Portable Point Cloud Generation for 3D Scanning Using DLP® Technology

About Test Results

The DLP 3D Scanner Reference Design offers a complete software solution for 3D scanning and 3D point cloud generation. The point cloud data below was generated using the DLP 3D Scanner Reference Design with a DLP® LightCrafter™ 3000 and Point Grey Flea3 USB camera. The generated point cloud data was visualized using MeshLab.

Related Documentation from Texas Instruments

- DLPC300 datasheet: *DLP Digital Controller for DLP3000*, DLPS023
- DLP3000 datasheet: *DLP 0.3WVGA DDR Series 220 DMD*, DLPS022
- *DLPC300 Software Programmer's Guide*, DLPU004
- *DLP LightCrafter DM365 Command Interface Guide,* DLPU007
- *DLP LightCrafter FPGA Overview,* DLPA042

If You Need Assistance

Please search the DLP & MEMS TI E2E Community support forums

Calibration Results

This chapter provides test data from the DLP 3D Scanner Reference Design for camera and projector calibration. 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 of a single square on the printed calibration board in the desired units of the point cloud (e.g. inches, millimeters)

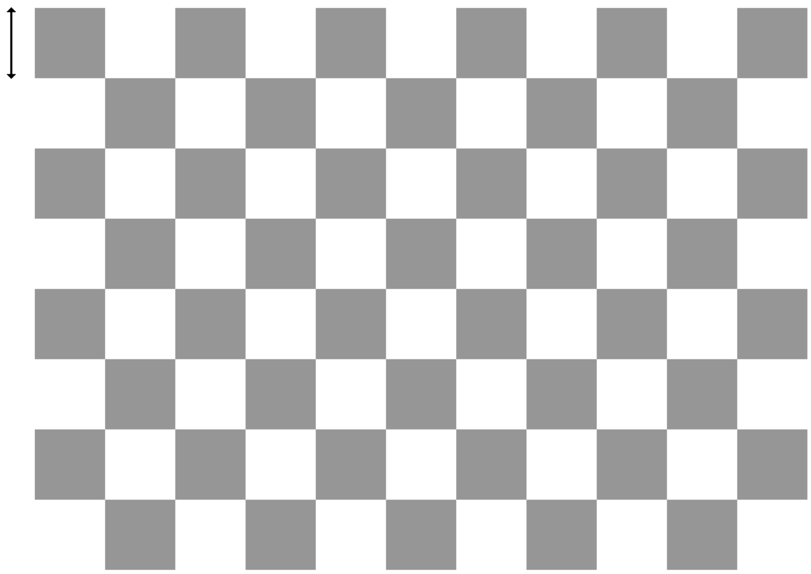

Figure 1 Camera calibration board measurement

2. From main menu of software, select “4: Calibrate camera” and follow instructions
3. From main menu of software, select “5: Calibrate system”

