Using LIDAR and Animation to Develop Surveillance Strategies

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Abstract

Stationary ground based LIght Detection And Ranging (LIDAR) is used to measure points in three-dimensional (3D) space and the processing of these points can generate an extremely accurate three-dimensional model of the scanned area. One 360 degree scan from a LIDAR instrument can generate 4 million or more points. Using the combined points from multiple scans, an accurate three-dimensional scene can be generated within a computer. By creating a virtual camera with select parameters, the viewer can virtually move to any point in the scene in order to display the scene from the chosen vantage point. This capability is used in conjunction with animation to assess the placement of surveillance cameras. The resulting animation highlights areas that are visible to the camera and those areas that the camera is unable to detect. The animation provides additional assessment for systems with multiple cameras to clearly visualize overlapping areas of coverage and to avoid blind spots.

This paper describes the process of conducting the LIDAR scans, transferring the scanned information into an animation program, and the process of assessing points in the scene to establish the location for surveillance cameras. This site assessment process provides an analysis that reduces the cost of a surveillance system by decreasing the number of cameras required while enhancing the surveillance coverage.

Introduction

Development of surveillance strategies in the placement of security cameras has received increased interest as security concerns have escalated. Most current methods of siting security cameras are founded on a two-dimensional (2D) footprint of the area of security concern. The 2D ground plane of the surveillance area in some models is extruded to develop a three-dimensional (3D) area of surveillance. Extrusions such as this provide vertical planes that simulate walls, barriers or other impediments to the line of site of the surveillance camera. Recent developments in LIDAR (LIght Detection And Ranging) technology have provided instruments that have the capability of creating a 3D surveyed representation of any site. These representations are a collection of points referred to as a point cloud. Each point in the point cloud is accurate to within 3 millimeters and the number of points obtained from a LIDAR scan can be several million. When the point cloud is displayed, the sheer number and accuracy of the points in the point cloud appears to be a photorealistic image of the area. The photorealism and accuracy of the points provides the ability to move anywhere within the point cloud and visualize the 3D scene from that point.

This paper couples the point cloud images obtained from LIDAR scans and the manipulation of digital cameras in animation software to locate surveillance cameras. The advantage of this process is that an actual 3D model of the surveillance area is used to place surveillance cameras. Within this 3D image the 3D view of the camera defined by the field of view (FOV), depth of field (DOF) and other characteristics of the selected camera is inserted to establish the 3D space visible to the camera. Animation is then used to assess the placement of cameras to for best coverage of the area of security concern. This assessment provides stratigic placement of security cameras in order to maximize coverage and minimize cost. The animated scene can also have lighting applied to simulate the actual lighting within the FOV of the camera. Additional lights can be added to the scene to assess increased visibility. The animated scene can also introduce obstacles to the FOV of the camera in the form of vehicular traffic, pedestrian traffic, or vegetative growth to simulate a variety of actual conditions.

Current Practice

The current practice in placing surveillance cameras typically follows one of two design scenarios: 1) minimize the number of cameras while covering the region of interest (ROI) and 2) maximizing the ROI using the minimum number of cameras. In each case the economics of the total cost of the system is typically a driving factor in the ultimate design. Initial camera acquisition and installation costs in addition to system maintenance and data storage cost are all factors driving the cost of the security system. Interviews with individuals from institutions and municipalities that currently own, operate and maintain surveillance systems indicate that the placement of the cameras of the system primarily follow guidelines identified by the Department of Homeland Security that are designed to secure and regulate physical access to facilities, enhance safety, prevent crimes, and assist in the investigation of criminal acts. Video surveillance also supports facility protection with its visible presence, and detects and deters unauthorized intrusion at facilities [1]. The design of camera placement within a security system varies dramatically in practice. The process can be as simple as standing at a particular location and observing the area to establish what can be viewed by a camera or it can be a complex process as described by Ghanem et. al. [2] which uses convex binary quadratic program to site cameras. This method allows the user to provide user-defined parameters in the design process in order to optimize the camera placement solution. The primary limitation to all current models is the limitation of placing cameras in a true 3D scene of the ROI and analyze and display the coverage in a 3D perspective.

