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# **Computer Vision-Based 3-D Reconstruction for Object Replication**

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### **Abstract**

The Microsoft Kinect for Windows has proven to be a valuable tool in the field of computer vision. The Kinect is comprised of an infrared laser projector and depth sensor. The depth data of a scene is run through a bilateral filter and vector mathematics is used to define the coordinates, connecting lines, the vertices, and edges to form a three-dimensional mesh. The software displays the raw depth data and infrared camera image, this allows the user to filter out objects closer or further than a specified depth, and exports the reconstructed three-dimensional mesh. That mesh is then sliced into horizontal layers and converted into G-Code, a machine language that maneuvers the three-dimensional printer where to extrude the ABS plastic to create a physical replica of the reconstructed object.

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## 1 Introduction

The Computer Vision–Based Three-Dimensional Reconstruction for Object Replication is accomplished by using a Kinect for Windows. Originally, the Kinect was created for entertainment, but recently it has been introduced to the field of robotics and computer vision. The Kinect is a quick, reliable, and affordable tool that uses a near-infrared laser pattern projector and an IR camera, along with the sensor and software development kit to calculate three-dimensional measurements.

The robotics field is beginning to find an increasing number of uses for the three-dimensional printer. The most innovative aspect of the three-dimensional printer is the ability to print an object, regardless of interconnecting internal components, and to have it function as intended. This means that any connecting gears that are printed with the three-dimensional printer will in fact turn as they are supposed to.

## 2 Methods

### 2.1 Calibration

The Kinect can be calibrated in a way similar to other cameras for computer vision, the only difference is that changes in the depth have to be present with the pattern in order to calibrate the depth camera. The Kinect needs to take an image of a checkerboard pattern.

### 2.2 Stereo Reconstruction

Once the Kinect has been calibrated, all that is needed for the stereo reconstruction is a triangulation of viewing rays.

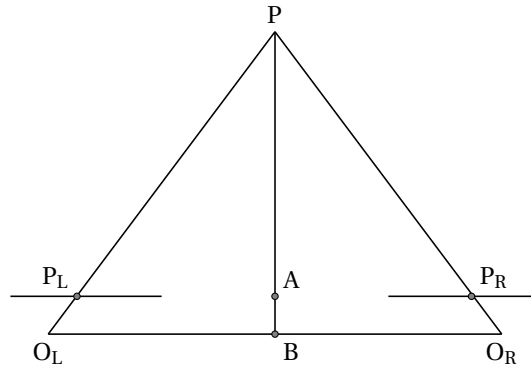


Figure 1: Visual Representation of Depth Disparity

P is the location of the object in the world,  $O_L$  and  $O_R$  are the left and right camera centers,  $P_R$  and  $P_L$  are the appearance of the point P in the two image planes where  $P_L = \begin{bmatrix} x_L \\ y_L \end{bmatrix}$ . The distance between  $O_L$  and  $O_R$  is T, the distance between the left and right camera. The distance between A and B is the focal length of each of the cameras. If the distance between P and B is defined as distance Z, the following equation can be used to represent the ratio between T and Z, using the theorem of like triangles:  $\frac{T}{Z} = \frac{T + x_L - x_R}{Z - f}$  or  $\frac{T - x_R - x_L}{Z - f}$ . Cross multiplying these equations results in:  $\frac{Z(T - x_R - x_L)}{Z - f} = \frac{T(Z - f)}{Z}$ . These calculations show that depth, Z, is inversely proportional to the disparity. Therefore,  $P_L = \frac{f^L P}{Z_L}$  and  $P_R = \frac{f^R P}{Z_R}$ .

Once there is a corresponding point pair for P from the two images, an algorithm would undo the scale and shift of the pixel points in order to obtain the two-dimensional camera coordinates. The midpoint algorithm is then used to find the real three-dimensional world coordinate that corresponds to that point pair.

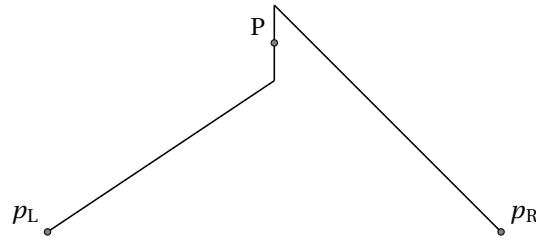


Figure 2: Visual Representation of the Midpoint Algorithm

Above are the rays  $O_R \vec{p}_R$  and  $O_L \vec{p}_L$ . The line connecting the two vectors, perpendicular to both, is obtained by taking the cross product of these two vectors. The vector from  $p_L$  is equal to  $a \vec{p}_L$ , since point  $p_R$  is distance  $T$  away from  $p_L$ , the vector from  $p_R$  is equal to  $b^L R_R \vec{p}_R + T$ . The segment connecting these two vectors can be represented as  $c \vec{p}_L x^L R_R \vec{p}_R$ , where  $a$ ,  $b$ , and  $c$  are unknown constants that can be solved using the three aforementioned equations.

The point  $P$  lies on the center of this line and be found by  ${}^L P = a \vec{p}_L + \frac{c}{2} \vec{p}_L x^L R_R \vec{p}_R$ . In order to get the world point  $M$ , this point would be divided by the intrinsic and extrinsic matrices.



Figure 3: The Xbox Kinect. The sensor on the left is the infrared light source, the center is a RGB camera, and the three-dimensional depth camera is on the right. In addition to these cameras, the base has a motorized tilt and a multi-array microphone that goes along the bottom of the wand.

The Kinect accomplishes triangulation by using the known information about the sensor, the data obtained from the infrared projection, and the image received from the camera. The sensor will project invisible light onto an object, the light bounces back, and the infrared sensor reads back the data. These clusters of light that are read back can be matched to the hard-coded images the Kinect has of the normal projected pattern, and allows for a search for correlations, or the matching points. While looking through the camera's focal point, the point of interest will fall on a specific pixel, depending on how close or far away it is, providing the end point for the trajectories coming from the camera and projector. These relative lines of trajectories, along with the known information about the distance between the cameras on the Kinect sensor, are used in the triangulation process to find the three-dimensional coordinates of the point. Figure 3 shows how the three cameras are arranged on the Kinect.

## 2.3 Bilateral Filter

In order to make this data more manageable, a bilateral filter is used to remove the erroneous measurements. This filter will take every point, and recalculate the value of that point based on the waited average of the surrounding pixels in a specified neighborhood. The process takes away some of the sharpness of the depth map, but it removes the noise that will skew the results of the three-dimensional reconstruction. The filter takes every pixel in the image

and replaces its value with  $BF[I]_P = \frac{1}{16} \begin{pmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{pmatrix}$  times the neighborhood of the three by three square of pixels around the pixel that is being changed. This resulting pixel value represents the average of the nine pixels, where the closer pixels weights in the average are heavier than the further pixel values' weights.

## 2.4 Mesh Construction

Once the depth data has been filtered, it can be used to create a three-dimensional mesh of the object. At each pixel location two vectors are made, each connecting that three-dimensional point to the next point to the right and the

next point below. Cross multiplying these two vectors results in the orientation vector for the point. As the loop goes through each point, it created a triangle in three-dimensional space out of the existing points and calculated orientations, which are recorded in three-dimensional point and vector collections. Each of these points must be added in the correct order, keeping with the right hand rule, so that each reconstructed triangle is oriented in the correct direction. While these three points and vectors are added, separate collections of the indices and texture informations are recorded.

While reconstructing the front face of the mesh, the code goes through every x and y pixel coordinate starting at (0,0) and ending with (230,640), incrementing by a set number. Down sampling, for testing, was accomplished by setting this number to two so that only every other point was processed. In the KinectScan software, the user can crop out the left, right, top or bottom of the image. Changing these sliders indicated where on the image the reconstruction of the mesh is going to begin and end. The user can also specify what they would like the minimum and maximum depth to be.