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

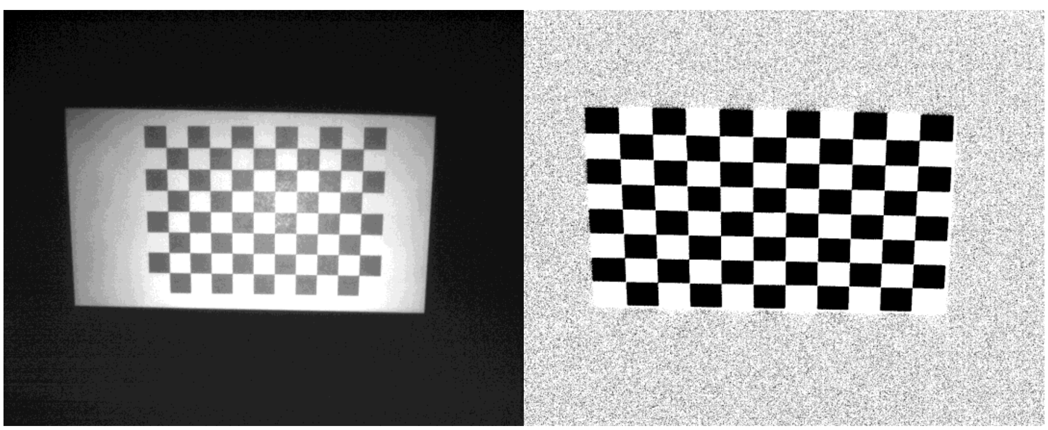

Figure 2 Printed calibration board and projected calibration board position 1

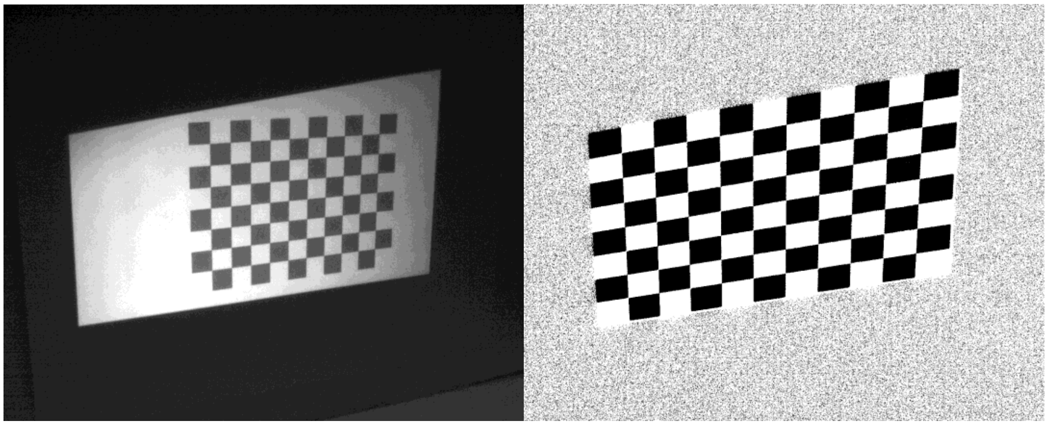

Figure 3 Printed calibration board and projected calibration board position 2

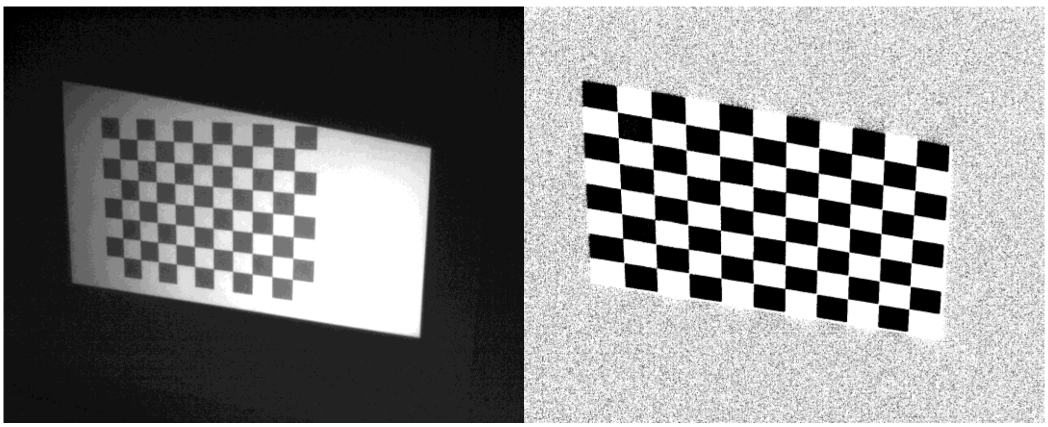

Figure 4 Printed calibration board and projected calibration board position 3

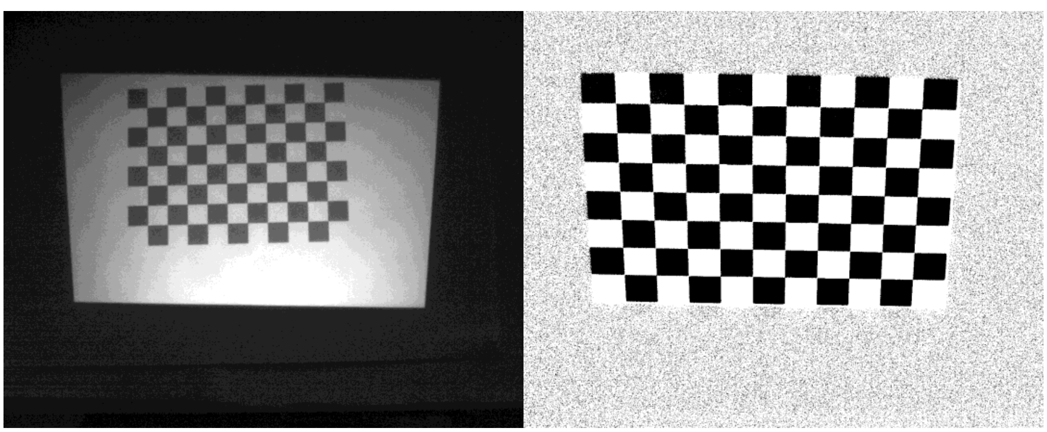

Figure 5 Printed calibration board and projected calibration board position 4

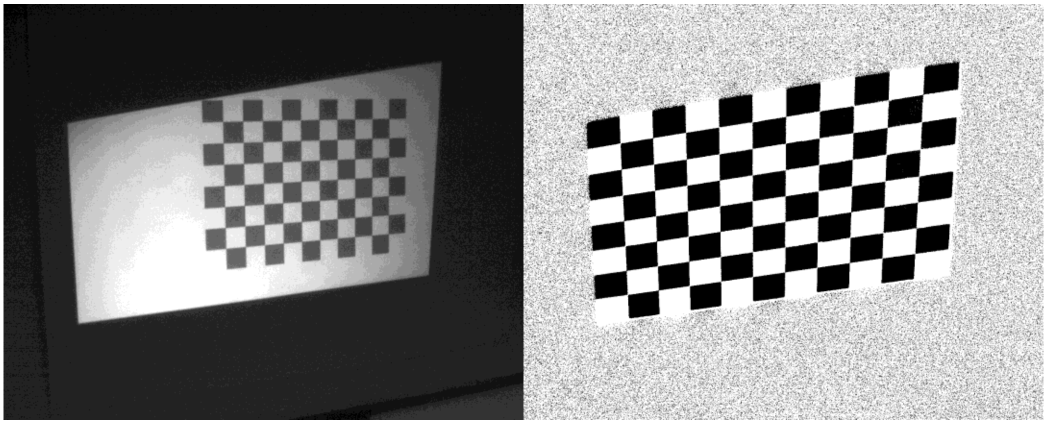

Figure 6 Printed calibration board and projected calibration board position 5

The following images show examples of the calibration XML files generated for the camera and projector.


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  <?xml version="1.0" ?>
- <opencv_storage>
    <DLP_CALIBRATION_DATA>1</DLP_CALIBRATION_DATA>
    <calibration_complete>1</calibration_complete>
    <calibration_of_camera>1</calibration_of_camera>
    <image_columns>1280</image_columns>
    <image_rows>1024</image_rows>
    <model_columns>1280</model_columns>
    <model_rows>1024</model_rows>
    <reprojection_error>2.5345121411948096e-001</reprojection_error>
  - <intrinsic type_id="opencv-matrix">
      <rows>3</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>1.7432381012704493e+003 0. 6.2772697403268523e+002 0. 1.7450979041833305e+003 5.2023527052016891e+002 0. 0. 1.</data>
    </intrinsic>
  - <distortion type_id="opencv-matrix">
      <rows>5</rows>
      <cols>1</cols>
      <dt>d</dt>
      <data>-1.0681554530635126e-001 2.5658916320242892e-001 4.3931704866851496e-004 -2.9244403855087950e-004 -
        1.6631911335410055e-001</data>
    </distortion>
  - <extrinsic type_id="opencv-matrix">
      <rows>2</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>2.4853249267503308e-001 4.1538025011909660e-002 6.6865084742224606e-003 -4.1789882706998904e+000 -
        3.6800653254790525e+000 3.2319701215835927e+001</data>
    </extrinsic>
  </opencv_storage>
```


Figure 12 Camera calibration XML output file

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    <calibration_of_camera>0</calibration_of_camera>
    <image_columns>1280</image_columns>
    <image_rows>1024</image_rows>
    <model_columns>608</model_columns>
    <model_rows>684</model_rows>
    <reprojection_error>4.7976422164604354e-001</reprojection_error>
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      <rows>3</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>1.0296852595706296e+003 0. 3.1102457621950163e+002 0. 1.0296852595706296e+003 3.7485814778612917e+002 0. 0. 1.</data>
    </intrinsic>
  - <distortion type_id="opencv-matrix">
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      <cols>1</cols>
      <dt>d</dt>
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        1.5824589404330223e+000</data>
    </distortion>
  - <extrinsic type_id="opencv-matrix">
      <rows>2</rows>
      <cols>3</cols>
      <dt>d</dt>
      <data>-7.5850879721983825e-003 4.3813455899180932e-002 -3.0196721816552934e-003 -4.0353432338902815e+000 -
        8.6576893791380893e+000 2.8770773925887408e+001</data>
    </extrinsic>
  </opencv_storage>
```


Figure 13 Projector calibration XML output file

Generated Point Cloud

This chapter provides test data from the DLP 3D Scanner Reference Design for structured light pattern decoding and point cloud generation. The patterns are generated to determine which projector rays are intersecting with the scanned object and the intersection between the projector and camera optical rays are calculated to generate a depth-map and point-cloud of 3D measurements.

The following procedure is used, which assumes the system is calibrated:

1. From main menu of software, select “3: Prepare system for calibration and scanning”
2. From main menu of software, select “8: Perform scan (vertical and horizontal patterns)”