Problem Definition

This paper details the use of LIDAR 3D scans of ROI in the development of a camera surveillance system with the use of animation. Current practice in siting security cameras, as described in the previous section, has a very wide range of sophistication. Even the most sophisticated methods provide limited 3D visualization of the region of interest. LIDAR scans of areas provide a 3D representation of the area and allow the viewer to digitally move anywhere within the scene and view of the region of interest from that vantage point. An example LIDAR scan is shown in Figure 1. The scan shown in Figure 1 consists of millions of points. Each point is plotted within the established coordinate system. A viewer (or camera) can be moved to any location within the scan and from that position observe all points to which there is a line of site. This process allows the actual siting of a camera and the determination of the coverage that results.

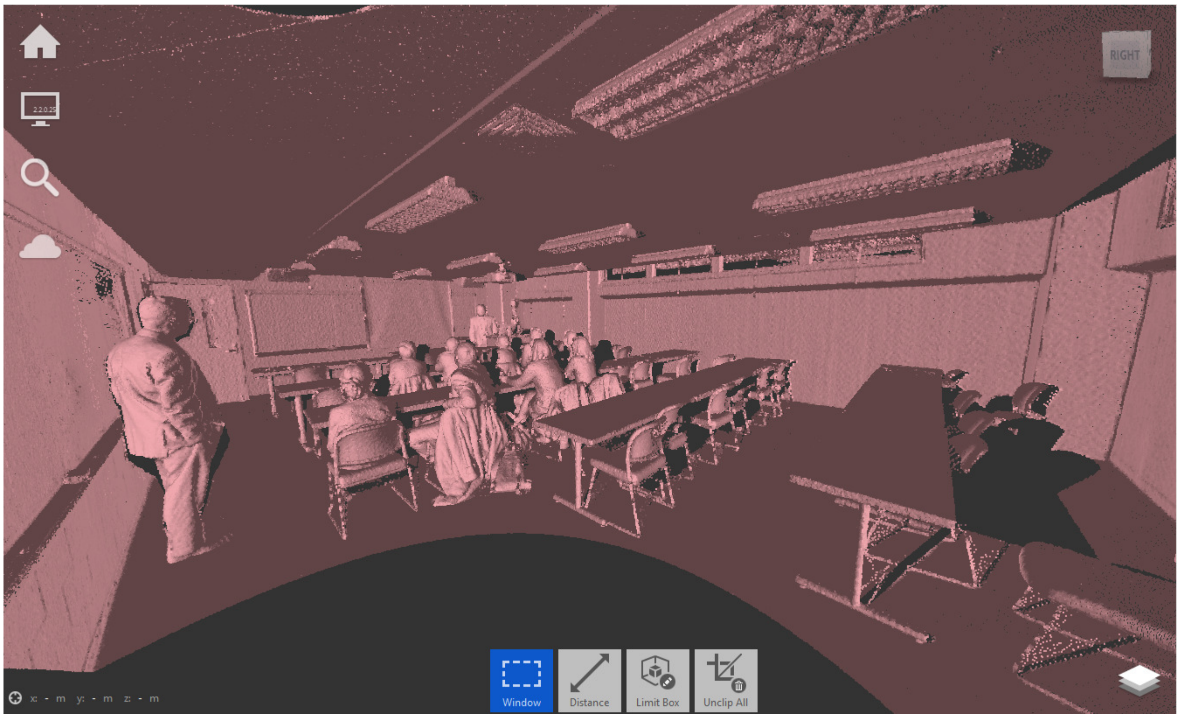

Figure 1: Example of a LIDAR scan. The point cloud shows a true 3D representation of the area.

The object of this work is to link the LIDAR 3D scanned image to animation software in order to assess the visual coverage of the ROI and in doing so minimize the number of cameras while maintaining or increasing the FOV. This assessment will decrease cost and enhance coverage of the security system. In addition, the animation assesses lighting within the region of interest and provides simulation of vehicular traffic, pedestrian traffic or vegetative growth.