In order to filter out depth that is further than the intended value, the software looks at the square where the point of interest is the upper left corner. If all four points are outside of the depth range, that point is skipped. If any of the four points on that square are within the depth range, the square is constructed. For this square, any point that is not within the depth range is given the depth of the back wall, the value specified by the user. Lastly, the back wall of the three-dimensional reconstruction is built. A loop goes through every point that is already in the three-dimensional point collection, each point is copied to the end of the collection with the depth changed to the depth of the back wall. The same number of orientation vectors are added to the collection of three-dimensional vectors, each one equaling [0,0,-1]. [1]

## 2.5 G-code Conversion

The RepRap firmware uses G-code to communicate to the three-dimensional printer, specifically to define the print head movements. This code has commands that tell the print head to move to a certain point with rapid or controlled movement, turn on a cooling fan, or select a different extruding tool. Since this three-dimensional printer does not have as many features, the G-code generator does not have to add much complicated code, but rather instructions to the printer head. Since the printer continuously dispenses plastic, it is necessary to find a path for it to take that will build up the reconstructed object layer by layer without placing too much plastic in any specific area. This requires cutting up the reconstructed object into layers and then finding the best path to traverse that layer without overlapping any part of that path. The G-code converter takes in the STL file, cuts it up into horizontal layers, and then calculates the amount of material that is needed to fill each slice.

### 3 Experimental Results



Figure 4: The Kinect raw depth field, with the RGB image mapped to it, without bilateral filter

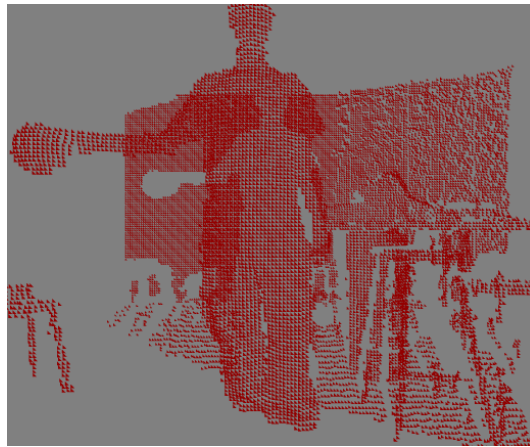


Figure 5: Triangles representing the three-dimensional data

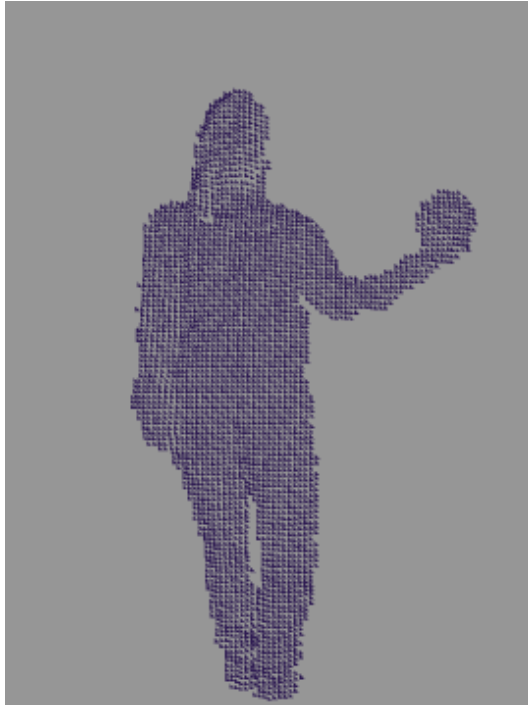


Figure 6: The three-dimensional data with the correct background filtered out

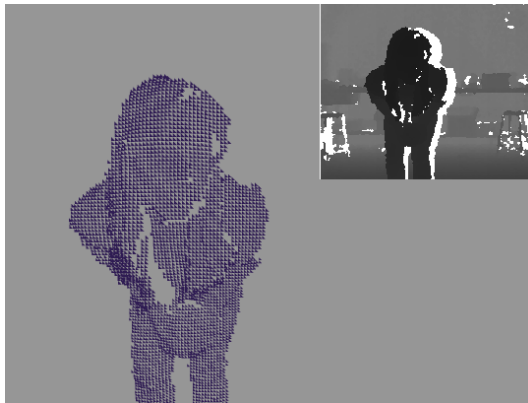


Figure 7: Comparison of the raw depth data and the Triangles that represent the three-dimensional data

## 4 Discussion

Part of the issue of working with this three-dimensional printer was that many of the parts used in the construction of the machine were actually printed by another three-dimensional printer. This meant that before we could start the construction of the printer, we had to wait for all of the correct parts to be printed. We discovered two important parts were missing and had to go to the Rutgers Maker Space to get these parts printed. We also found that many of the holes in the plastic parts were made to be the exact diameter of the rods that were supposed to be fitting in; it took a lot of force to get some of the components to fit together properly. At one point we tried to use hot water to make the printed plastic more malleable, but we fear that this made some of the pieces warp.

Another big issue with the construction of the three-dimensional printer was the lack of good documentation



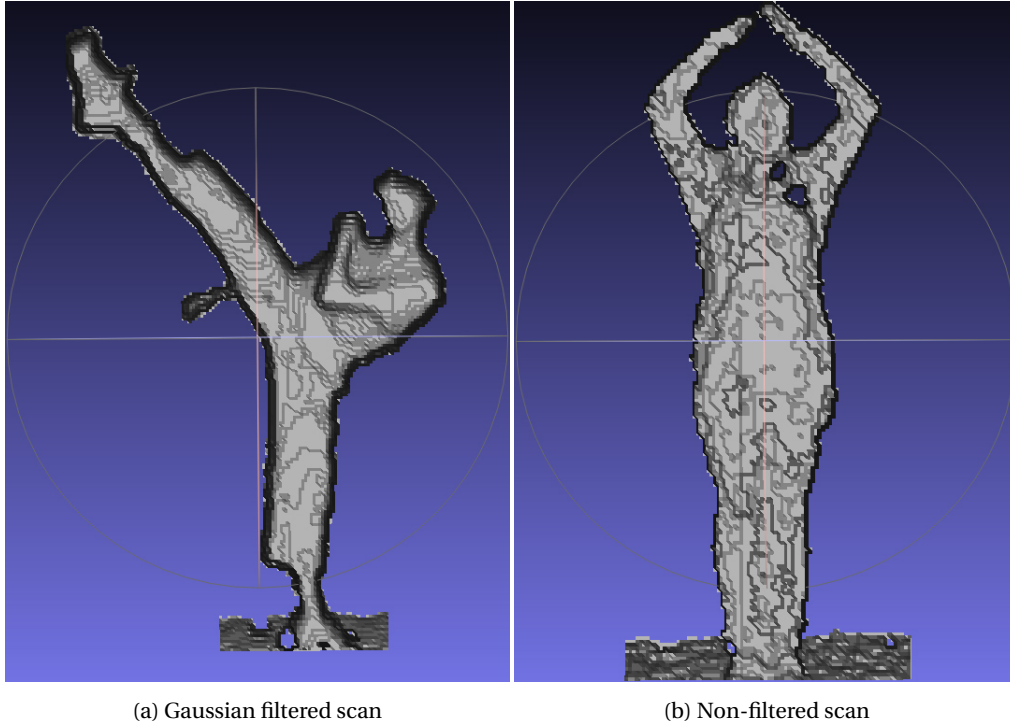


Figure 8: As can be seen on the left figure it is clear that filtering the depth data provides a nicer and cleaner result.

on the assembly process. The triangular base structure had to be taken apart and reassembled multiple time in order to fix errors. One example was the motor bracket for the motor that controls the movement along the y-axis: there were not good diagrams to show which side of the machine this part should be placed and what direction it should be oriented. Figure 9 shows a number of the unlabeled parts that we received from the Institute of Electrical and Electronics Engineers (IEEE). Since documentation is hard to find and none of the parts were labeled, we also had trouble finding the correct STL files to send to get printed. We knew that we were missing the brackets that connect the two top motors to the threaded rod that controls the movement along the z-axis, but we did not know exactly what file needed to be printed.



Figure 9: Parts of the three-dimensional Printer

Even once the mechanical parts of the three-dimensional printer have been constructed, we still need to calibrate all of the axes, add all of the electrical components, calibrate the firmware, and build the protective frame around the printer. Figure 10 shows the constructed frame, x,y, and z-axes and the installed printed. One of the issues that we will run into as we complete the three-dimensional printer is the extruder. This component is responsible for heating and melting the Acrylonitrile Butadiene Styrene (ABS) plastic and placing it onto the right

spot on the heat bed. We have discovered a problem that normal solder cannot handle the heat that is needed to melt the ABS plastic, and the piece falls apart as the machine heats up. In order to fix this issue, we need to order silver solder that will be capable of withstanding 221 degrees Fahrenheit.