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

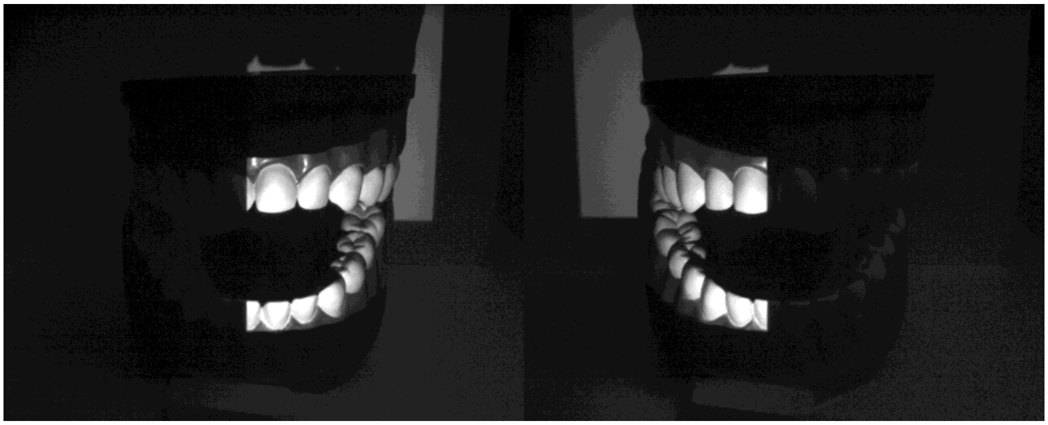

Figure 14 Non-inverted and inverted vertical Gray code pattern 1 capture

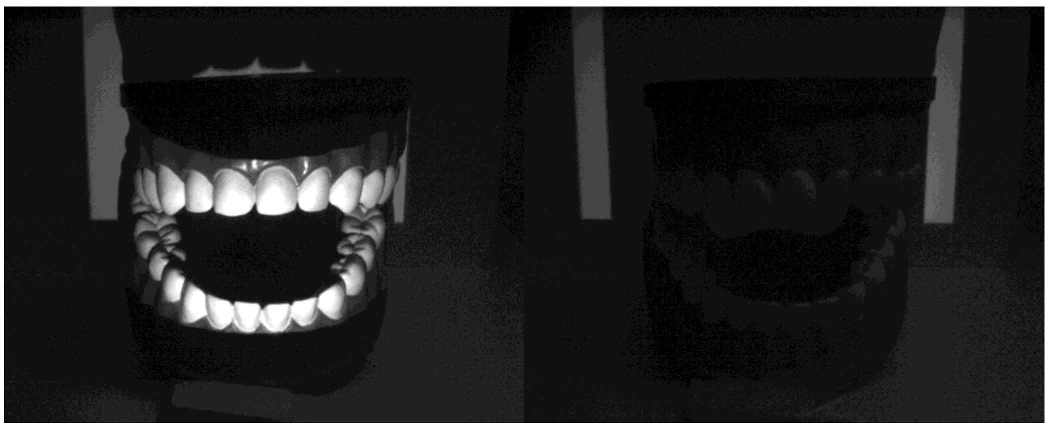

Figure 15 Non-inverted and inverted vertical Gray code pattern 2 capture

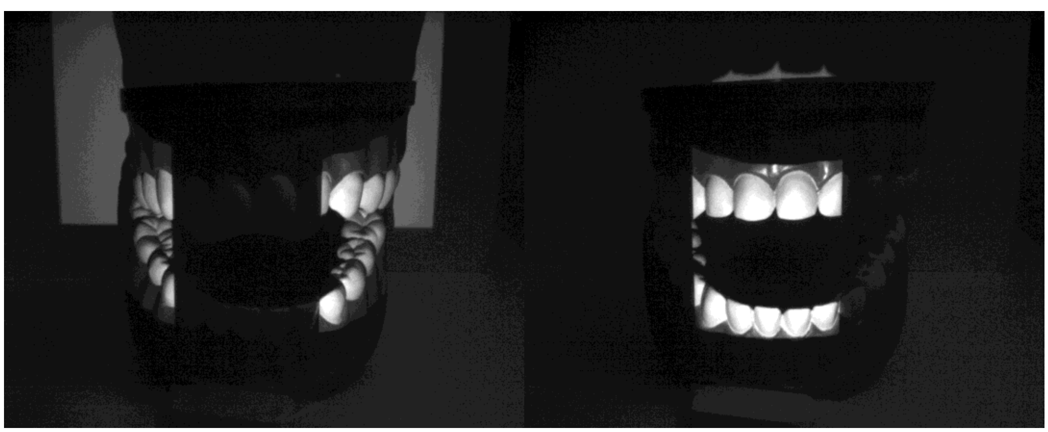

Figure 16 Non-inverted and inverted vertical Gray code pattern 3 capture

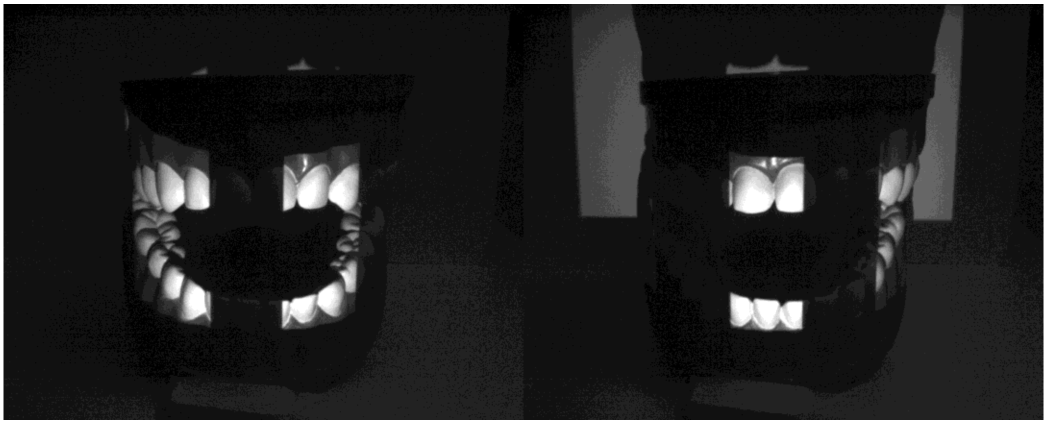

Figure 17 Non-inverted and inverted vertical Gray code pattern 4 capture

Figure 18 Non-inverted and inverted vertical Gray code pattern 5 capture

Figure 19 Non-inverted and inverted vertical Gray code pattern 6 capture

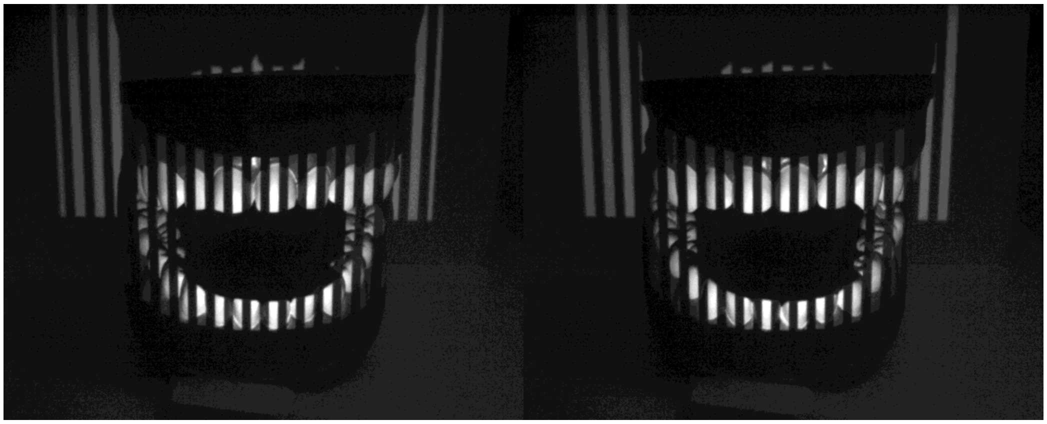