LIDAR Scanning to Obtain 3D Image of Surveillance Area

LIDAR, which stands for LIght Detection And Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to objects. These light pulses combine with other data recorded by the LIDAR instrument and generate precise, three-dimensional information about the shape of objects and other surface information [3]. The laser pulse from a LIDAR instrument is similar to radar technology, which uses radio waves (instead of light) to range to an object by measuring the time delay between the transmission of a pulse and the detection of the return signal. LIDAR instruments can collect an enormous number of points in a very short period of time. The image acquired and shown in Figure 1 had a collection rate of approximately 120,000 points per second. The 360 degree scan obtained in order to generate Figure 1 was made in about 4 minutes which resulted in approximately 29 million points in this one scan. As describe above LIDAR uses a laser to measure distance and therefore will only record distances to objects that are within the line of site of the instrument. In order to obtain a true 3D rendering of a region of interest, several scans—each from a different location within the area—may be required. Figure 2 shows the same scene depicted in Figure 1 but from a different viewing angle. The darker region of Figure 2 in the lower left of the image indicates an area that was not visible by the scan position of the instrument and therefore had no returns. In order to represent this region in the 3D rendering, the LIDAR instrument would be moved to a point where this region is visible and another scan would provide points in this area. Software available with the LIDAR scanner allows the two scans (two point clouds) to be combined. Multiple scans can be digitally assembled to represent the entire scene.

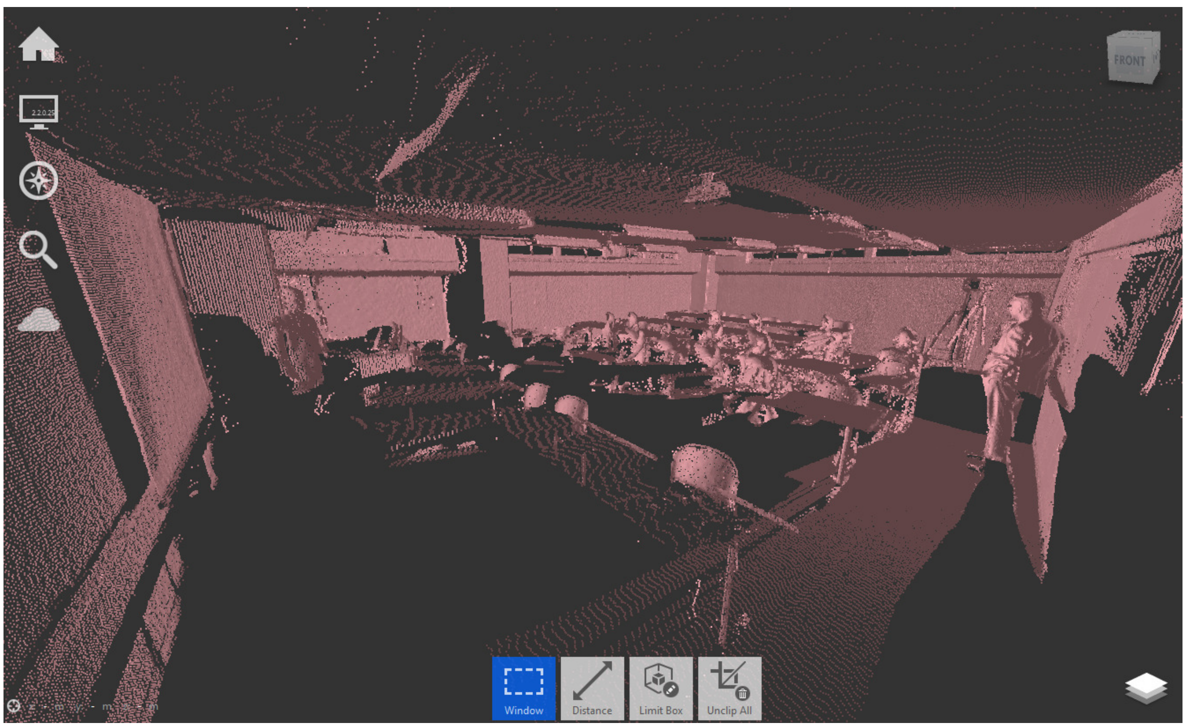

Figure 2: Example of LIDAR scan viewed from a different perspective within the scene.

LIDAR also has the capability of monitoring reflectance and amplitude. Figure 3 is an example of the reflectance recorded for each point measured in the scan shown in the two previous figures. The reflectance parameter displays as white or lighter color indicating high reflectance and a darker color indicating low reflectance. Since security cameras are recording reflected light, areas of low reflectivity may result in poor image quality. Analysis

ISBN 978-1-60643-379-9

of the LIDAR scan using the reflectivity return can identify these regions of low reflectivity indicating areas that may require additional lighting for optimal surveillance.