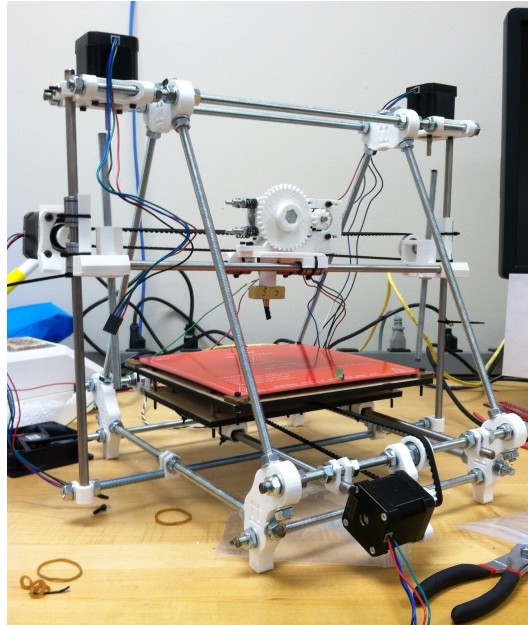


Figure 10: Construction of the three-dimensional Printer Frame and x,y, and z-axes

The biggest issue that we have had with the software component of this project was the lack of examples. Other people who have worked on similar projects used the original version of the Microsoft Kinect Software Development Kit (SDK). This means that a many implementations were using packages that are no longer part of the SDK that we have to work with. We have had to find ways to make the new SDK, which was released in 2012, work in a way similar to the old SDK.

## 5 Cost Analysis

Item	Description	Cost
RepRap Prusa Mendel Iteration 2	Open Hardware based 3-D Printer	\$ 725.00
Microsoft Kinect for Xbox	Video camera and depth sensor	\$ 98.79
Acrylic casing, small tools, glue, misc..	Parts for creating the case	\$ 59.65
Kinect Power Supply Cable	External power source for Kinect	\$ 6.70
	<b>Total Cost:</b>	<b>\$ 890.14</b>

Table 1: Overview of hardware and cost for project.

## 6 Current Trends in Robotics and Computer Vision

### 6.1 Kinect Revolution

One of the reasons that the Kinect has become so popular for computer vision projects is that it is cheap, quick, and highly reliable for three-dimensional measurements. Many researchers are beginning to look into the possibility of using this device to achieve everything from a three-dimensional reconstruction of a scene to aiding in a Simultaneous Localization and Mapping (SLAM) algorithm. The fact that this device is so affordable, and so many new resources are available, makes the Kinect a viable device for conducting research in the field of robotics and computer vision.

The KinectFusion Project is slightly different than other projects that use the Kinect; instead of using both the RGB cameras and the sensor, this project tracks the three-dimensional sensor pose and preforms a reconstruction in real time using exclusively the depth data. This paper points out that depth cameras are not exactly new, but the Kinect is a low-cost, real-time, depth camera that is much more accessible. The accuracy of the Kinect is called into question, the point cloud that the depth data creates usually contains noise and sometimes has holes where no readings were obtained. Considering the Kinect's low X/Y resolution and depth accuracy, the project fixes the quality of the images using depth super resolution. KinectFusion looks into using multiple Kinects to perform a three-dimensional body scan; this raises more issues because the quality of the overlapping sections of the images is compromised.

Another KinectFusion Project is the Real-time Three-dimensional Reconstruction and Interaction; it is impressive because the entire process is done using a moving depth camera. With this software, the user can hold a Kinect camera up to a scene, and create a three-dimensional reconstruction in real time. Not only would the user be able to see the three-dimensional reconstruction, but he would be able to interact with it; for instance, if the user were to throw a handful of spheres onto the scene, they would land on the top of appropriate surfaces and fall under appropriate objects following the rules of physics. The depth camera is used to track the three-dimensional pose and the sensor is used to reconstruct the scene in real time. Different views of the scene are taken and fused together into a single representation; the pipeline segments the objects in the scene and uses them to create a global surface based reconstruction. This project shows the real-time capabilities of the Kinect and why it is an innovative tool for computer vision

A study shown in the Asia Simulation Conference in 2011 demonstrated that a calibrated Kinect can be combined with Structure from Motion to find the three-dimensional data of a scene and reconstruct the surface by multi-view stereo. This study proved that the Kinect was more accurate for this procedure than a SwissRanger SR-4000 three-dimensional-TOF camera and close to a medium resolution SLR Stereo rigs. The Kinect works by using a near-infrared laser pattern projector and an IR camera as a stereo pair to triangulate points in three-dimensional space, then the RGB camera is used to reconstruct the correct texture to the three-dimensional points. This RGB camera, which outputs medium quality images, can also be used for recognition. One issue this study found was that the resulting IR and depth images were shifted. To figure out what the shift was, the Kinect recorded pictures of a circle from different distances. The shift was found to be around 4 pixels in the  $u$  direction and three pixels in the  $v$  direction. Even after the camera has been fully calibrated, there are a few remaining residual errors in the close range three-dimensional measurements. An easy fix for this error was to form a  $z$ -correction image of  $z$  values constructed as the pixel-wise mean of all residual images, and then subtract that correction image from the  $z$  coordinates of the three-dimensional image.[2] Though the SLR Stereo was the most accurate, the error  $e$  (or the Euclidean distance between the points returned by the sensors and points reconstructed in the process of calibration) of the SR-400 was much higher than the Kinect and the SLR. This study shows that the Kinect is a possible cheaper

and simpler alternative to previously used cameras and rigs in the computer vision field.

Another subject of research looking into using the Kinect, is the simultaneous localization and mapping algorithm, used to create a three-dimensional map of the world so that the robot can avoid collision with obstacles or walls. The SLAM problem could be solved using GPS if the robot is outside, but while the robot is inside, one needs to use wheel or visual odometry. Visual odometry determines the position and the orientation of the robot using the associated camera images. Algorithms like Scale Invariant Feature Transformation (SIFT), used to find the interest points, and laser sensors, are used to collect depth data. Since the Kinect has both the RGB camera and a laser sensor, this technology is a good piece of hardware to use for robots computing the SLAM Algorithm. In the study conducted in the Graduates School of Science and Technology at Meiji University, the students found that the Kinect worked well for this process for horizontal and straight movement, but they had errors when they tried to recreate an earlier experiment. Their algorithm successfully solves the initial problem, but accuracy fell over time.[5] The students found that the issue was not with the Kinect, and that it could be solved using the Speed-Up Robust Feature algorithm (SURF) and Smirnov-Grubbs test to further improve the accuracy of their SLAM Algorithm. This study proved that the Kinect was a reasonable, inexpensive and non-special piece of equipment that is capable of performing well in computer vision applications.

It seems as though the Kinect is a popular choice of camera and depth sensor in current robotics and computer vision. This device is affordable, easily obtainable, and capable of a lot more than is expected from a video game add on. The Kinect is surprisingly accurate, requiring minimal calibration and only some optimization software to make the results comparable to the results from a medium resolution SLR Stereo rig.

## **6.2 3-D Printing Future**

One of the most innovative uses for the three-dimensional Printer is its application in the medical field. Since 2010, people have been using three-dimensional printers to print out prosthetic limbs. One company in California has been printing the customizable prosthetics, which cost about one tenth of traditional prosthetics limbs. Another company is looking at the possibility of using a three-dimensional printer to print a house. Currently, the design fits on the back of a tractor trailer and the three-dimensional printer prints out custom concrete parts that are assembled to complete the house. Some three-dimensional printers have the ability to change the printing head, so it can begin printing with one material and then switch to a different material, all based on the code it receives. That a three-dimensional printer could theoretically print the concrete part of the house and switch to printing the plastic siding or the glass windows, all on the same path around the outside of the house. The most important aspect of these three-dimensional printer's application is that it drastically cuts down on production costs, allowing the consumer to pay a lower price and get a completely customized product. Rather than paying a person to design the object and have another construct it, with a three-dimensional printer all that needs to be done is the design and the three-dimensional printer automates the entire construction process. For example, the three-dimensional printed prosthetics cost 5,000 dollars to print and customize by covering the three-dimensional printed material in a shoe or sleeve while a normal generic prosthetics would cost about 60,000 dollars.[6] The three-dimensional printer is a piece of technology that could continue to make the price of consumer goods fall and allow for more customization than has ever existed for consumer products.