Figure 20 Non-inverted and inverted vertical Gray code pattern 7 capture

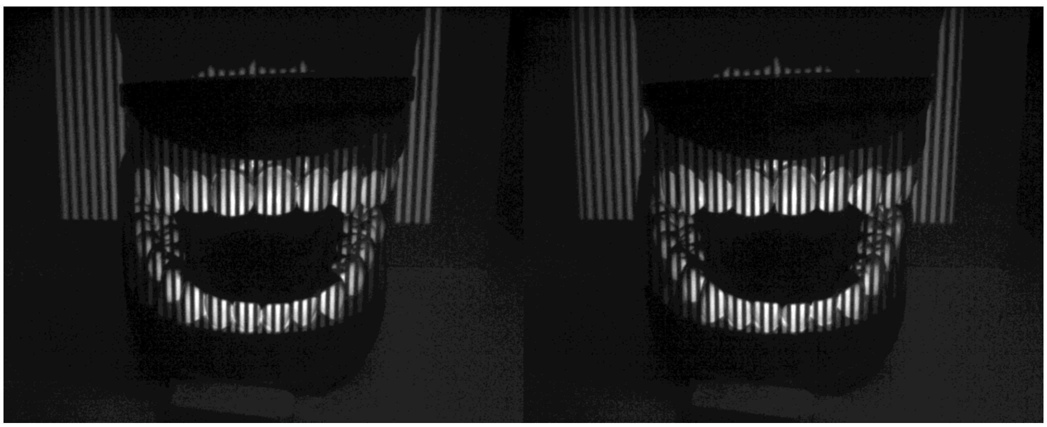

Figure 21 Non-inverted and inverted vertical Gray code pattern 8 capture

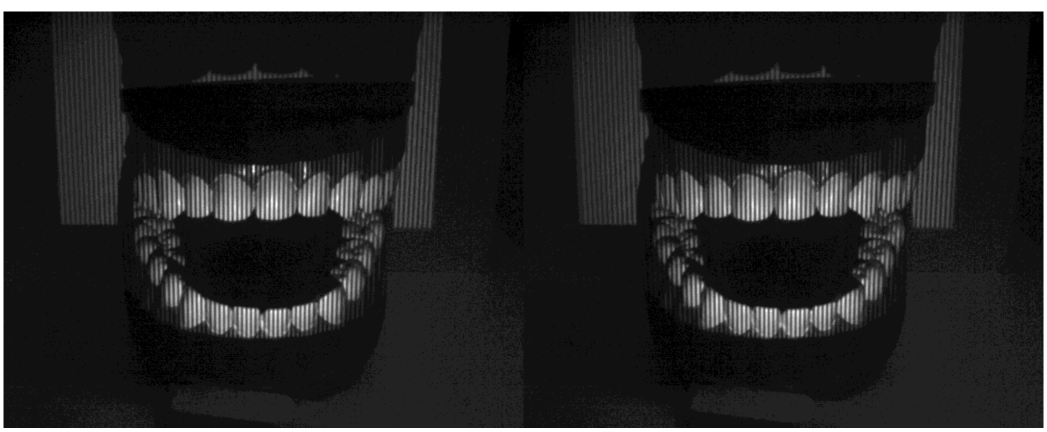

Figure 22 Non-inverted and inverted vertical Gray code pattern 9 capture

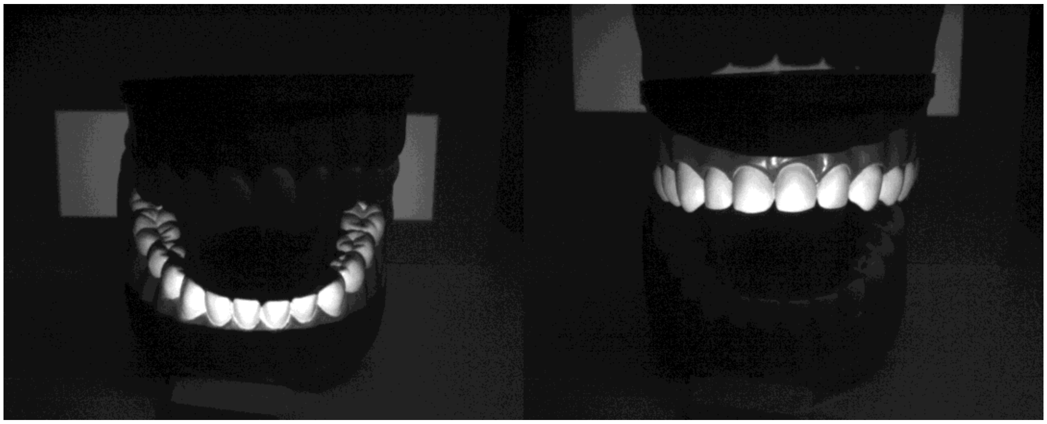

Figure 23 Non-inverted and inverted horizontal Gray code pattern 1 capture

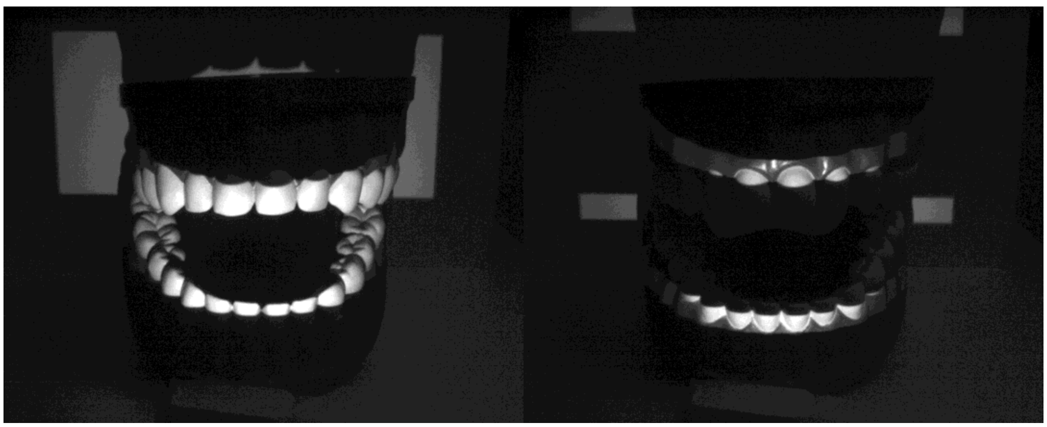

Figure 24 Non-inverted and inverted horizontal Gray code pattern 2 capture

Figure 25 Non-inverted and inverted horizontal Gray code pattern 3 capture

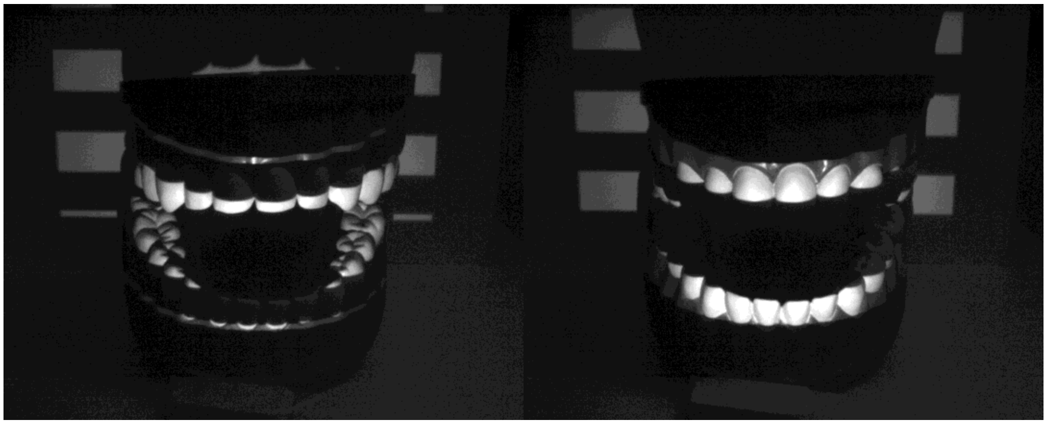