LIDAR scanning of a region of interest can be completed relatively rapidly. One scan position can acquire an image in approximately 15 minutes. The complexity of the region of interest will dictate the required number of scan positions in order to generate a true 3D rendering with minimal blind spots.

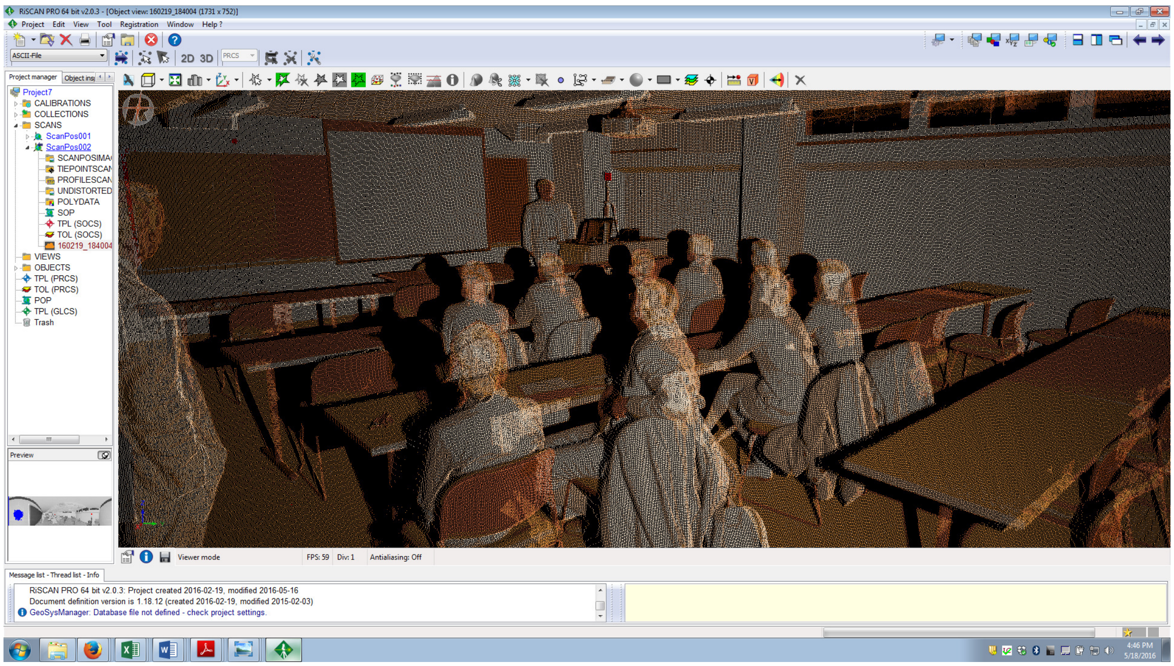

Figure 3: Recorded reflectance of LIDAR scan (lighter color higher reflectance darker color lower reflectance).

Integrating the 3D LIDAR Scan into Animation Software

The LIDAR equipment comes with provided software which is meant to interpret the scanned scene. Although robust in its interpretation of data, points, and other collected information, the software is not animation software. Animation software can typically provide creation of lights, creation of cameras, and time-based media such as the movement of animated objects. All of these examples can be adjusted with complexity to demonstrate a wide range of environmental changes in the ROI.

One of the biggest challenges to bridging the gap between the provided LIDAR software and the animation software is the interpretation of the point cloud as a visible entity. In the LIDAR software, each point appears as a solid orb. The overlapping of the orbs creates the illusion of a solid surface. However, many animation programs require a “mesh” for an object’s visualization and cannot show a point cloud in the same manner as the LIDAR software. A mesh is a series of vertices connected by edges. If the edges connect and form a closed shape like a triangle, the edges are filled-in with a flat face and appear as a solid shape. In this way, a collection of connected faces create the appearance of a surface. The following process outlines one way to navigate through creating a mesh from the scanned LIDAR point cloud.

