image_rows>
8  <model_columns>912</model_columns>
9  <model_rows>1140</model_rows>
10 <reprojection_error>3.9379608297983898e-001</reprojection_error>
11 <intrinsic type_id="opencv-matrix">
12   <rows>3</rows>
13   <cols>3</cols>
14   <dt>d</dt>
15   <data>
16     1.2992683297032597e+003 0. 4.4089914044914326e+002 0.
17     1.3004633529916375e+003 7.9905029183791737e+002 0. 0. 1.</data></intrinsic>
18 <distortion type_id="opencv-matrix">
19   <rows>5</rows>
20   <cols>1</cols>
21   <dt>d</dt>
22   <data>
23     -4.4013430929637429e-002 -1.1965526013186709e-002
24     -8.6009185550299223e-004 3.5107086019087613e-005
25     2.2370656290682970e-002</data></distortion>
26 <extrinsic type_id="opencv-matrix">
27   <rows>2</rows>
28   <cols>3</cols>
29   <dt>d</dt>
30   <data>
31     1.9325957672261140e-002 2.9406928861904845e-002
32     -1.3972914292070636e-002 -7.0747479076213679e+001
33     -1.6333143311740773e+002 5.0868125470187073e+002</data></extrinsic>
34 </opencv_storage>
35

```

**Figure 13** Projector calibration XML output file

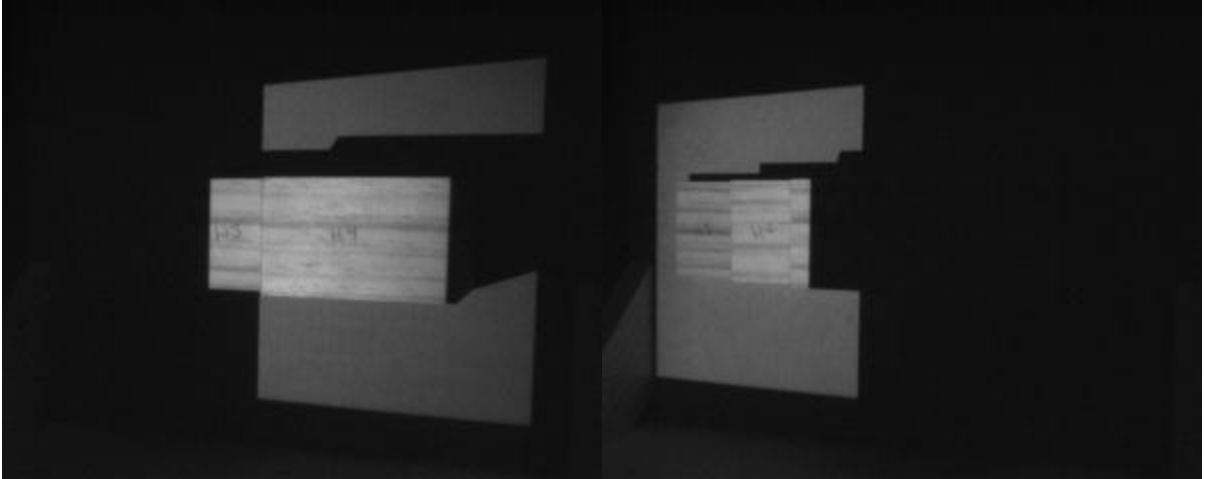