In recent news, biomedical scientists have taken the three-dimensional printing technology a step further than prosthetics. A man had 75% of his skull replaced but a three-dimensional printed implant made by Oxford Performance Materials. Since the 1940's, normal plastics have been used to replace missing bone fragments; now, three-dimensional modeling techniques can be used to exactly match the size and shape of the plastic to someone's skull. This Connecticut based company combined the three-dimensional modeling techniques with three-dimensional

printing technology to produce the replacement part that took only five days to fabricate.[2] The material used has some of the same properties as bones and are osteoconductive, meaning the skull will actually grow and attach itself to the implant. The plastic is much better than metals, which would block doctors from seeing past the implant in X-rays. This company is now also looking at using this procedure to three-dimensionally print other replacement bones for victims of cancerous bone or trauma.

Even though lower cost of production is a goal for many industries, the three-dimensional printing technology can be considered a disruptive technology, meaning that over the course of a short period of time it could change an existing market and value network, while replacing existing technology. An article in the Harvard Business Review explains that goods would be produced at or close to their point of purchase or consumption. Even if this is not the case with every industry, the cost will be offset by the elimination of shipping of the completed object to the consumer, something like car parts could be printed in a metropolitan area rather than made and shipped from a factory. This article also mentions how the three-dimensional printer would allow for cheap and efficient customization of these products. Since changing the shape, color, or material of what the machine is printing is only a matter of changing code, the first model could be relatively different than the second model for virtually no extra cost. [3] The three-dimensional printer could also potentially affect the global market. Many products are manufactured overseas since it is much cheaper for the pieces to be created and assembled by underpaid workers. When three-dimensional printing is perfected, the parts could be made and assembled by a machine in the US for less than it costs to have the product manufactured and shipped from overseas.

An article in Machine Design talks about what changes are being made to the three-dimensional printers in order to make them more durable, user friendly, and affordable. One brand, LeapFrog, has made the entire device out of aluminum and replaced the stepper-motor drivers with professional drivers that last longer. This company has also added a dual option extruder so that the printer could construct something like a bridge by adding the plastic from one extruder and a water soluble support system with the other extruder. This water soluble support system can be easily washed away once the printing is finished. The printer also uses PLA plastic, which is more brittle and has a lower melting temperature and can print smoother edges than the usual ABS plastic. Another brand, FormLabs, uses a liquid photopolymer instead of a spool of plastic. The resin cuts the price of printing materials in half and allows for a layer thickness of only 25 microns. The RepRap three-dimensional printer has been designated a self-replicating printer because it can be used to print parts for constructing another three-dimensional printer. It is believed that between 20,000 and 30,000 of these machines are now in existence.[4] The company Staples has started "Staples Easy three-dimensional" in Belgium and the Netherlands, where anyone can upload their file to the center and later pick up the three-dimensional model at their local Staples or have it shipped to their house. Services like this are a sign that three-dimensional printing will soon be as mainstream as two-dimensional printing is.

## 7 Appendix

### 0.1 KinectScan Application Code

```
1  ðŹnamespace kinectScan
   {
3      using System;
       using System.ComponentModel;
5      using System.Globalizati3n;
```

```

using System.IO;
7 using System.Threading.Tasks;
using System.Drawing;
9 using System.Diagnostics;
using System.Windows;
11 using System.Windows.Controls;
using System.Windows.Media;
13 using System.Windows.Media.Imaging;
using System.Windows.Media.Media3D;
15 using System.Windows.Threading;

17 using HelixToolkit.Wpf;

19 using Microsoft.Kinect;
using Microsoft.Kinect.Toolkit;

21
/// <summary>
23 /// Interaction logic for MainWindow.xaml
/// </summary>
25 public partial class MainWindow : Window
{
27
    /// <summary>
29    /// Timestamp of last depth frame in milliseconds
    /// </summary>
31    private long lastFrameTimestamp = 0;

33    /// <summary>
    /// Timer to count FPS
35    /// </summary>
    private DispatcherTimer fpsTimer;

37
    /// <summary>
39    /// Timer stamp of last computation of FPS
    /// </summary>
41    private DateTime lastFPSTimestamp;

43    /// <summary>
    /// Event interval for FPS timer
45    /// </summary>
    private const int FpsInterval = 5;

47
    /// <summary>

```

```

49      /// The counter for frames that have been processed
      /// </summary>
51      private int processedFrameCount = 0;

53      /// <summary>
      /// Active Kinect sensor
55      /// </summary>
      private KinectSensor sensor;

57      /// <summary>
59      /// Kinect sensor chooser object
      /// </summary>
61      private KinectSensorChooser sensorChooser;

63      /// <summary>
      /// Format of depth image to use
65      /// </summary>
      private const DepthImageFormat dFormat = DepthImageFormat.Resolution320x240Fps30;

67      /// <summary>
69      /// Format of color image to use
      /// </summary>
71      private const ColorImageFormat cFormat = ColorImageFormat.
          InfraredResolution640x480Fps30;

73      // stores furthest depth in the scene
      public ushort greatestDepth = 0;

75      // array for all of the depth data
77      private int[] Depth = new int[320 * 240];

79      // stores all of the 3D triangles with normals and points
      Model3DGroup modelGroup = new Model3DGroup();

81      // material placed over the mesh for viewing
83      public GeometryModel3D msheet = new GeometryModel3D();

85      // collection of corners for the triangles
      public Point3DCollection corners = new Point3DCollection();

87      // collection of all the triangles
89      public Int32Collection Triangles = new Int32Collection();

```

```

91      public MeshGeometry3D tmesh = new MeshGeometry3D();
93
94      // collection of all the cross product normals
95      public Vector3DCollection Normals = new Vector3DCollection();
96
97      // add texture to the mesh
98      public PointCollection myTextureCoordinatesCollection = new PointCollection();
99
100     // storage for camera, scene, etc...
101     public ModelVisual3D modelsVisual = new ModelVisual3D();
102
103
104     public Viewport3D myViewport = new Viewport3D();
105
106     // test variable
107     public int samplespot;
108
109     // variable for changing the quality 1 is the best 16 contains almost no data
110     public int s = 1;
111
112     // depth point collection
113     public int[] depths_array = new int[4];
114
115     // collection of points
116     Point3D[] points_array = new Point3D[4];
117
118     // collection of vectors
119     Vector3D[] vectors_array = new Vector3D[5];
120
121     //used for displaying RGB camera
122     public byte[] colorPixels;
123     public WriteableBitmap colorBitmap;
124
125     public MainWindow()
126     {
127         InitializeComponent();
128     }
129
130     private void WindowLoaded(object sender, RoutedEventArgs e)
131     {
132         // Start Kinect sensor chooser
133         this.sensorChooser = new KinectSensorChooser();

```



```

135         this.sensorChooserUI.KinectSensorChooser = this.sensorChooser;
136         this.sensorChooser.KinectChanged += this.OnKinectSensorChanged;
137         this.sensorChooser.Start();
138
139         // Start fps timer
140         this.fpsTimer = new DispatcherTimer(DispatcherPriority.Send);
141         this.fpsTimer.Interval = new TimeSpan(0, 0, FpsInterval);
142         this.fpsTimer.Tick += this.FpsTimerTick;
143         this.fpsTimer.Start();
144
145         // Set last fps timestamp as now
146         this.lastFPSTimestamp = DateTime.Now;
147     }
148
149     /// <summary>
150     /// Execute shutdown tasks
151     /// </summary>
152     /// <param name="sender">object sending the event</param>
153     /// <param name="e">event arguments</param>
154     private void WindowClosing(object sender, System.ComponentModel.CancelEventArgs e
155     )
156     {
157         // Stop timer
158         if (null != this.fpsTimer)
159         {
160             this.fpsTimer.Stop();
161             this.fpsTimer.Tick -= this.FpsTimerTick;
162         }
163
164         // Unregister Kinect sensor chooser event
165         if (null != this.sensorChooser)
166         {
167             this.sensorChooser.KinectChanged -= this.OnKinectSensorChanged;
168         }
169
170         // Stop sensor
171         if (null != this.sensor)
172         {
173             this.sensor.Stop();
174             this.sensor.DepthFrameReady -= this.SensorDepthFrameReady;
175             this.sensor.ColorFrameReady -= this.SensorColorFrameReady;
176         }
177     }