Upon successful completion of a LIDAR scan(s), the point cloud(s) are then assembled in the LIDAR software and exported for cleanup. This demonstration used an ASCII file which is a text-based recording of all points in the point cloud. Autodesk Recap 360 [4] offers a wide range of interpretations of point cloud files including the ability to open *.las, *.asc, and *.xyz. A full list of Autodesk Recap 360 Ultimate's supported file types can be seen in Figure 4.

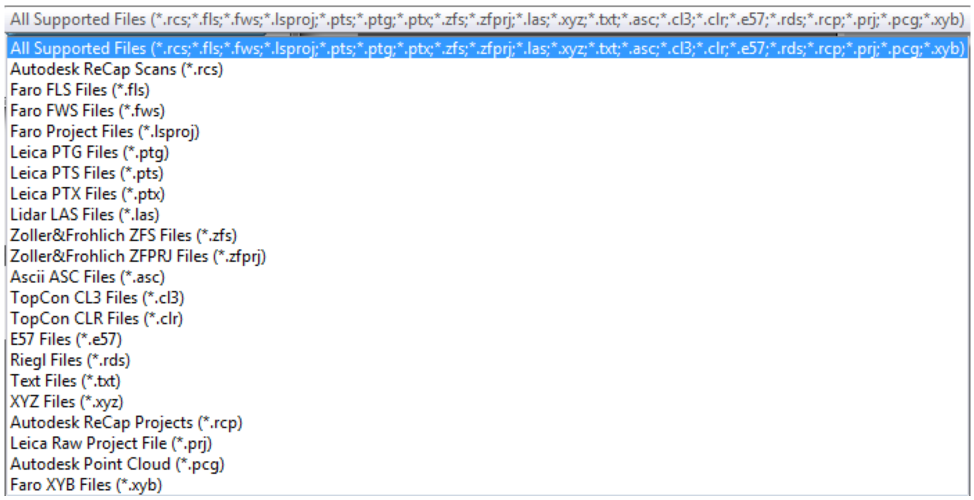

Figure 4: Supported file types for importing into Autodesk Recap 360 Ultimate

Since LIDAR relies on lasers for collecting data, the recorded points in a point cloud can reach a significant distance from the LIDAR's physical scan location. To facilitate the next step in creating a mesh, it is best to reduce unnecessary points by deleting them. Figure 5 shows how a laser penetrated the scanned room through transparent surfaces such as windows or semi-transparent surfaces such as leaves and collected other points. The block in the lower right corner represents the room displayed in Figures 1 and 2. The software can easily "fence-in" a designated area by clicking around the desired location to keep (in this case the room) and clip out all other points—see Figure 6.

What remains after the clean-up is consistent with the visuals from Figure 1 and Figure 2. Clean-up is an easy way to reduce file size and ignore points that should not be part of the mesh-creation for the following steps. The file is now ready to be exported for mesh-creation. Typically, exporting as a *.pts file will yield the best results for the next program.

There are a few programs such as MeshLab and CloudCompare which offer the necessary commands to create normals and tessellate a mesh. This paper will examine the use of CloudCompare [5]. It should also be noted that CloudCompare has the capability to clean-up the original point cloud which would negate the use of Autodesk Recap 360, but the ease of use in Autodesk Recap 360 "fence-in" process facilitated a faster pipeline to the end product.

Figure 5: Demonstration of full point cloud from single scan prior to point cloud clean-up.