## Generated Point Cloud

This chapter provides test data from the DLP Structured Light SDK for structured light pattern decoding and point cloud generation. The structured light module generates patterns to determine which projector rays are intersecting with the scanned object and the geometry module finds the intersection between the projector and camera optical rays to generate a depth-map and point-cloud.

To calibrate the system, the following procedure is used:

1. Calibrate the camera and system
2. From main menu of software, select "4: Setup structured light and prepare projector"
3. From main menu of software, select "5: Perform scan"

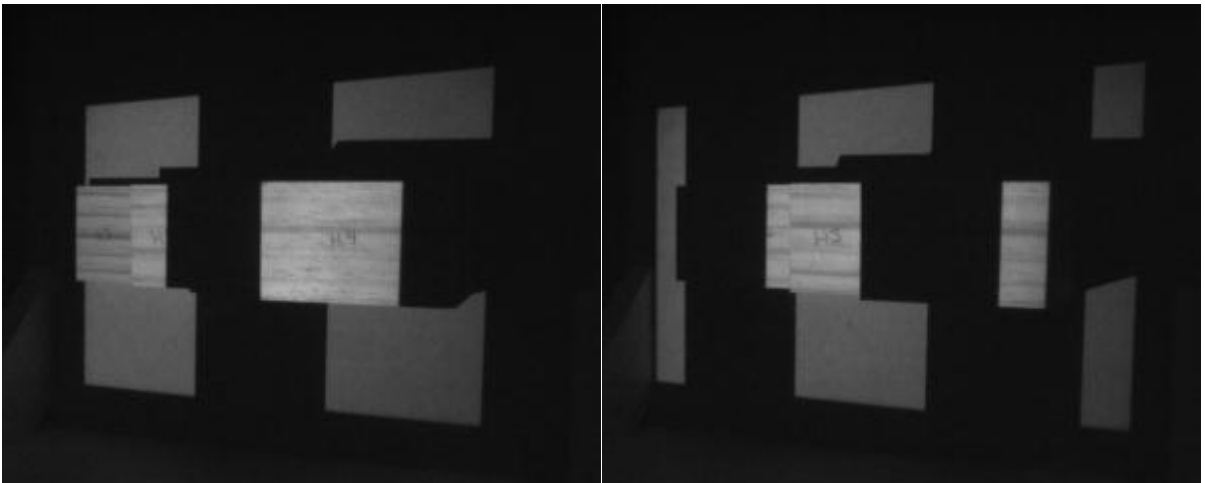
The following images show the camera captures of the projected structured light patterns:



**Figure 14** Non-inverted and inverted vertical gray code pattern 1 capture

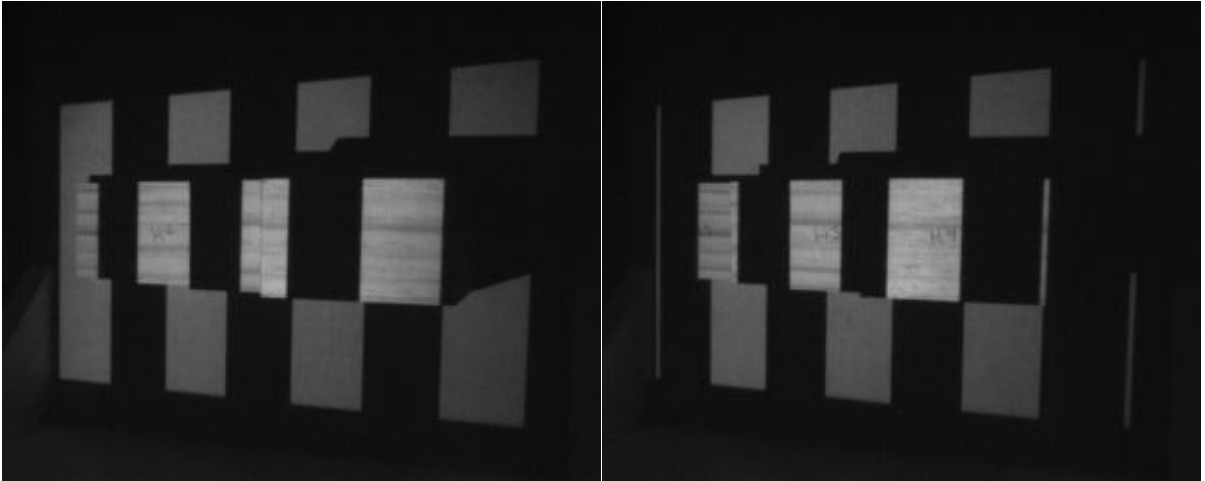


**Figure 15** Non-inverted and inverted vertical gray code pattern 2 capture



**Figure 16** Non-inverted and inverted vertical gray code pattern 3 capture





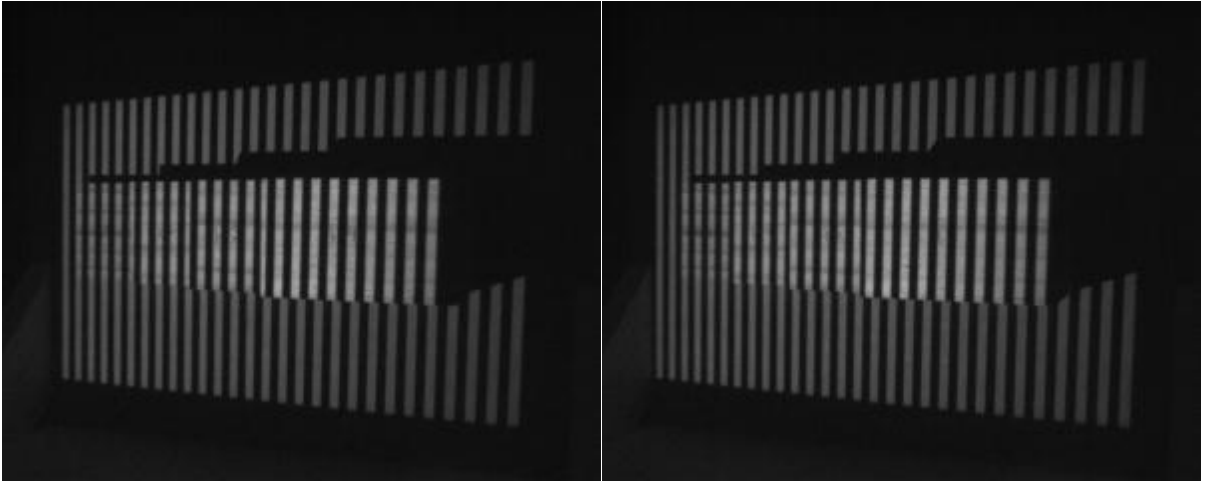