```

```

177         // Empty the canvas
        this.ClearMesh();
    }

179
    /// <summary>
181    /// Handles adding a new kinect
    /// </summary>
183    /// <param name="sender">object sending the event</param>
    /// <param name="e">event arguments for the newly connected Kinect</param>
185    private void OnKinectSensorChanged(object sender, KinectChangedEventArgs e)
    {
187        // Check new sensor's status
        if (this.sensor != e.NewSensor)
189        {
            // Stop old sensor
191            if (null != this.sensor)
            {
193                this.sensor.Stop();
                this.sensor.DepthFrameReady -= this.SensorDepthFrameReady;
195                this.sensor.ColorFrameReady -= this.SensorColorFrameReady;
            }

197            this.sensor = null;

199
            if (null != e.NewSensor && KinectStatus.Connected == e.NewSensor.Status)
201            {
                // Start new sensor
203                this.sensor = e.NewSensor;
                this.StartCameraStream(dFormat, cFormat);
205            }
        }

207
        if (null == this.sensor)
209        {
            // if no kinect clear the text on screen
211            this.statusBarText.Content = Properties.Resources.NoKinectReady;
            this.IR_Title.Content = "";
213            this.Model_Title.Content = "";
            this.RGB_Title.Content = "";
215        }
    }

217
    /// <summary>

```

```

219    /// Handler for FPS timer tick
220    /// </summary>
221    /// <param name="sender">Object sending the event</param>
222    /// <param name="e">Event arguments</param>
223    private void FpsTimerTick(object sender, EventArgs e)
224    {
225
226        if (null == this.sensor)
227        {
228            // Show "No ready Kinect found!" on status bar
229            this.KinectStatusText.Content = Properties.Resources.NoReadyKinect;
230        }
231        else
232        {
233            // Calculate time span from last calculation of FPS
234            double intervalSeconds = (DateTime.Now - this.lastFPSTimestamp).
                TotalSeconds;
235
236            // Calculate and show fps on status bar
237            this.KinectStatusText.Content = string.Format(
                System.Globalization.CultureInfo.InvariantCulture,
238            Properties.Resources.Fps,
239            (double) this.processedFrameCount / intervalSeconds);
240        }
241
242        // Reset frame counter
243        this.processedFrameCount = 0;
244        this.lastFPSTimestamp = DateTime.Now;
245    }
246
247    /// <summary>
248    /// Reset FPS timer and counter
249    /// </summary>
250    private void ResetFps()
251    {
252        // Restart fps timer
253        if (null != this.fpsTimer)
254        {
255            this.fpsTimer.Stop();
256            this.fpsTimer.Start();
257        }
258
259        // Reset frame counter

```

```

261         this.processedFrameCount = 0;
262         this.lastFPSTimestamp = DateTime.Now;
263     }

264     /// <summary>
265     /// Start depth stream at specific resolution
266     /// </summary>
267     /// <param name="format">The resolution of image in depth stream</param>
268     private void StartCameraStream(DepthImageFormat dFormat, ColorImageFormat cFormat
269     )
270     {
271         try
272         {
273             // Enable streams, register event handler and start
274             this.sensor.DepthStream.Enable(dFormat);
275             this.sensor.DepthFrameReady += this.SensorDepthFrameReady;
276             this.sensor.ColorStream.Enable(cFormat);
277             this.sensor.ColorFrameReady += this.SensorColorFrameReady;
278             this.sensor.Start();
279         }
280         catch (IOException ex)
281         {
282             // Device is in use
283             this.sensor = null;
284             this.ShowStatusMessage(ex.Message);
285
286             return;
287         }
288         catch (InvalidOperationException ex)
289         {
290             // Device is not valid, not supported or hardware feature unavailable
291             this.sensor = null;
292             this.ShowStatusMessage(ex.Message);
293
294             return;
295         }

296
297         // Allocate space to put the pixels we'll receive
298         this.colorPixels = new byte[this.sensor.ColorStream.FramePixelDataLength];
299
300         //// This is the bitmap we'll display on-screen
301         this.colorBitmap = new WriteableBitmap(this.sensor.ColorStream.FrameWidth,
            this.sensor.ColorStream.FrameHeight, 96.0, 96.0, PixelFormats.Gray16, null)

```

```

        );
    }

303
    /// <summary>
305    /// Event handler for Kinect sensor's ColorFrameReady event
    /// </summary>
307    /// <param name="sender">object sending the event</param>
    /// <param name="e">event arguments</param>
309    void SensorColorFrameReady(object sender, ColorImageFrameReadyEventArgs e)
    {
311        using (ColorImageFrame colorFrame = e.OpenColorImageFrame())
        {
313            if (colorFrame != null)
            {
315                // Copy the pixel data from the image to a temporary array
                colorFrame.CopyPixelDataTo(this.colorPixels);
317
                // Write the pixel data into our bitmap
319                this.colorBitmap.WritePixels(
                    new Int32Rect(0, 0, this.colorBitmap.PixelWidth, this.colorBitmap
                        .PixelHeight),
321                    this.colorPixels,
                    this.colorBitmap.PixelWidth * colorFrame.BytesPerPixel,
323                    0);
            }
325
            // set the RGB image to the RGB camera
327            this.KinectRGBView.Source = this.colorBitmap;
329        }
    }

331
    /// <summary>
333    /// Event handler for Kinect sensor's DepthFrameReady event
    /// Take in depth data
335    /// </summary>
    /// <param name="sender">object sending the event</param>
337    /// <param name="e">event arguments</param>
    void SensorDepthFrameReady(object sender, DepthImageFrameReadyEventArgs e)
339    {

341        DepthImageFrame imageFrame = e.OpenDepthImageFrame();
        if (imageFrame != null)

```

```

343     {
344         double maxDepth = Far_Filter_Slider.Value;
345         short[] pixelData = new short[imageFrame.PixelDataLength];
346         imageFrame.CopyPixelDataTo(pixelData);
347         this.greatestDepth = 0;
348         for (int y = 0; y < 240; y++)
349         {
350             for (int x = 0; x < 320; x++)
351             {
352                 // scale depth down
353                 this.Depth[x + (y * 320)] = ((ushort)pixelData[x + y * 320]) /
354                     100;
355
356                 // finds the furthest depth from all the depth pixels
357                 if ((this.Depth[x + y * 320] > this.greatestDepth) && (this.Depth
358                     [x + y * 320] < maxDepth))
359                 {
360                     this.greatestDepth = (ushort)this.Depth[x + y * 320];
361                 }
362             }
363         }
364         // Blur Filter -- Guassain
365         if (Filter_Blur.IsChecked == true)
366         {
367             for (int i = 641; i < this.Depth.Length - 641; ++i)
368             {
369
370                 short depthaverage = (Int16)((this.Depth[i - 641] + (2 * this.
371                     Depth[i - 640]) + this.Depth[i - 639] +
372                         (2 * this.Depth[i - 1]) + (4 * this.
373                             Depth[i]) + (2 * this.Depth[i +
374                                 2]) +
375                             this.Depth[i + 639] + (2 * this.
376                                 Depth[i + 640]) + this.Depth[i +
377                                     641]) / 16);
378
379                 this.Depth[i] = depthaverage;
380                 if ((this.Depth[i] > this.greatestDepth) && (this.Depth[i] <
381                     maxDepth))
382                 {
383                     this.greatestDepth = (ushort)this.Depth[i];
384                 }
385             }
386         }
387     }