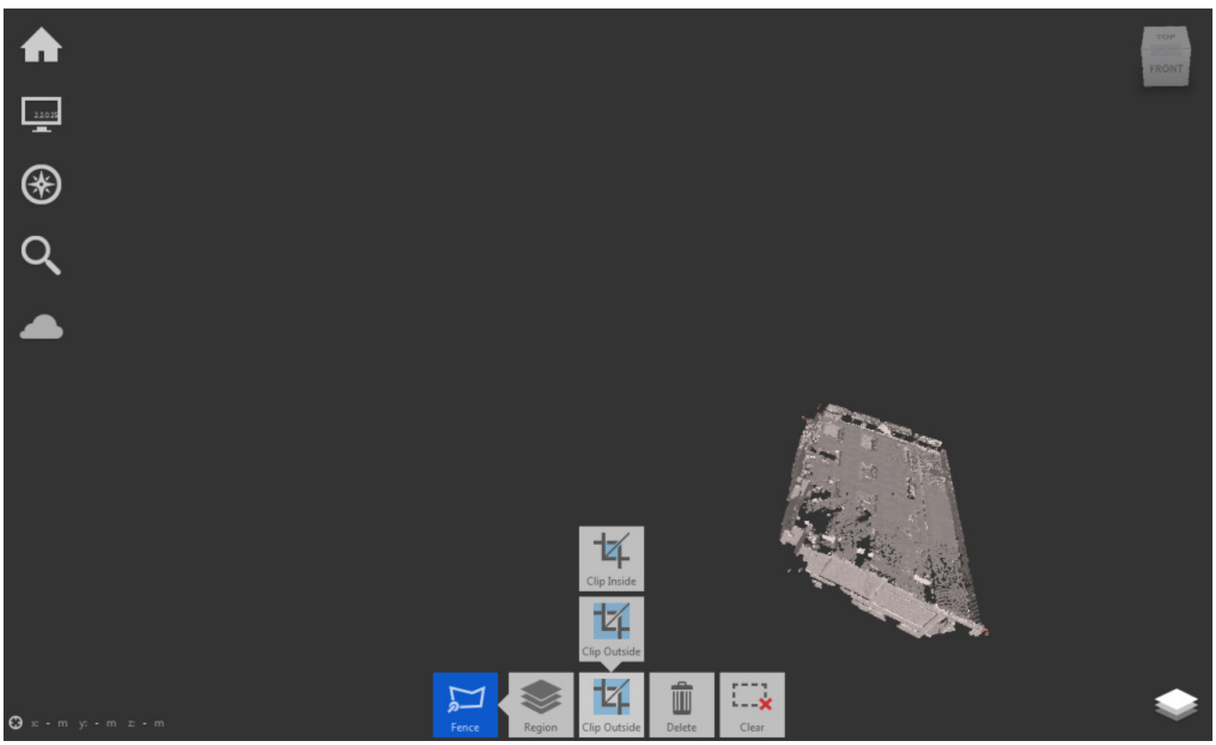

Figure 6: Fencing-in desired location and clipping all other points.

CloudCompare offers an extensive list of compatible file extensions including *.pts (See Figure 7). Upon opening a *.pts file it is necessary to skip the header in the text file; this may be important for other file types as well.

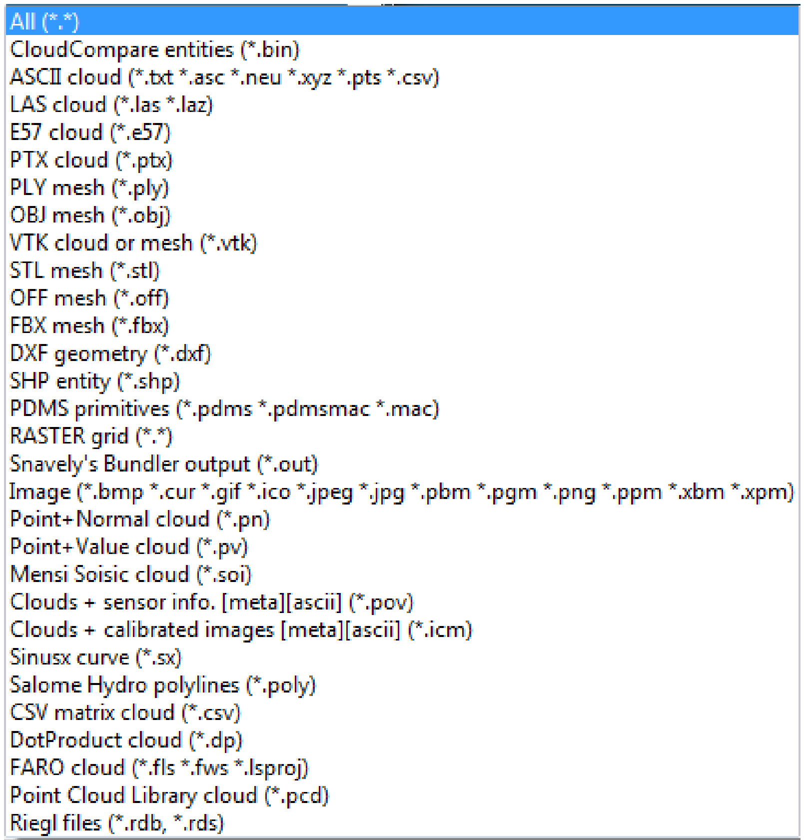

Figure 7: List of file extensions compatible with CloudCompare.