**Figure 17** Non-inverted and inverted vertical gray code pattern 4 capture



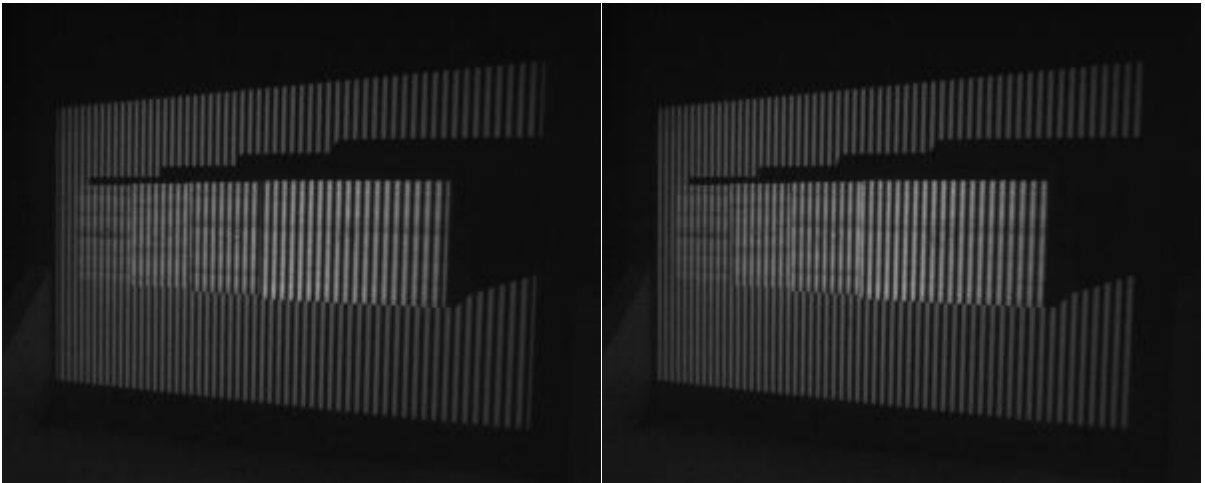
**Figure 18** Non-inverted and inverted vertical gray code pattern 5 capture



**Figure 19** Non-inverted and inverted vertical gray code pattern 6 capture



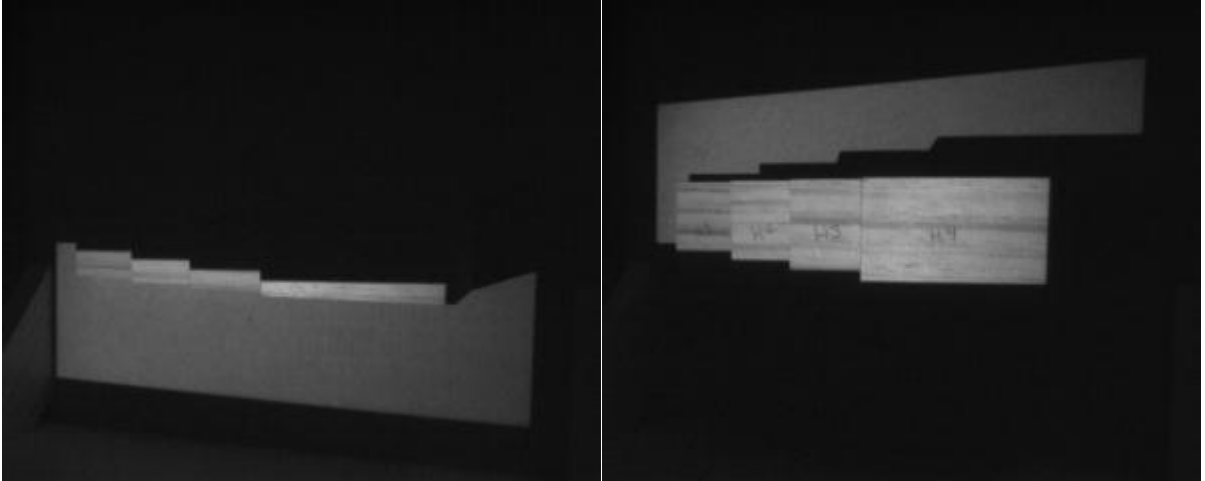
**Figure 20** Non-inverted and inverted vertical gray code pattern 7 capture



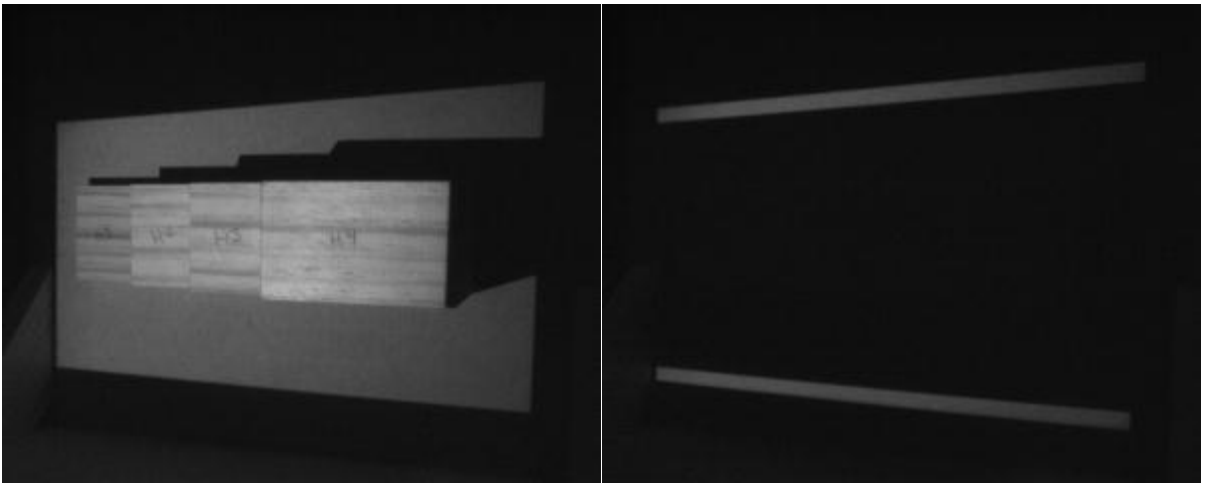
**Figure 21** Non-inverted and inverted vertical gray code pattern 8 capture



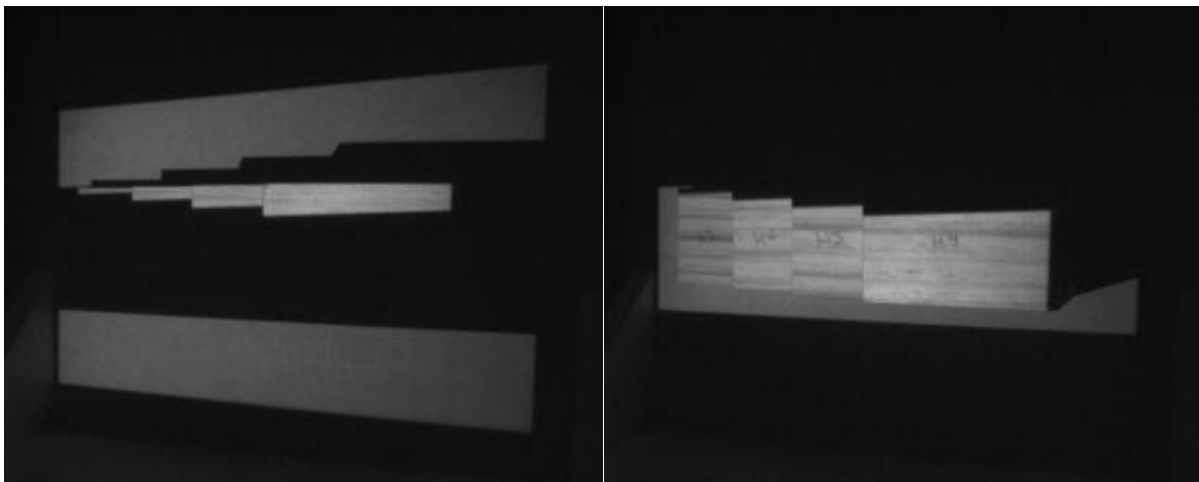