```

```

379         }
380     }
381 }
382
383 // Set the depth image to the Depth sensor view
384 this.KinectDepthView.Source = DepthToBitmapSource(imageFrame);
385 }
386
387
388 /// <summary>
389 /// Flag check for a point within the bounding box
390 /// </summary>
391 /// <param name="x">location on the x plane</param>
392 /// <param name="y">location on the y plane</param>
393 private bool PointInRange(int x, int y)
394 {
395     double minDepth = Near_Filter_Slider.Value;
396     double maxDepth = Far_Filter_Slider.Value;
397     return ((this.Depth[x + (y * 320)] >= minDepth && this.Depth[x + (y * 320)]
398         <= maxDepth) ||
399         (this.Depth[(x + s) + (y * 320)] >= minDepth && this.Depth[(x + s) + (y *
400             320)] <= maxDepth) ||
401         (this.Depth[x + ((y + s) * 320)] >= minDepth && this.Depth[x + ((y + s) *
402             320)] <= maxDepth) ||
403         (this.Depth[(x + s) + ((y + s) * 320)] >= minDepth && this.Depth[(x + s)
404             + ((y + s) * 320)] <= maxDepth));
405 }
406
407 /// <summary>
408 /// Create the mesh
409 /// </summary>
410 void BuildMesh()
411 {
412     double maxDepth = Far_Filter_Slider.Value;
413     int i = 0;
414     for (int y = (int)Top_Slider.Value; y < ((int)Bot_Slider.Value - s); y = y +
415         s)
416     {
417         for (int x = (int)Left_Slider.Value; x < ((int)Right_Slider.Value - s); x
418             = x + s)
419         {

```

```

415 //Any point less than max
    if (PointinRange(x, y))
417 {
        if (this.Depth[x + ((y + s) * 320)] >= maxDepth)
419 {
            depths_array[0] = -this.greatestDepth;
421 }
        else
423 {
            depths_array[0] = -this.Depth[x + ((y + s) * 320)];
425 }

        if (this.Depth[x + (y * 320)] >= maxDepth)
427 {
            depths_array[1] = -this.greatestDepth;
429 }
        else
431 {
            depths_array[1] = -this.Depth[x + (y * 320)];
433 }

        if (this.Depth[(x + s) + (y * 320)] >= maxDepth)
435 {
            depths_array[2] = -this.greatestDepth;
437 }
        else
439 {
            depths_array[2] = -this.Depth[(x + s) + (y * 320)];
441 }

        if (this.Depth[(x + s) + ((y + s) * 320)] >= maxDepth)
445 {
            depths_array[3] = -this.greatestDepth;
447 }
        else
449 {
            depths_array[3] = -this.Depth[(x + s) + ((y + s) * 320)];
451 }

    // triangle point locations
453
    points_array[0] = new Point3D(x, (y + s), depths_array[0]);
    points_array[1] = new Point3D(x, y, depths_array[1]);
    points_array[2] = new Point3D((x + s), y, depths_array[2]);
457

```



```

459     points_array[3] = new Point3D((x + s), (y + s), depths_array[3]);

461     // create vectors of size difference between points
    vectors_array[0] = new Vector3D(points_array[1].X - points_array
        [0].X, points_array[1].Y - points_array[0].Y, points_array[1].
        Z - points_array[0].Z);
    vectors_array[1] = new Vector3D(points_array[1].X - points_array
        [2].X, points_array[1].Y - points_array[2].Y, points_array[1].
        Z - points_array[2].Z);
463     vectors_array[2] = new Vector3D(points_array[2].X - points_array
        [0].X, points_array[2].Y - points_array[0].Y, points_array[2].
        Z - points_array[0].Z);
    vectors_array[3] = new Vector3D(points_array[3].X - points_array
        [0].X, points_array[3].Y - points_array[0].Y, points_array[3].
        Z - points_array[0].Z);
465     vectors_array[4] = new Vector3D(points_array[2].X - points_array
        [3].X, points_array[2].Y - points_array[3].Y, points_array[2].
        Z - points_array[3].Z);

467     // add the corners to the 2 triangles to form a square
    corners.Add(points_array[0]);
469     corners.Add(points_array[1]);
    corners.Add(points_array[2]);
471     corners.Add(points_array[2]);
    corners.Add(points_array[3]);
473     corners.Add(points_array[0]);

475     // add triangles to the collection
    Triangles.Add(i);
477     Triangles.Add(i + 1);
    Triangles.Add(i + 2);
479     Triangles.Add(i + 3);
    Triangles.Add(i + 4);
481     Triangles.Add(i + 5);

483     // find the normals of the triangles by taking the cross product
    Normals.Add(Vector3D.CrossProduct(vectors_array[0], vectors_array
        [2]));
485     Normals.Add(Vector3D.CrossProduct(vectors_array[0], vectors_array
        [1]));
    Normals.Add(Vector3D.CrossProduct(vectors_array[1], vectors_array
        [2]));

```

```

487         Normals.Add(Vector3D.CrossProduct(vectors_array[1], vectors_array
        [2]));
        Normals.Add(Vector3D.CrossProduct(vectors_array[3], vectors_array
        [4]));
489         Normals.Add(Vector3D.CrossProduct(vectors_array[0], vectors_array
        [2]));

491         i = i + 6;
        }

493     }

495 }

497     // add the flat back wall
    int numcorners = corners.Count;
499     for (int p = 0; p < numcorners; p++)
    {
501         Point3D cornertocopy = corners[p];
        corners.Add(new Point3D(cornertocopy.X, cornertocopy.Y, -this.
            greatestDepth));
503         Triangles.Add(i);
        Normals.Add(new Vector3D(0, 0, 1));
505         i = i + 1;
    }

507

509 }

511     /// <summary>
    /// Create depth image from depth frame
513     /// </summary>
    /// <param name="imageFrame">collection of depth data</param>
515     BitmapSource DepthToBitmapSource(DepthImageFrame imageFrame)
    {
517         short[] pixelData = new short[imageFrame.PixelDataLength];
        imageFrame.CopyPixelDataTo(pixelData);
519         BitmapSource bmap = BitmapSource.Create(
            imageFrame.Width,
521            imageFrame.Height,
            96, 96,
523            PixelFormats.Gray16,
            null,
525            pixelData,

```

```

        imageFrame.Width * imageFrame.BytesPerPixel);
527     return bmap;
    }

529
    /// <summary>
531 /// take a photo when button is clicked
    /// </summary>
533 /// <param name="sender">object sending the event</param>
    /// <param name="e">event arguments</param>
535 private void Begin_Scan_Click(object sender, RoutedEventArgs e)
    {
537         //clear the canvas
        this.ClearMesh();

539
        // add light to the scene
541 DirectionalLight DirLight1 = new DirectionalLight();
        DirLight1.Color = Colors.White;
543 DirLight1.Direction = new Vector3D(0, 0, -1);

545
        // add a camera to the scene
        PerspectiveCamera Cameral = new PerspectiveCamera();

547
        // set the location of the camera
549 Cameral.Position = new Point3D(160, 120, 480);
        Cameral.LookDirection = new Vector3D(0, 0, -1);
551 Cameral.UpDirection = new Vector3D(0, -1, 0);

553
        // create the mesh from depth data
        this.BuildMesh();

555
        // add texture to all the points
557 tmesh.Positions = corners;
        tmesh.TriangleIndices = Triangles;
559 tmesh.Normals = Normals;
        tmesh.TextureCoordinates = myTextureCoordinatesCollection;
561 msheet.Geometry = tmesh;
        msheet.Material = new DiffuseMaterial((SolidColorBrush)(new BrushConverter().
            ConvertFrom("#52318F")));

563
        // build the scene and display it
565 this.modelGroup.Children.Add(msheet);
        this.modelGroup.Children.Add(DirLight1);
567 this.modelsVisual.Content = this.modelGroup;

```

```

569         this.myViewport.IsHitTestVisible = false;
        this.myViewport.Camera = Camera1;
        this.myViewport.Children.Add(this.modelsVisual);
571 KinectNormalView.Children.Add(this.myViewport);
        this.myViewport.Height = KinectNormalView.Height;
573 this.myViewport.Width = KinectNormalView.Width;
        Canvas.SetTop(this.myViewport, 0);
575 Canvas.SetLeft(this.myViewport, 0);

577     }

579     /// <summary>
580     /// Export the completed mesh to a .obj file
581     /// </summary>
582     /// <param name="sender">object sending the event</param>
583     /// <param name="e">event arguments</param>
private void Export_Model_Click(object sender, RoutedEventArgs e)
585     {
        //function from Helix Toolkit
587         string fileName = Model_Name.Text + ".obj";

589         using (var exporter = new ObjExporter(fileName))
        {
591             exporter.Export(this.modelGroup);
        }

593         // test code for seeing depth frame values
595         Process.Start("explorer.exe", "/select,\"\" + fileName + "\"");

597         string fileName2 = "depth.txt";

599         using (System.IO.StreamWriter file = new System.IO.StreamWriter(fileName2))
        {
601             //file.Write(string.Join(",", this.Depth));
            file.Write(greatestDepth);
603         }

605     }

607     /// <summary>
608     /// Show exception info on status bar
609     /// </summary>
    /// <param name="message">Message to show on status bar</param>