Figure 26 Non-inverted and inverted horizontal Gray code pattern 4 capture

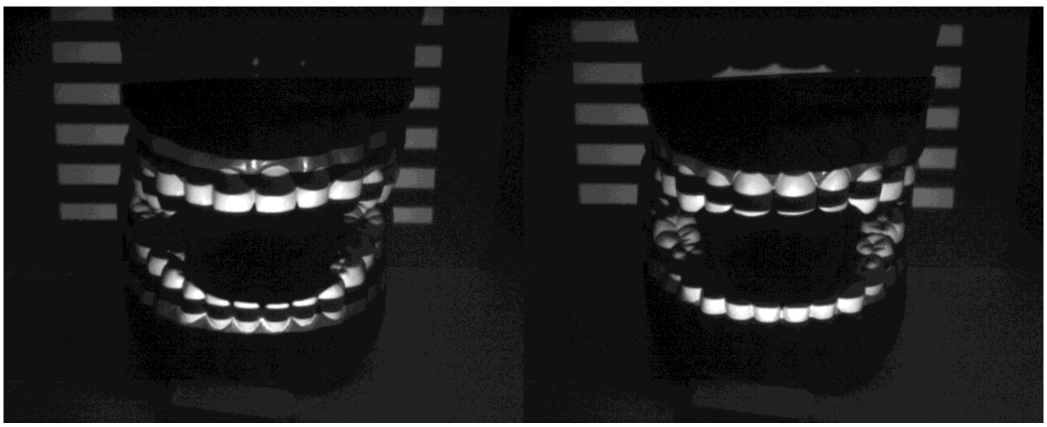

Figure 27 Non-inverted and inverted horizontal Gray code pattern 5 capture

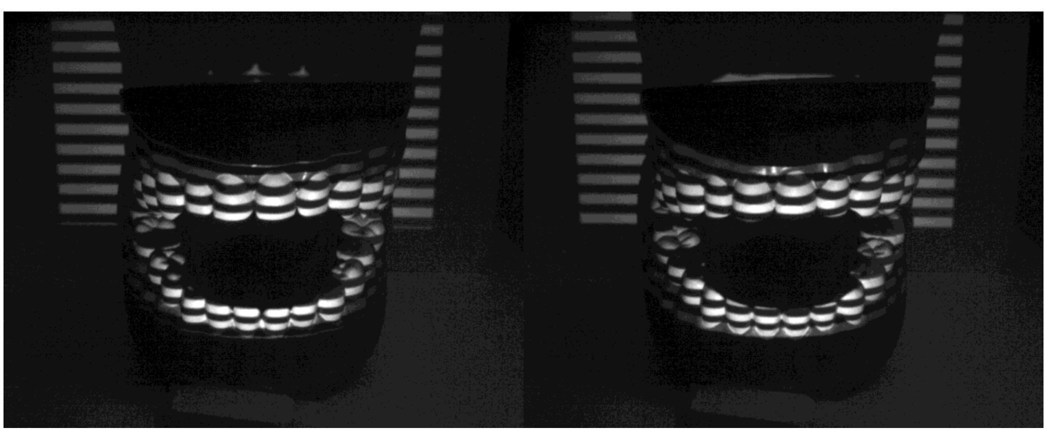

Figure 28 Non-inverted and inverted horizontal Gray code pattern 6 capture

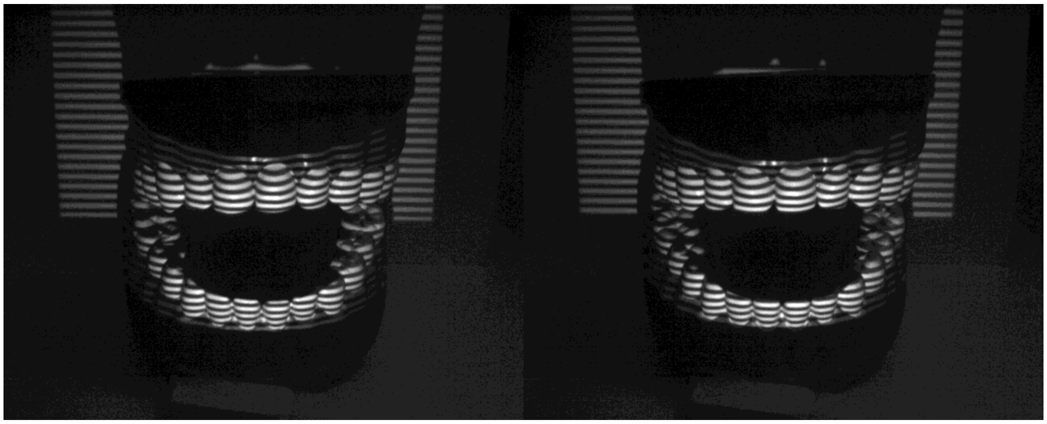

Figure 29 Non-inverted and inverted horizontal Gray code pattern 7 capture

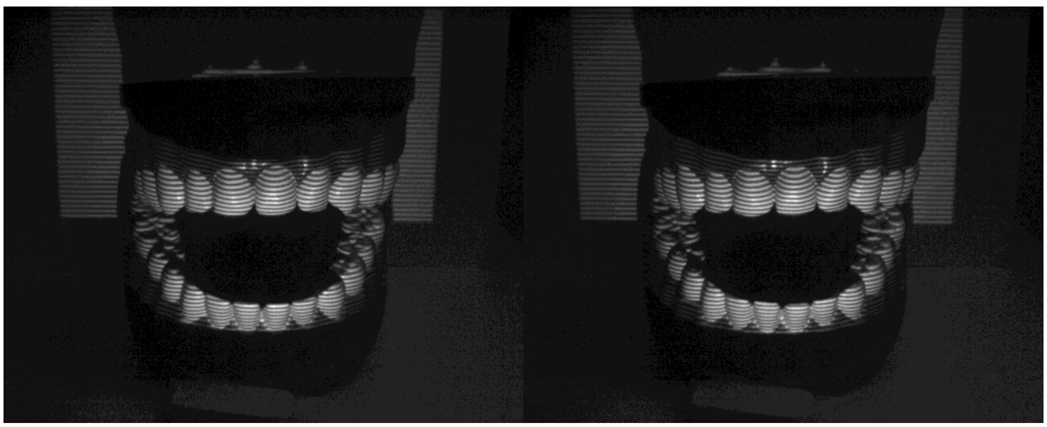

Figure 30 Non-inverted and inverted horizontal Gray code pattern 8 capture

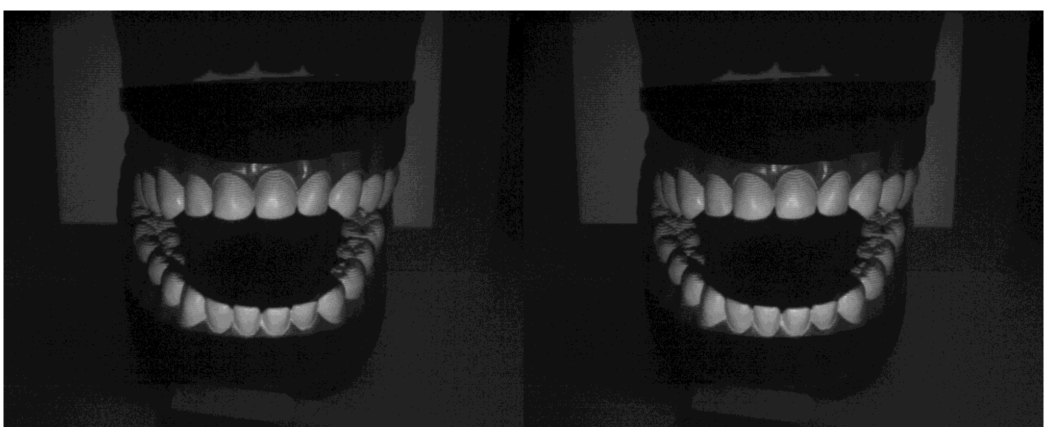

Figure 31 Non-inverted and inverted horizontal Gray code pattern 9 capture

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