**Figure 22** Non-inverted and inverted vertical gray code pattern 9 capture



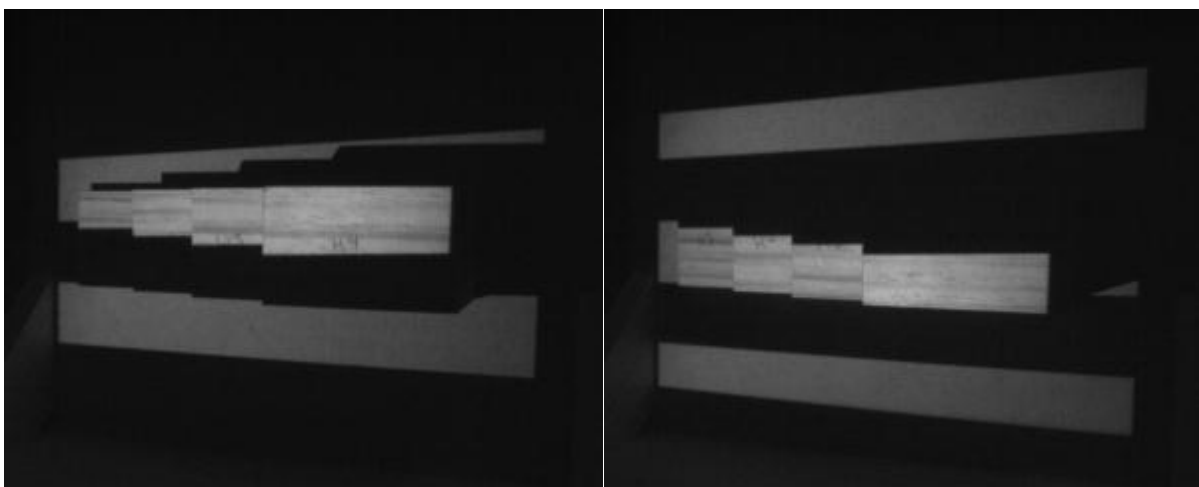
**Figure 23** Non-inverted and inverted horizontal gray code pattern 1 capture



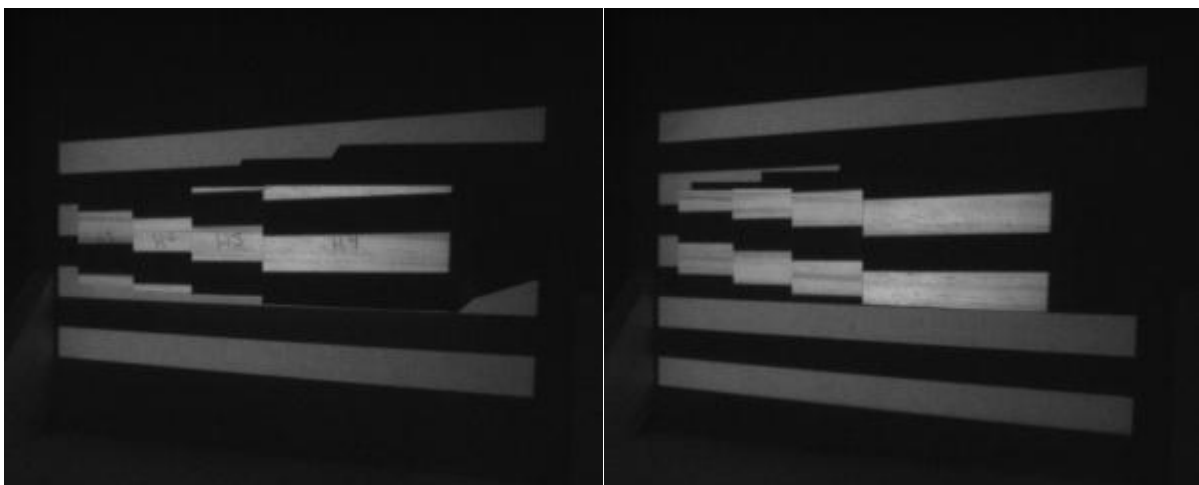
**Figure 24** Non-inverted and inverted horizontal gray code pattern 2 capture



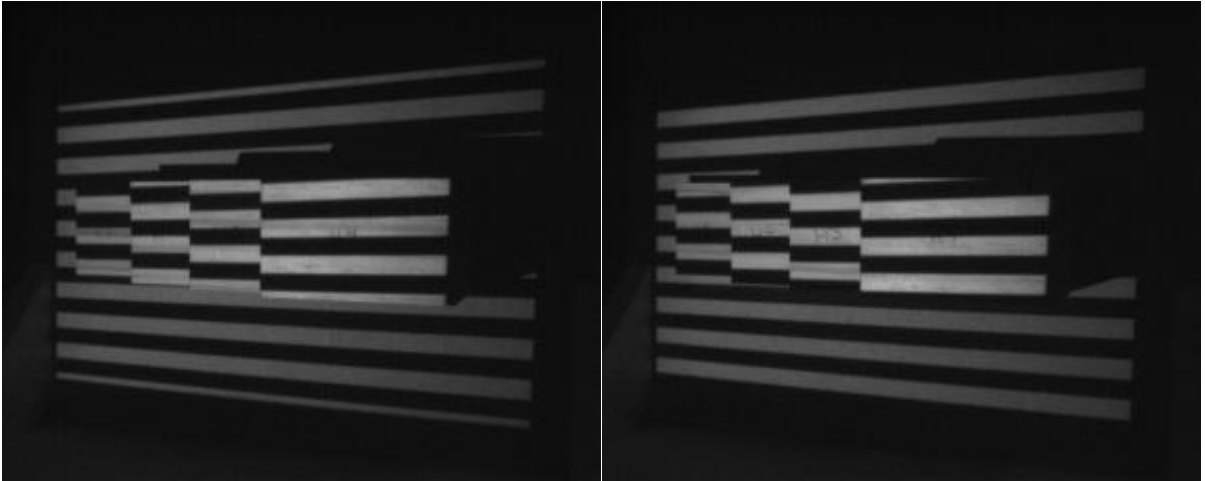
**Figure 25** Non-inverted and inverted horizontal gray code pattern 3 capture



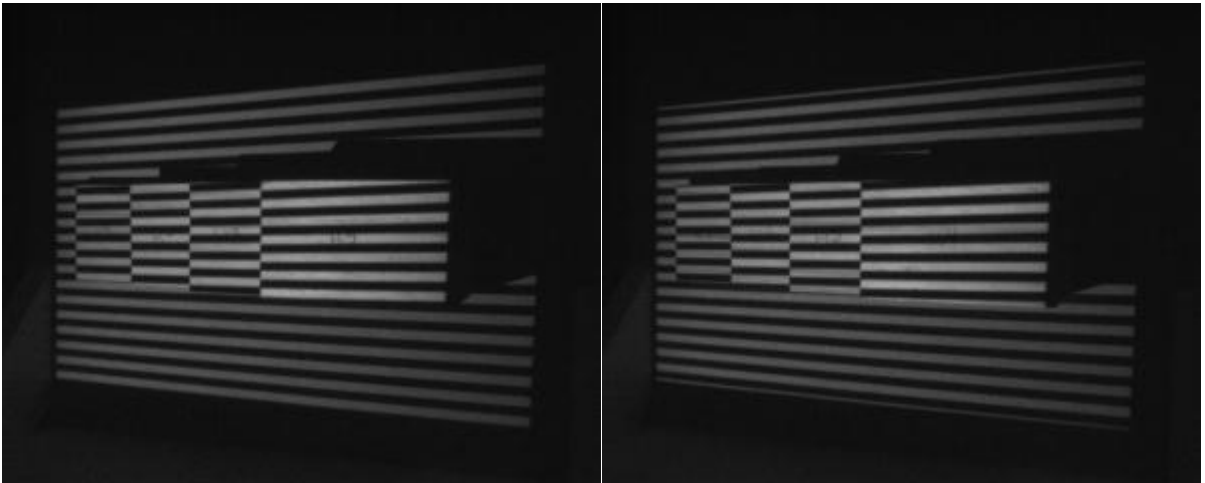
**Figure 26** Non-inverted and inverted horizontal gray code pattern 4 capture



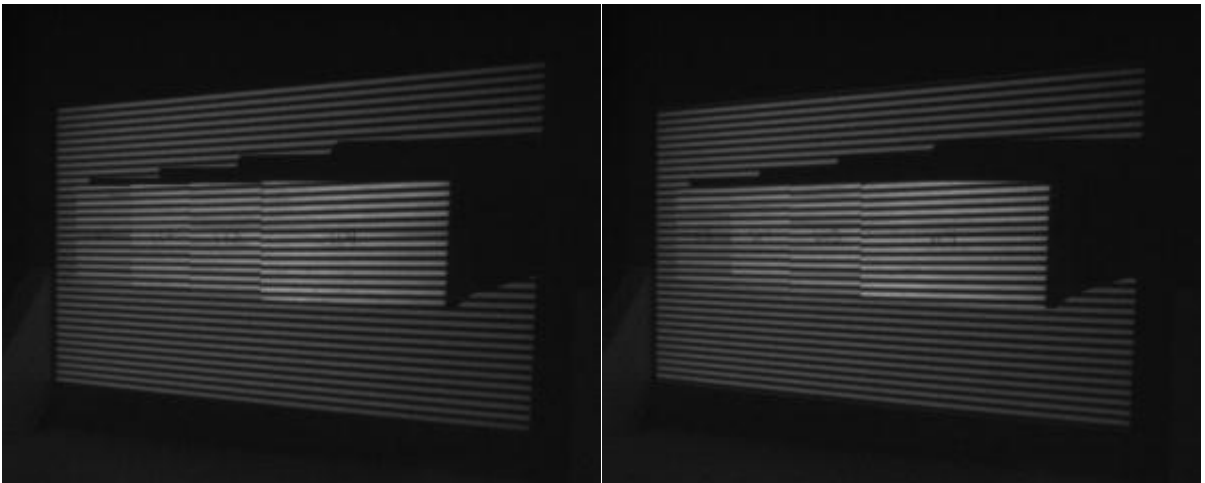