```

```

611     private void ShowStatusMessage(string message)
        {
613         this.Dispatcher.BeginInvoke((Action) (() =>
            {
615             this.ResetFps();
             this.KinectStatusText.Content = message;
617         }));
        }

619     /// <summary>
621     /// clear everything from the scene and canvas
623     /// </summary>
        public void ClearMesh()
        {
625             KinectNormalView.Children.Clear();
             modelGroup.Children.Clear();
627             myViewport.Children.Clear();
             modelsVisual.Children.Clear();
629             tmesh.Positions.Clear();
             tmesh.TriangleIndices.Clear();
631             tmesh.Normals.Clear();
             tmesh.TextureCoordinates.Clear();
633         }

635     /// <summary>
637     /// Clear canvas button click
639     /// </summary>
        /// <param name="sender">object sending the event</param>
        /// <param name="e">event arguments</param>
641     private void End_Scan_Click(object sender, RoutedEventArgs e)
        {
643         this.ClearMesh();
        }

645     }
}

```

## 0.2 KinectScan Graphical User Interface Code

```

1  ĩžŁ<Window
2      xmlns="http://schemas.microsoft.com/winfx/2006/xaml/presentation"
      xmlns:x="http://schemas.microsoft.com/winfx/2006/xaml"
4      xmlns:local="clr-namespace:kinectScan"

```

```

xmlns:sys="clr-namespace:System;assembly=mscorlib"
xmlns:d="http://schemas.microsoft.com/expression/blend/2008" xmlns:mc="http://
schemas.openxmlformats.org/markup-compatibility/2006" mc:Ignorable="d" x:Class
="kinectScan.MainWindow"
xmlns:tk="clr-namespace:Microsoft.Kinect.Toolkit;assembly=Microsoft.Kinect.
Toolkit"
Title="kinectScan" Height="870" Width="1028" Loaded="WindowLoaded" Closing="
WindowClosing" Top="0" Left="0" Icon="Images/Kinect.ico">

<Window.Resources>

    <ResourceDictionary Source="/KinectResources.xaml" />

</Window.Resources>

<Grid x:Name="LayoutGrid" Margin="0,0,0,0">

    <Grid.RowDefinitions>
        <RowDefinition />
    </Grid.RowDefinitions>

    <Grid.ColumnDefinitions>
        <ColumnDefinition Width="700" />
        <ColumnDefinition Width="30" />
        <ColumnDefinition />
    </Grid.ColumnDefinitions>

    <Rectangle Fill="{StaticResource_SecondaryBrandBrush}" />

    <Grid x:Name="CameraZone" Margin="0,0,0,0" TextBlock.FontFamily="{StaticResource_
KinectFont}" Grid.Column="0">

        <Grid.RowDefinitions>
            <RowDefinition Height="270" />
            <RowDefinition Height="30" />
            <RowDefinition Height="30" />
            <RowDefinition Height="510" />
        </Grid.RowDefinitions>

        <Grid.ColumnDefinitions>
            <ColumnDefinition Width="700" />
        </Grid.ColumnDefinitions>

```

```

44 <!-- Depth Camera -->
    <Rectangle Fill="{StaticResource_MediumNeutralBrush}" Grid.Row="0" Height="
        240" Width="320" Margin="30,30,350,0" />
    <Image Name="KinectDepthView" Grid.Row="0" Height="240" Width="320" Margin="
        30,30,350,0" />
46
    <!-- Bilateral Camera -->
48    <Rectangle Fill="{StaticResource_MediumNeutralBrush}" Grid.Row="0" Height="
        240" Width="320" Margin="350,30,30,0" />
    <Image Name="KinectRGBView" Grid.Row="0" Height="240" Width="320" Margin="
        350,30,30,0" />
50
    <!-- Reconstruction Model -->
52    <Grid x:Name="Reconstruction_Grid" Grid.Row="3">
        <Grid.ColumnDefinitions>
54            <ColumnDefinition Width="30" />
            <ColumnDefinition />
56            <ColumnDefinition Width="30" />
        </Grid.ColumnDefinitions>
58
        <Grid.RowDefinitions>
60            <RowDefinition Height="480" />
            <RowDefinition />
62        </Grid.RowDefinitions>

64        <Rectangle Fill="{StaticResource_MediumNeutralBrush}" Grid.Row="3" Height
            ="480" Width="640" Margin="30,0,30,30" />
        <Canvas Name="KinectNormalView" Grid.Column="1" Height="480" Width="640"
            Margin="0,0,0,30" Background="{StaticResource_MediumNeutralBrush}" />
66
        <!-- Bounding Box -->
68        <!-- <Border BorderBrush="Red" BorderThickness="1" Grid.Column="1" /> -->

70    </Grid>

72    <!-- Titles -->
    <Label x:Name="IR_Title" Content="IR_DEPTH_CAMERA" Grid.Row="1" Foreground="
        White" HorizontalAlignment="Left" Margin="30,0,0,0" VerticalAlignment="Top
        " />
74    <Label x:Name="RGB_Title" Content="RGB_CAMERA" Grid.Row="1" Foreground="
        White" HorizontalAlignment="Right" Margin="0,0,30,0" VerticalAlignment="
        Top" />

```

```

76      <Label x:Name="Model_Title" Content="RECONSTRUCTED_MODEL" Grid.Row="2"
          Foreground="White" HorizontalAlignment="Center" Margin="0,0,0,0"
          VerticalAlignment="Bottom" />
      <Label x:Name="statusBarText" Grid.Row="1" Foreground="White"
          HorizontalAlignment="Center" Margin="0,0,0,0" VerticalAlignment="Center"
          Grid.RowSpan="2" />
      <Label x:Name="KinectStatusText" Content="Kinect_Status:_Loading..." Grid.
          Row="3" Foreground="White" HorizontalAlignment="Left" Margin="10,0,0,5"
          VerticalAlignment="Bottom" />
78
      </Grid>
80      <!--CameraZone-->
82
      <Grid x:Name="MenuArea" Background="White" Grid.Column="2">
84
          <Grid.RowDefinitions>
              <RowDefinition Height="90" />
86              <RowDefinition Height="240" />
              <RowDefinition Height="50" />
88              <RowDefinition />
              <RowDefinition Height="30" />
90              <RowDefinition Height="100" />
          </Grid.RowDefinitions>
92
          <Grid.ColumnDefinitions>
94              <ColumnDefinition Width="290" />
          </Grid.ColumnDefinitions>
96
          <Button x:Name="Begin_Scan" Content="RECORD_FRAME" Margin="0,30,0,0" Style="
              {StaticResource_KinectButton}" Grid.Row="0" Click="Begin_Scan_Click" />
98      <Button x:Name="End_Scan" Content="CLEAR_CANVAS" Margin="137,30,0,0" Style="
              {StaticResource_KinectButton}" Grid.Row="0" Click="End_Scan_Click" />
100
      <!--BeginSlider Area-->
      <Grid x:Name="SliderArea" Background="White" Grid.Row="1" Margin="0,0,30,30"
          Grid.RowSpan="2">
102          <Grid.RowDefinitions>
              <RowDefinition Height="40" />
104              <RowDefinition Height="40" />
              <RowDefinition Height="40" />
106              <RowDefinition Height="40" />
              <RowDefinition Height="40" />
108              <RowDefinition Height="40" />