Figure 32 Depth-map of object from 3D scan

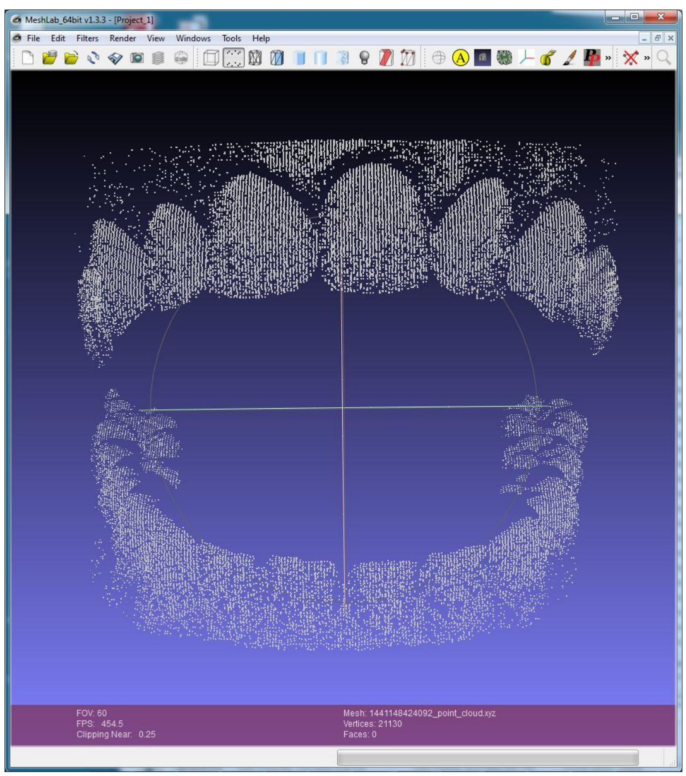

Figure 33 Front view of point-cloud from 3D scan

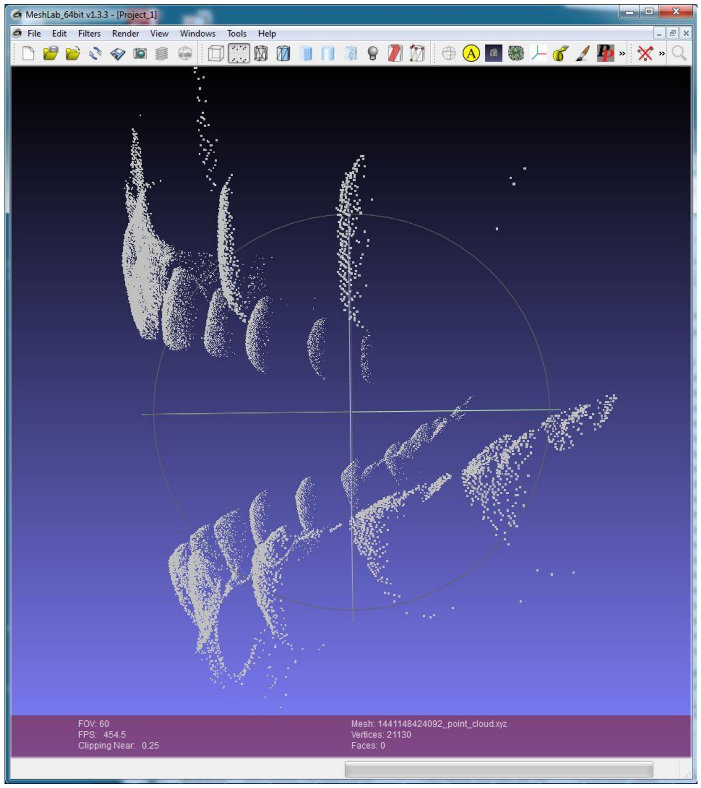

Figure 34 Side view of point-cloud from 3D scan

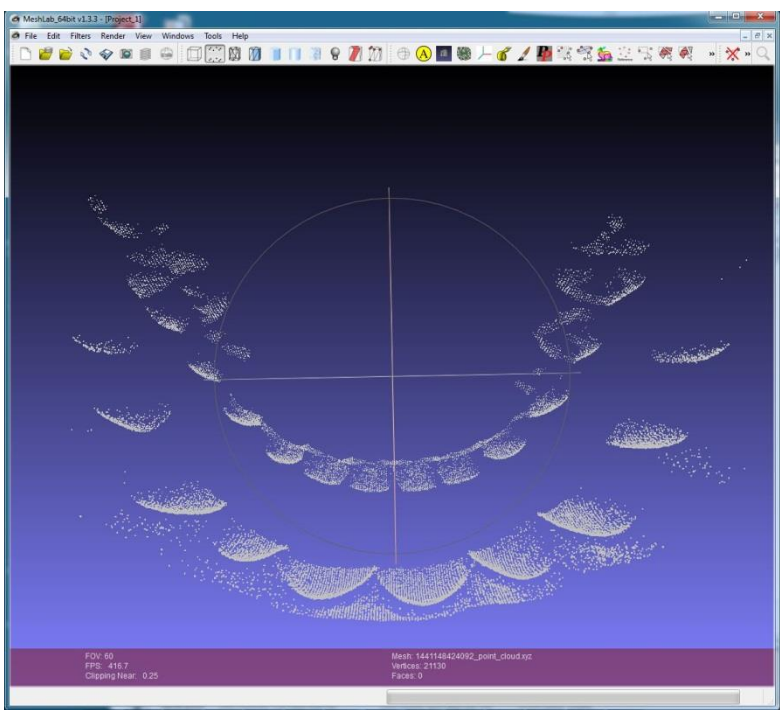

Figure 35 Top view of point-cloud from 3D scan

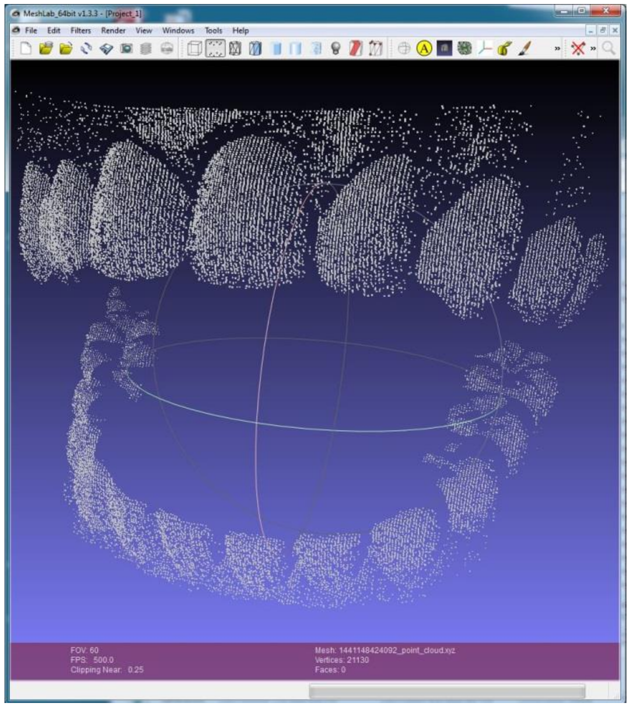

Figure 36 Isometric view of point-cloud from 3D scan

Generated Point Cloud from Hybrid 3-Phase Scanning

The following procedure is used, which assumes the system is calibrated:

1. From main menu of software, select “3: Prepare system for calibration and scanning”
2. From main menu of software, select “7: Perform scan (horizontal patterns)”