**Figure 27** Non-inverted and inverted horizontal gray code pattern 5 capture



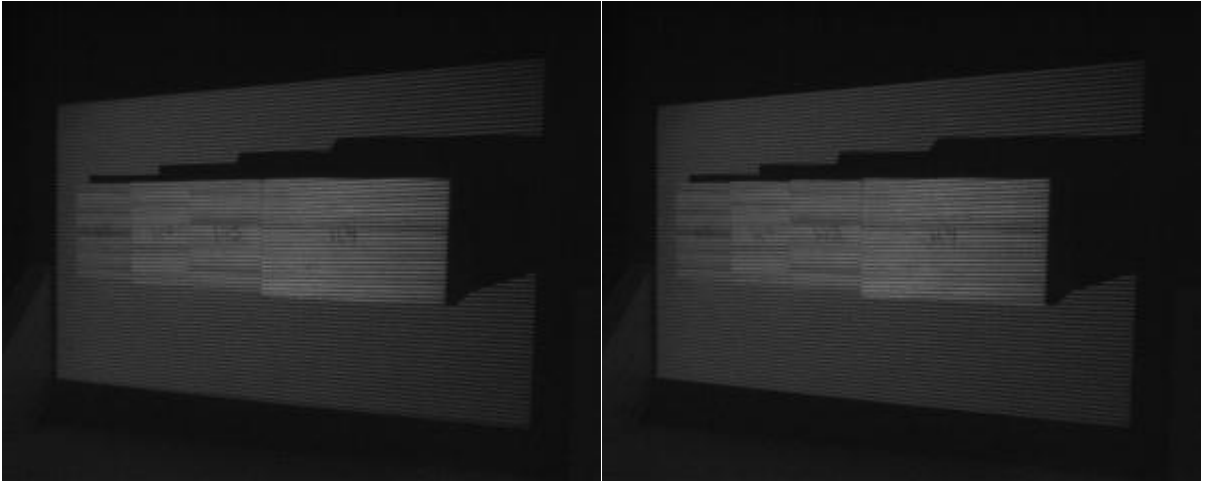
**Figure 28** Non-inverted and inverted horizontal gray code pattern 6 capture



**Figure 29** Non-inverted and inverted horizontal gray code pattern 7 capture

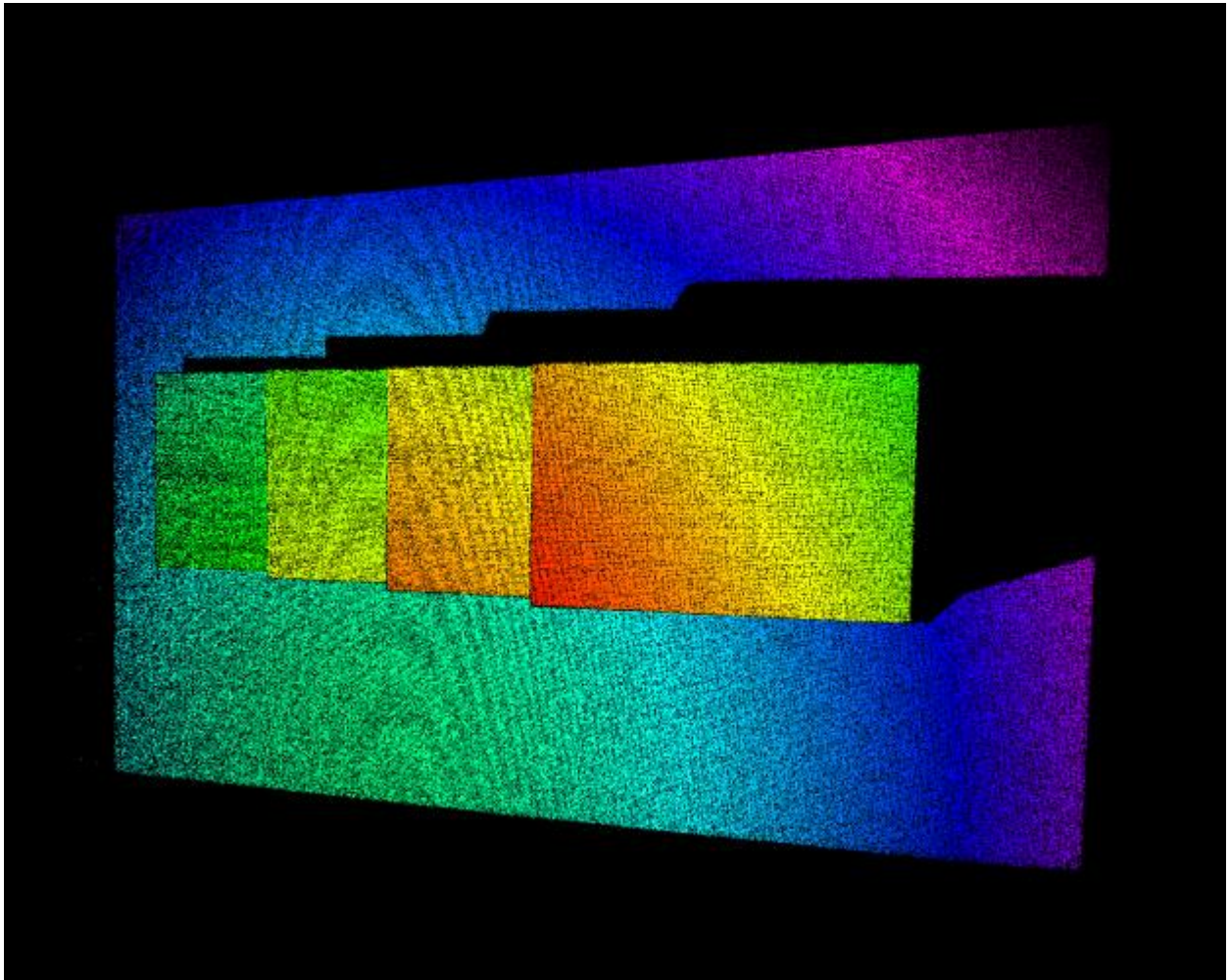


**Figure 30** Non-inverted and inverted horizontal gray code pattern 8 capture

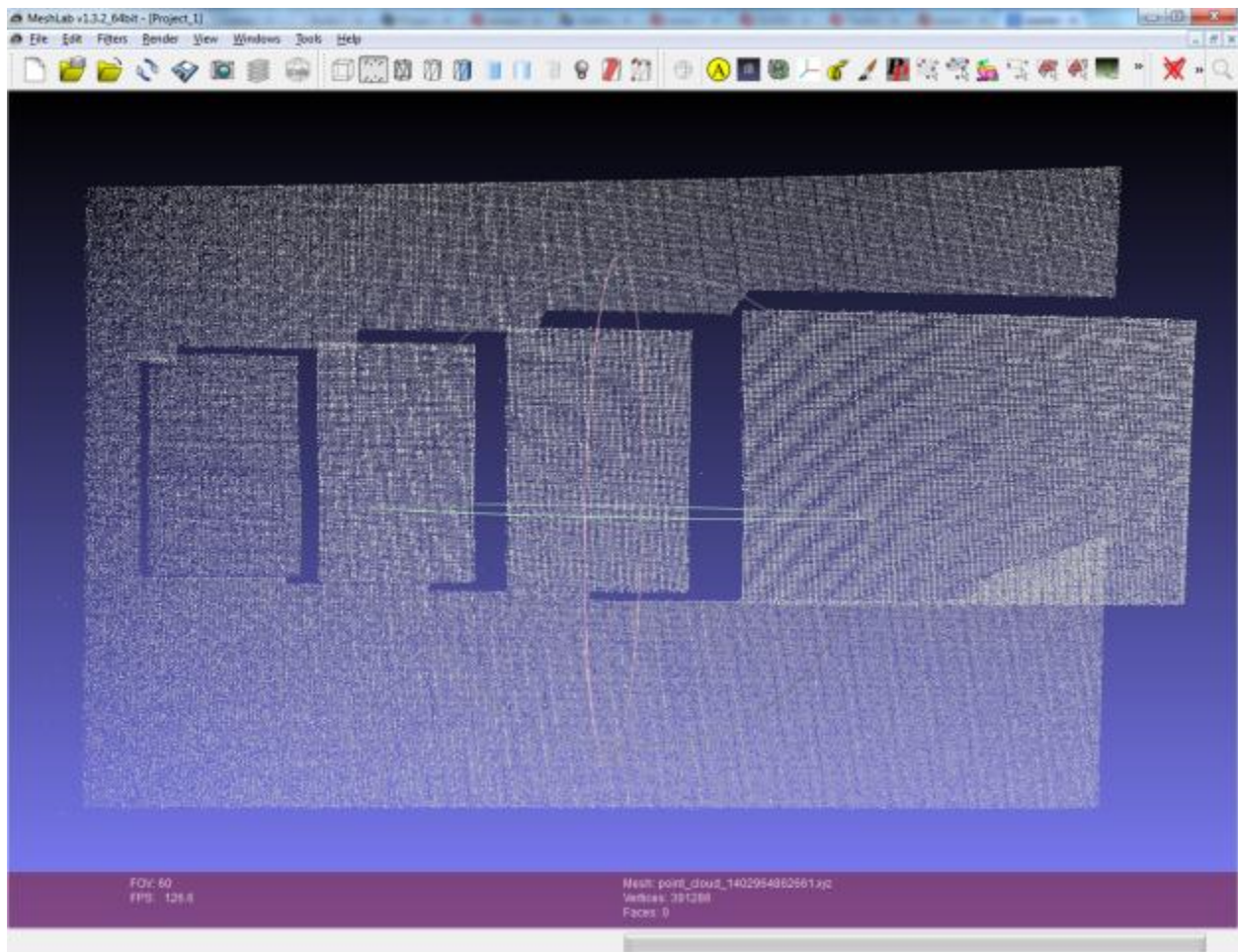


**Figure 31** Non-inverted and inverted horizontal gray code pattern 9 capture

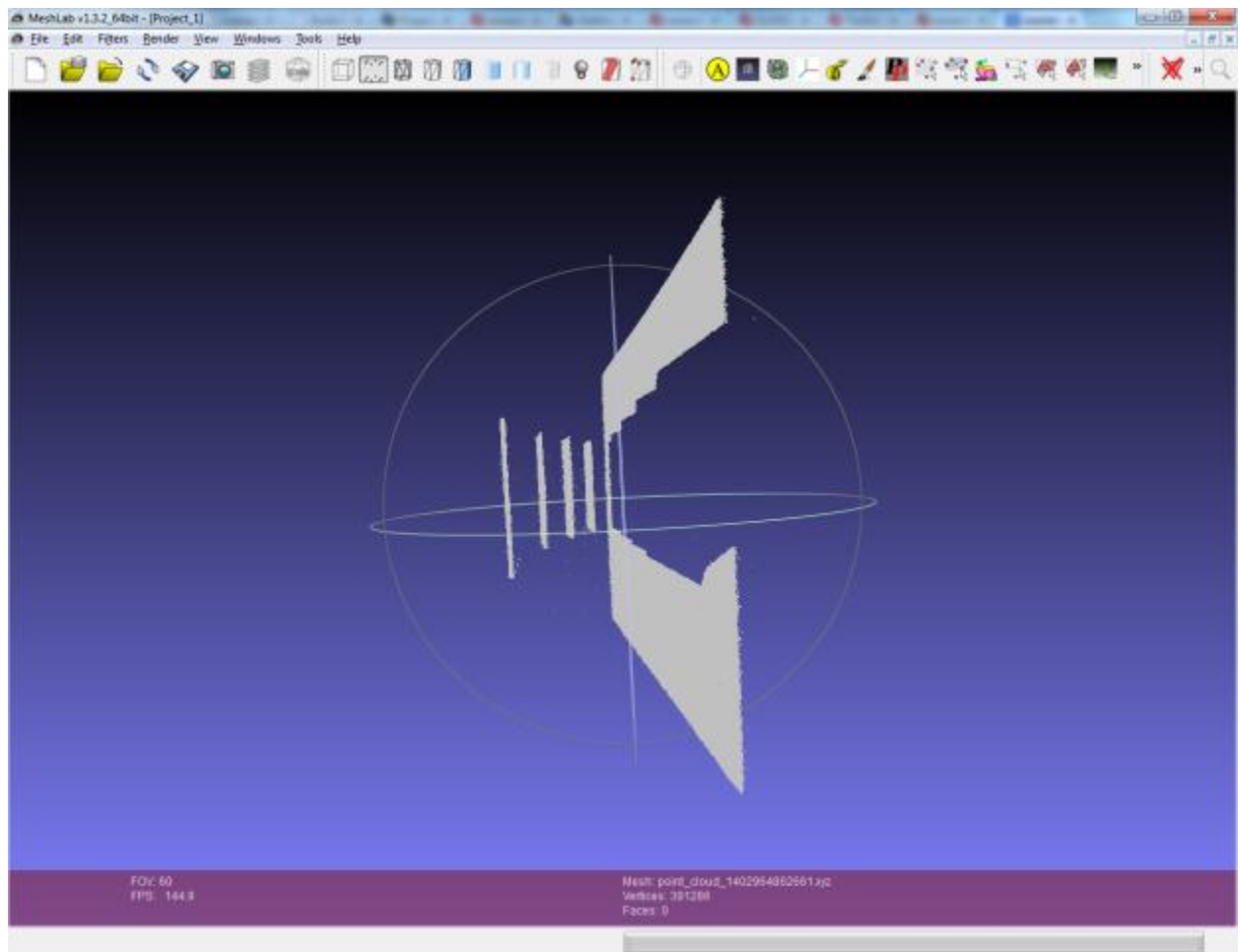