```



```

110         <RowDefinition Height="40" />
    </Grid.RowDefinitions>

112    <Grid.ColumnDefinitions>
        <ColumnDefinition Width="220" />
114        <ColumnDefinition Width="40" />
    </Grid.ColumnDefinitions>

116    <Label x:Name="Near_Filter_Title" Content="MIN_FILTER_DEPTH" Foreground="{
        {StaticResource_SecondaryBrandBrush}" HorizontalAlignment="Left"
        Margin="10,0,0,0" VerticalAlignment="Top" Grid.Row="0" Grid.Column="0"
        />
118    <Slider x:Name="Near_Filter_Slider" HorizontalAlignment="Left" Margin="
        10,20,0,0" VerticalAlignment="Top" Width="200" Style="{StaticResource_
        SliderStyle}" Grid.Row="0" Grid.Column="0" Minimum="0" Maximum="654"
        Value="0" />
        <Label x:Name="Near_Filter_Value" Content="{Binding_ElementName=
        Near_Filter_Slider,Path=Value}" ContentStringFormat="{0:N0}" Grid.
        Row="0" Grid.Column="1" Foreground="{StaticResource_
        SecondaryBrandBrush}" HorizontalAlignment="Left" VerticalAlignment="
        Center" />

120    <Label x:Name="Far_Filter_Title" Content="MAX_FILTER_DEPTH" Foreground="{
        StaticResource_SecondaryBrandBrush}" HorizontalAlignment="Left" Margin
        ="10,0,0,0" VerticalAlignment="Top" Grid.Row="1" Grid.Column="0" />
122    <Slider x:Name="Far_Filter_Slider" HorizontalAlignment="Left" Margin="
        10,20,0,0" VerticalAlignment="Top" Width="200" Style="{StaticResource_
        SliderStyle}" Grid.Row="1" Grid.Column="0" Minimum="{Binding_
        ElementName=Near_Filter_Slider,Path=Value}" Maximum="654" Value="300" /
        >
        <Label x:Name="Far_Filter_Value" Content="{Binding_ElementName=
        Far_Filter_Slider,Path=Value}" ContentStringFormat="{0:N0}" Grid.Row
        ="1" Grid.Column="1" Foreground="{StaticResource_SecondaryBrandBrush}"
        HorizontalAlignment="Left" VerticalAlignment="Center" />

124    <Label x:Name="Left_Title" Content="LEFT_BOUND" Foreground="{
        StaticResource_SecondaryBrandBrush}" HorizontalAlignment="Left" Margin
        ="10,0,0,0" VerticalAlignment="Top" Grid.Row="2" Grid.Column="0" />
126    <Slider x:Name="Left_Slider" HorizontalAlignment="Left" Margin="
        10,20,0,0" VerticalAlignment="Top" Width="200" Style="{StaticResource_
        SliderStyle}" Grid.Row="2" Grid.Column="0" Minimum="0" Maximum="320"
        Value="0" />

```

```
<Label x:Name="Left_Value" Content="{Binding_ElementName=Left_Slider ,Path
=Value}" ContentStringFormat="{0:N0}" Grid.Row="2" Grid.Column="1"
Foreground="{StaticResource_SecondaryBrandBrush}" HorizontalAlignment=
"Left" VerticalAlignment="Center" />
```

```
<Label x:Name="Right_Title" Content="RIGHT_BOUND" Foreground="{
StaticResource_SecondaryBrandBrush}" HorizontalAlignment="Left" Margin
="10,0,0,0" VerticalAlignment="Top" Grid.Row="3" Grid.Column="0" />
```

```
<Slider x:Name="Right_Slider" HorizontalAlignment="Left" Margin="
10,20,0,0" VerticalAlignment="Top" Width="200" Style="{StaticResource_
SliderStyle}" Grid.Row="3" Grid.Column="0" Minimum="0" Maximum="320"
Value="320"/>
```

```
<Label x:Name="Right_Value" Content="{Binding_ElementName=Right_Slider ,
Path=Value}" ContentStringFormat="{0:N0}" Grid.Row="3" Grid.Column="
1" Foreground="{StaticResource_SecondaryBrandBrush}"
HorizontalAlignment="Left" VerticalAlignment="Center" />
```

```
<Label x:Name="Top_Title" Content="TOP_BOUND" Foreground="{StaticResource
_SecondaryBrandBrush}" HorizontalAlignment="Left" Margin="10,0,0,0"
VerticalAlignment="Top" Grid.Row="4" Grid.Column="0" />
```

```
<Slider x:Name="Top_Slider" HorizontalAlignment="Left" Margin="10,20,0,0
" VerticalAlignment="Top" Width="200" Style="{StaticResource_
SliderStyle}" Grid.Row="4" Grid.Column="0" Minimum="0" Maximum="240"
Value="0"/>
```

```
<Label x:Name="Top_Value" Content="{Binding_ElementName=Top_Slider ,Path=
Value}" ContentStringFormat="{0:N0}" Grid.Row="4" Grid.Column="1"
Foreground="{StaticResource_SecondaryBrandBrush}" HorizontalAlignment=
"Left" VerticalAlignment="Center" />
```

```
<Label x:Name="Bot_Title" Content="BOTTOM_BOUND" Foreground="{
StaticResource_SecondaryBrandBrush}" HorizontalAlignment="Left" Margin
="10,0,0,0" VerticalAlignment="Top" Grid.Row="5" Grid.Column="0" />
```

```
<Slider x:Name="Bot_Slider" HorizontalAlignment="Left" Margin="10,20,0,0
" VerticalAlignment="Top" Width="200" Style="{StaticResource_
SliderStyle}" Grid.Row="5" Grid.Column="0" Minimum="0" Maximum="240"
Value="240"/>
```

```
<Label x:Name="Bot_Value" Content="{Binding_ElementName=Bot_Slider ,Path=
Value}" ContentStringFormat="{0:N0}" Grid.Row="5" Grid.Column="1"
Foreground="{StaticResource_SecondaryBrandBrush}" HorizontalAlignment=
"Left" VerticalAlignment="Center" />
```

```
</Grid>
```

```
<!--EndSliderArea-->
```

```

144 <!--Begin Radio-->
    <Label x:Name="Filter_Type_Title" Content="FILTER_TYPE" Foreground="{
        StaticResource_SecondaryBrandBrush}" HorizontalAlignment="Left" Margin="
        10,0,0,0" VerticalAlignment="Top" Grid.Row="2" />
    <RadioButton Name="Filter_Off" Content="Off" HorizontalAlignment="Left"
        Margin="10,30,0,0" Grid.Row="2" VerticalAlignment="Top" IsChecked="True" /
        >
146 <RadioButton Name="Filter_Blur" Content="Blur" HorizontalAlignment="Left"
        Margin="60,30,0,0" Grid.Row="2" VerticalAlignment="Top" />
    <!--End Radio-->
148
    <!--ModelNameArea-->
150 <Grid x:Name="ModelNameArea" Grid.Row="4">
        <Grid.RowDefinitions>
152         <RowDefinition />
        </Grid.RowDefinitions>
154
        <Grid.ColumnDefinitions>
156         <ColumnDefinition Width="100" />
        <ColumnDefinition />
158 </Grid.ColumnDefinitions>
        <Label x:Name="Name_Label" Content="MODEL_NAME:" Foreground="{
            StaticResource_SecondaryBrandBrush}" HorizontalAlignment="Left"
            VerticalAlignment="Top" Grid.Column="0" Margin="7,0,0,0" />
160 <TextBox x:Name="Model_Name" Text="modelName" HorizontalAlignment="Left"
            VerticalAlignment="Top" Width="140" Margin="17,0,0,0" Grid.Column="1
            " />
        </Grid>
162 <!--EndModelNameArea-->
164 <Button x:Name="Export_Model" VerticalAlignment="Bottom" Margin="50,0,0,23"
        Style="{StaticResource_KinectButton}" Grid.Row="5" Click="
        Export_Model_Click">
        <StackPanel Orientation="Horizontal">
166         <Label x:Name="Export_Label" Content="EXPORT_MODEL" Foreground="White
            " FontFamily="{StaticResource_KinectFont}" FontSize="14" Padding="
            0,0,10,0" />
            <Image x:Name="Download" Source="Images/download.png" Width="23"
                Height="23" HorizontalAlignment="Left" VerticalAlignment="Top" />
168         </StackPanel>
        </Button>
170 <!-- <TextBox Name="test_text" HorizontalAlignment="Left" Height="109" Margin
        ="42,124,0,0" Grid.Row="3" TextWrapping="Wrap" Text="TextBox"

```

```

172         VerticalAlignment="Top" Width="209" /> -->
173     </Grid>
174     <!--MenuArea-->
175     <tk:KinectSensorChooserUI Name="sensorChooserUI" HorizontalAlignment="Center"
176         Margin="330,0,330,5" />
177 </Grid>
178 <!--LayoutGrid-->
179
180 </Window>

```

## References

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- [6] Ashlee Vance. 3-d printing spurs a manufacturing revolution. *New York Times*, 2010.