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

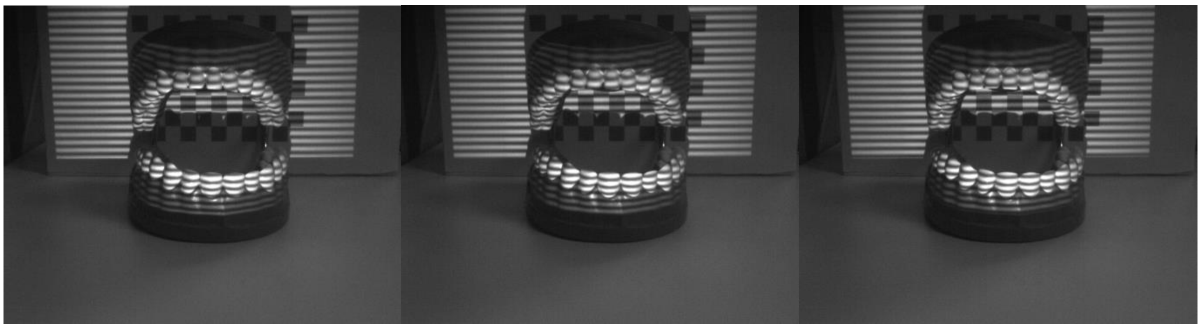

Figure 37 Three phase hybrid scan captures

Figure 38 Non-inverted and inverted horizontal Gray code pattern 1 capture

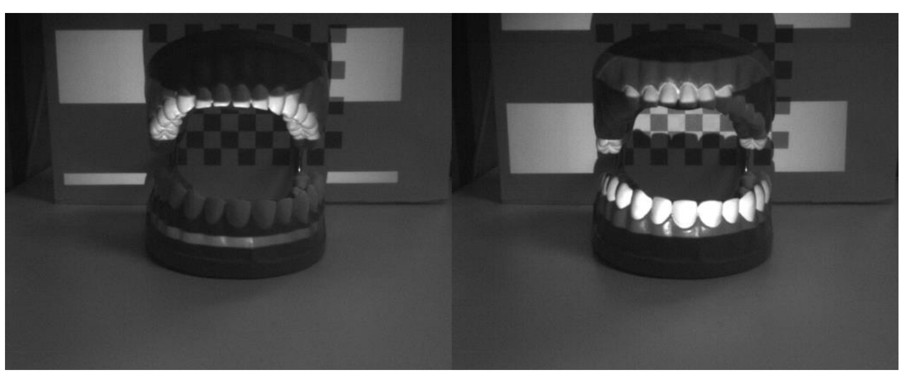

Figure 39 Non-inverted and inverted horizontal Gray code pattern 2 capture

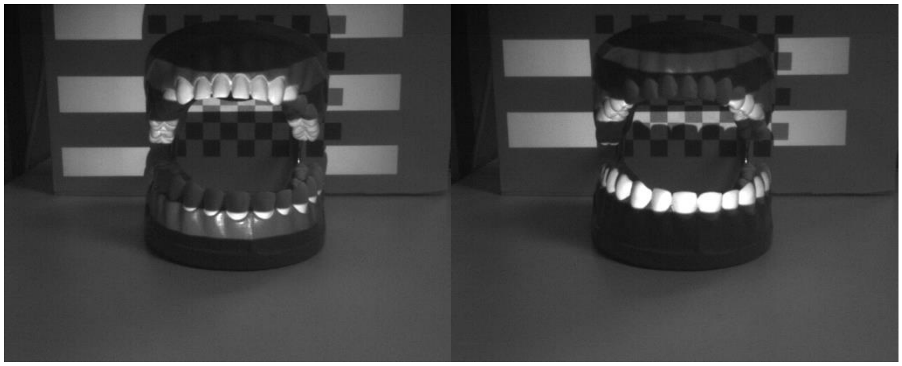

Figure 40 Non-inverted and inverted horizontal Gray code pattern 3 capture

Figure 41 Non-inverted and inverted horizontal Gray code pattern 4 capture

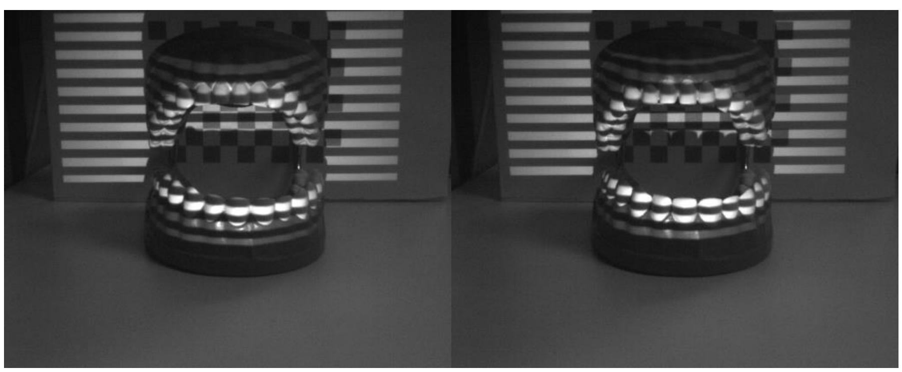

Figure 42 Non-inverted and inverted horizontal Gray code pattern 5 capture