The following images show the depth-map and various views of the generated point cloud:



**Figure 32** Depth-map of object from 3D scan

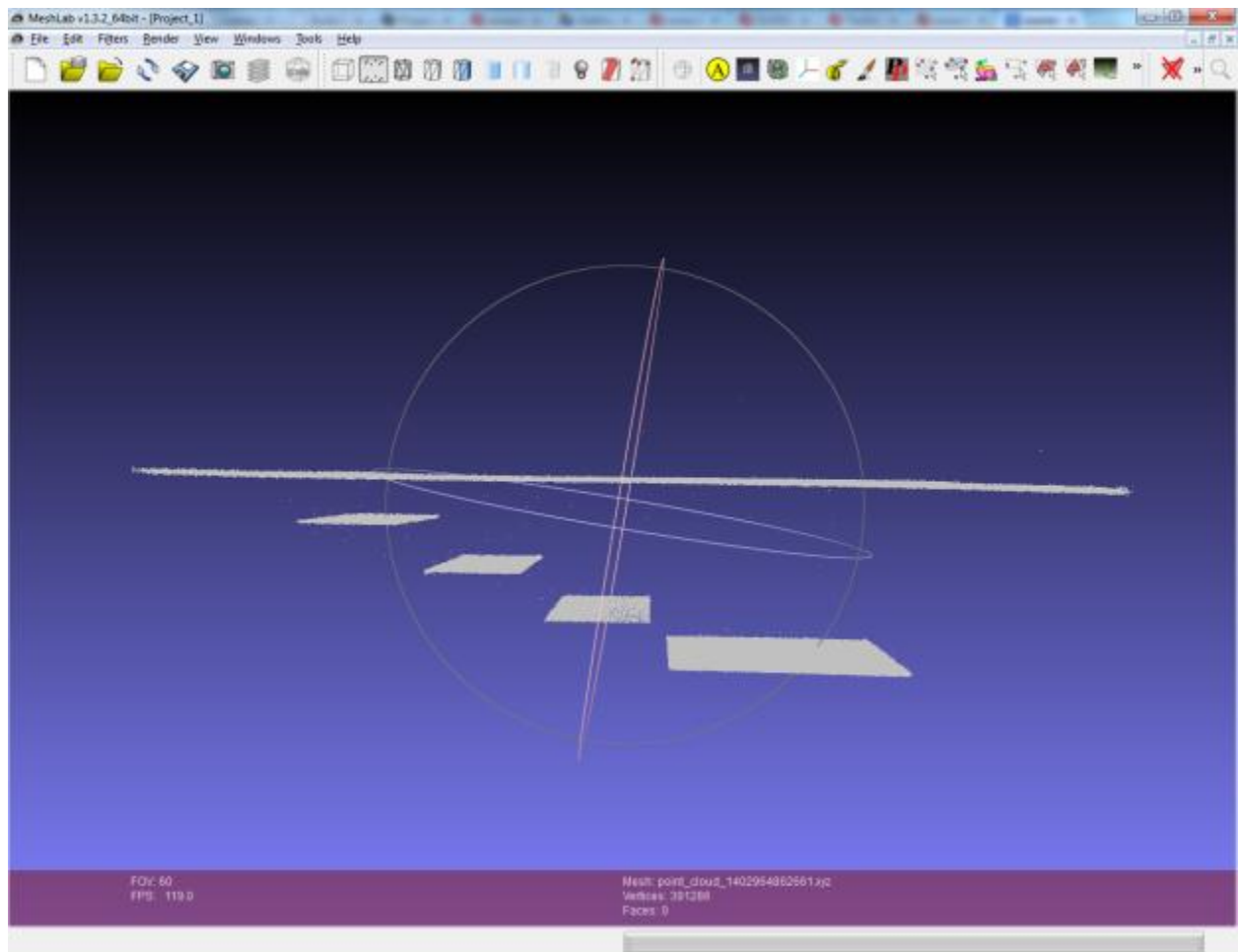


**Figure 33** Front view of point-cloud from 3D scan

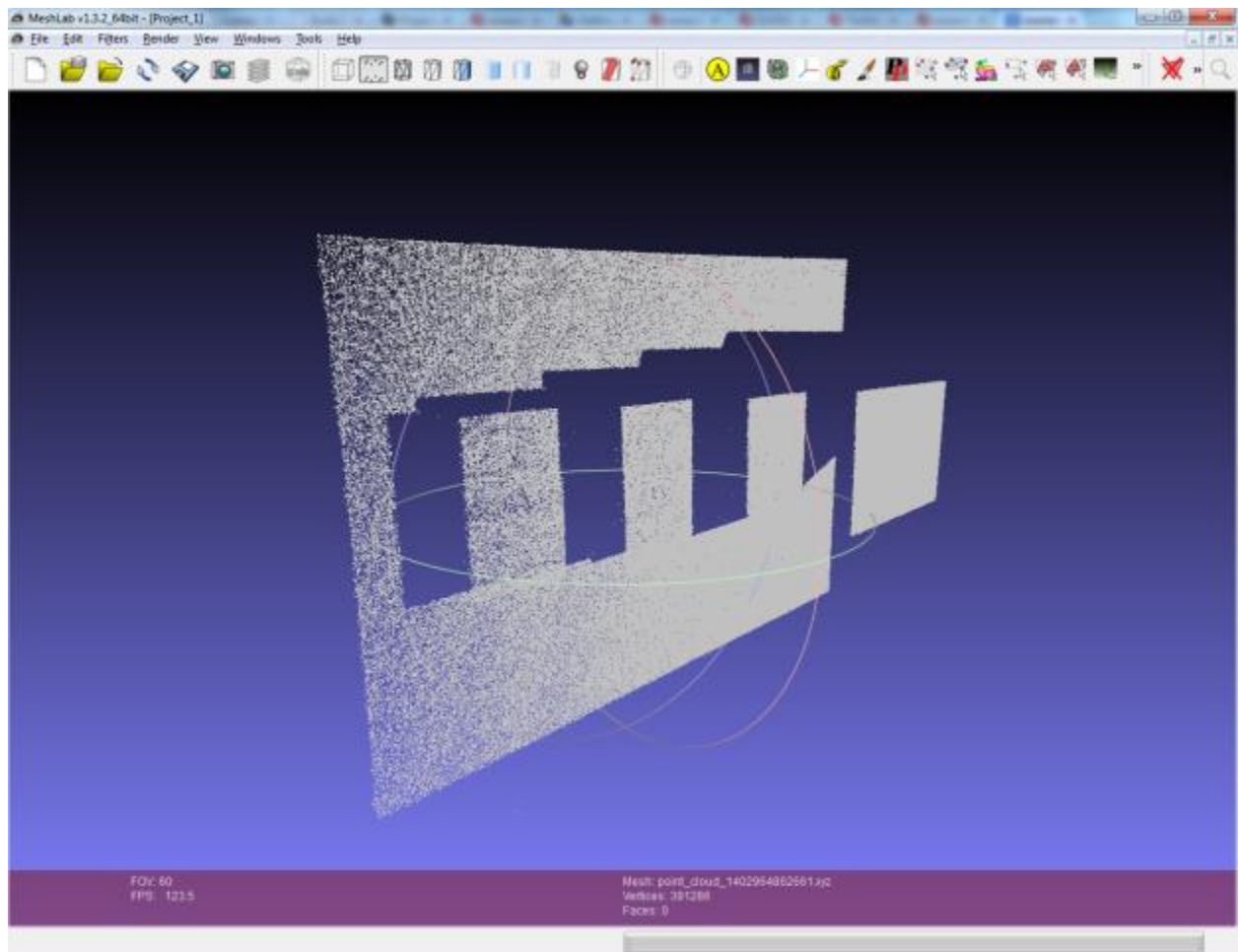


**Figure 34** Side view of point-cloud from 3D scan





**Figure 35** Top view of point-cloud from 3D scan



**Figure 36** Isometric view of point-cloud from 3D scan

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