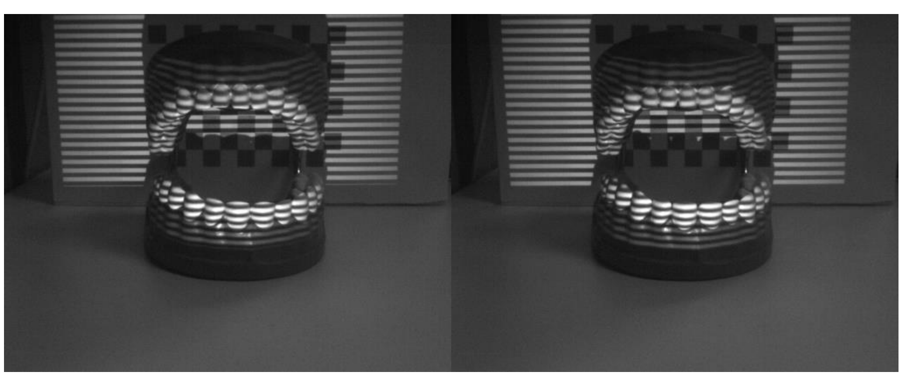

Figure 43 Non-inverted and inverted horizontal Gray code pattern 6 capture

Figure 43 Non-inverted and inverted horizontal Gray code pattern 7 capture

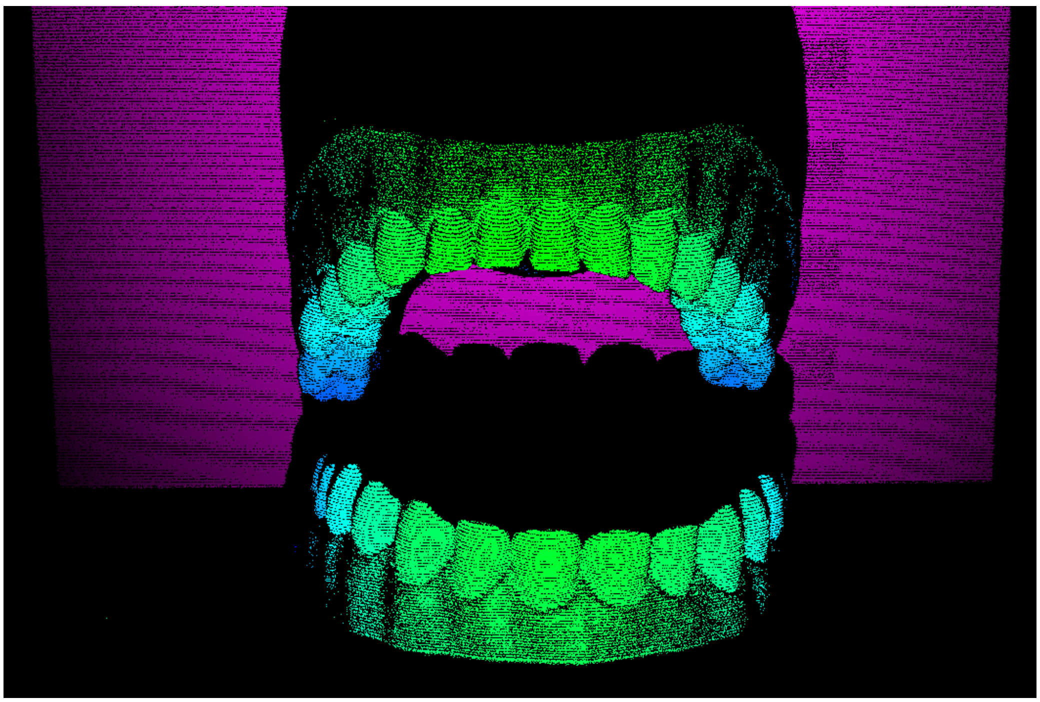

Figure 44 Depth map from the three phase hybrid scan

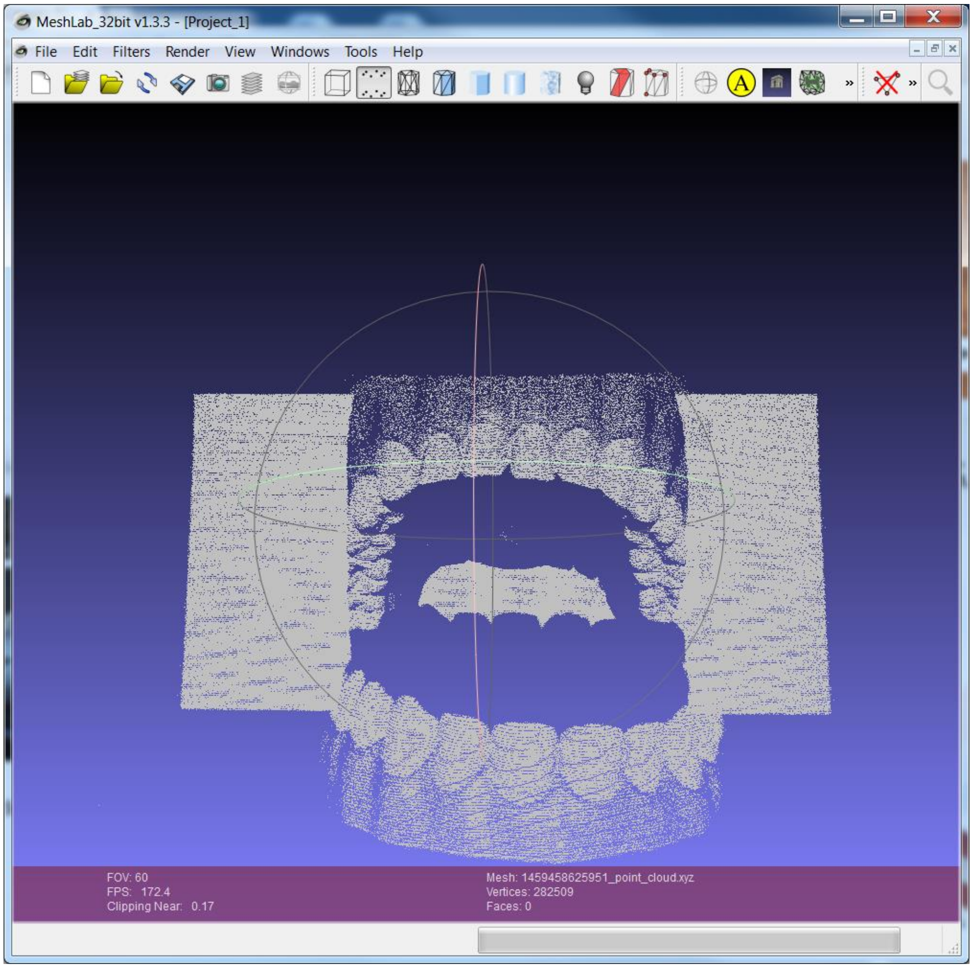

Figure 45 Front view of the point cloud

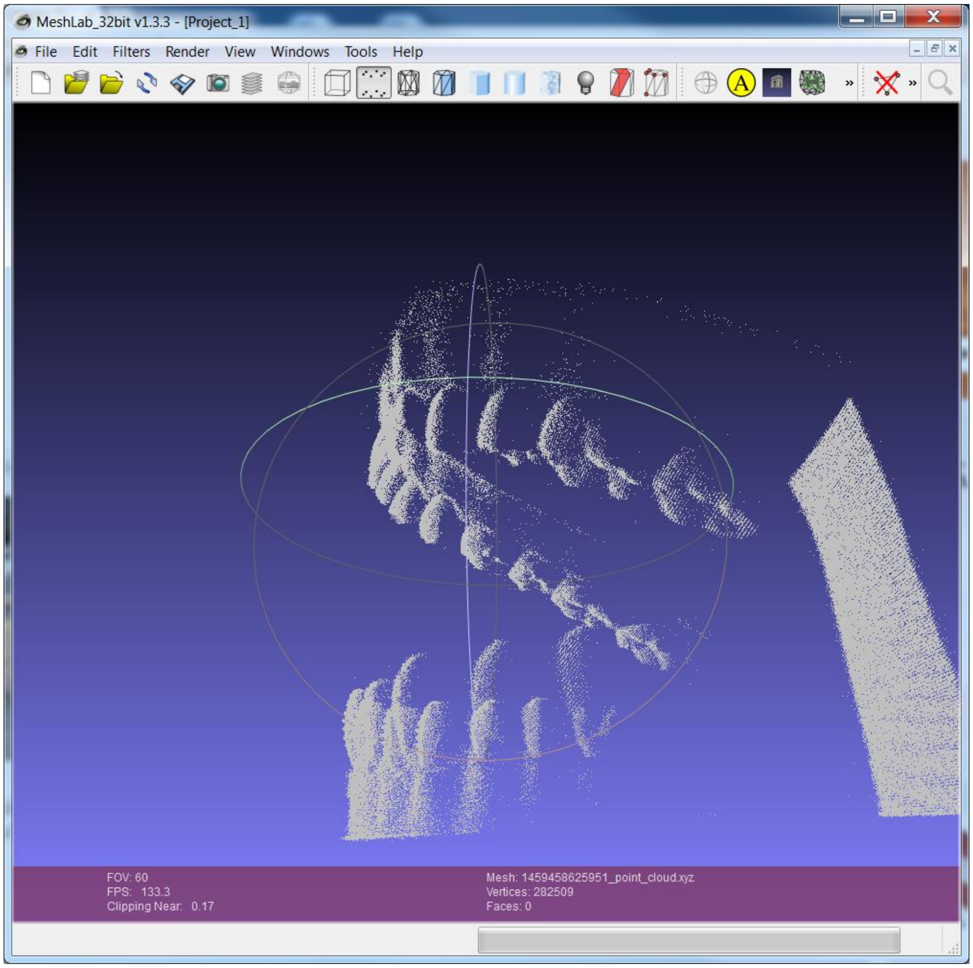

Figure 46 Side view of the point cloud

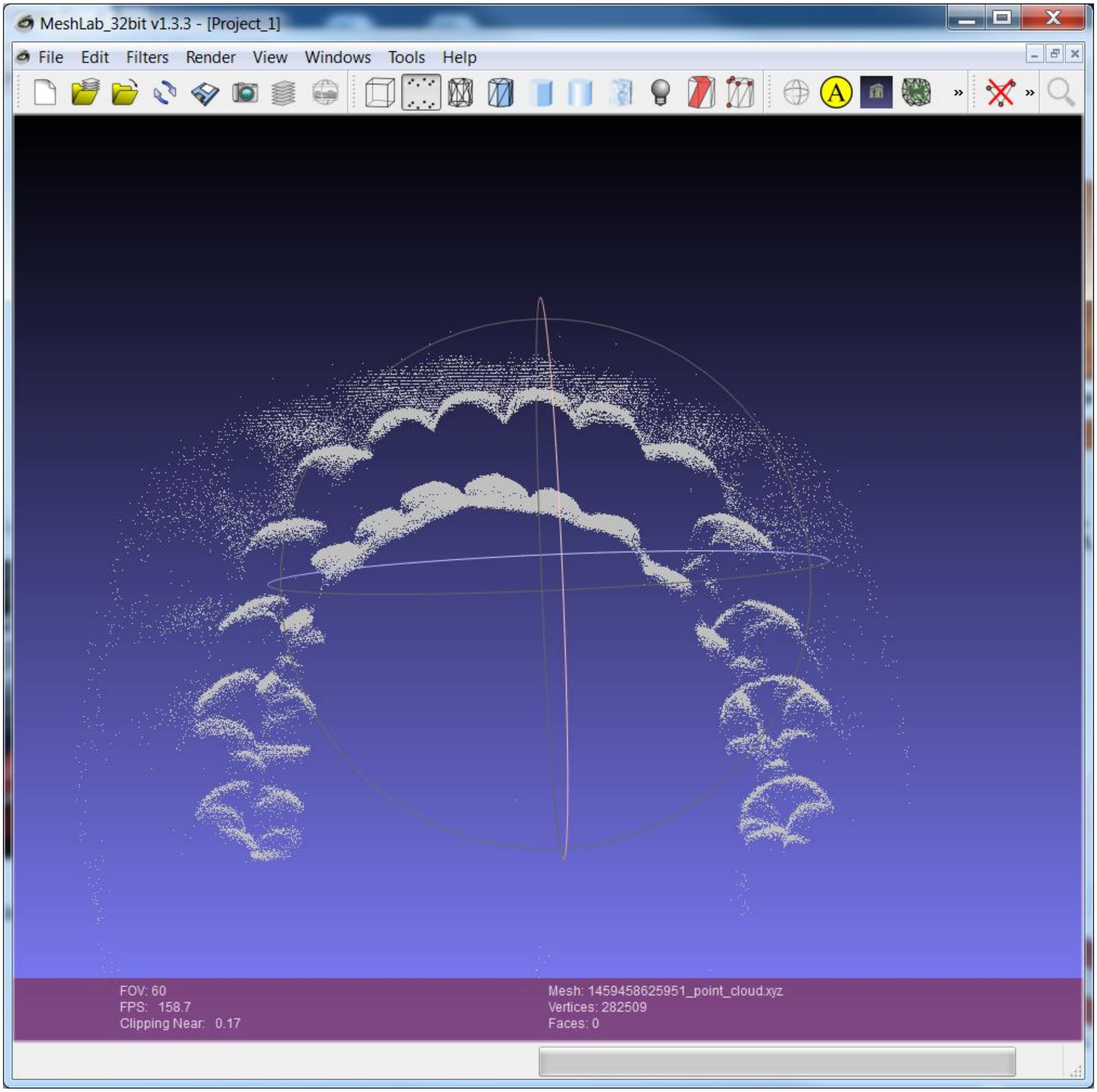

Figure 47 Top view of the point cloud

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