Upon opening the point cloud in CloudCompare, it is necessary to prepare it for mesh creation. To do so, the point cloud must first generate normals. Normals assist the orientation of a face within a mesh. Since a face has no thickness, it is important for the face to determine which side of the face in inward-facing and which side is outward-facing. This is particularly important for the animation software to render the texture or color on the mesh and to create usable data in lighting situations. As such, this is a common and easy procedure in CloudCompare. With the point cloud selected, simply choose Edit>Normals>Compute. Depending on the settings, each point determines which way to orient a normal based off of the points around it.

Once the normals are computed, the points are now ready to generate a mesh. This paper will use the established Poisson Surface Reconstruction method. Figure 8 shows the differences based on the Octree depth calculation; the higher the Octree depth, the better the detail of the mesh, but the file size can become unruly when reaching high numbers. When the mesh is generated, CloudCompare can export many common polygonal mesh types such as *.fbx, *.obj, *.stl, *.dxf, *.ply, and *.ma.

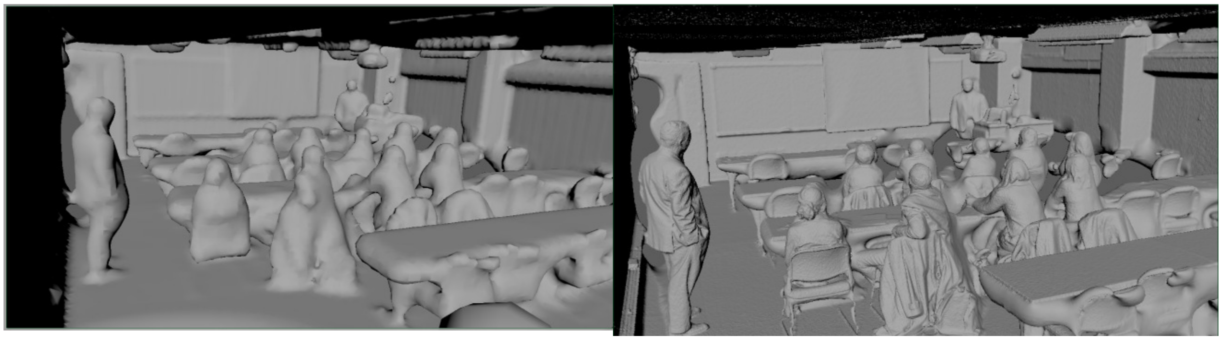

Figure 8: Mesh within Autodesk Maya. Octree level 8 (left)—file-size 18.4MB—and level 13 (right)—file-size 1.15GB.

Importing the mesh file into animation software such as Autodesk Maya, Autodesk 3DS Max, or Blender is easily completed. This paper will demonstrate use of animation techniques in Autodesk Maya [6]. Note that CloudCompare can export the Maya file extension *.ma which simply needs to be opened in Maya versus imported.

With the mesh created and imported into the animation software, the animator can create cameras to view the mesh from any angle, lights to emulate visual conditions such as night visibility, street lighting, and shadows, and animation to simulate typical movement in a scene to demonstrate visual coverage.

Multiple cameras can be placed in one Maya scene similar to visualizing the point cloud in the LIDAR software as demonstrated in Figure 9. Note that the mesh was based off of the point cloud, so any shortcoming in terms of line of site from the scan will also be reflected in the mesh. The camera benefit to the animation software is the customization of the camera's settings. In Maya, each camera can have independent settings for position and rotation, making it easy to set up multiple cameras and switch between them for comparison. Additionally, parameters such as resolution, focal length, center of interest, and depth of field (among others) can all be adjusted per camera. These settings can be adjusted to generate visuals in order to compare different camera technical specifications. Any of the settings can also be animated within Maya to change over time. An example of practical application for camera animation would be a camera that is continually sweeping or scanning an area.

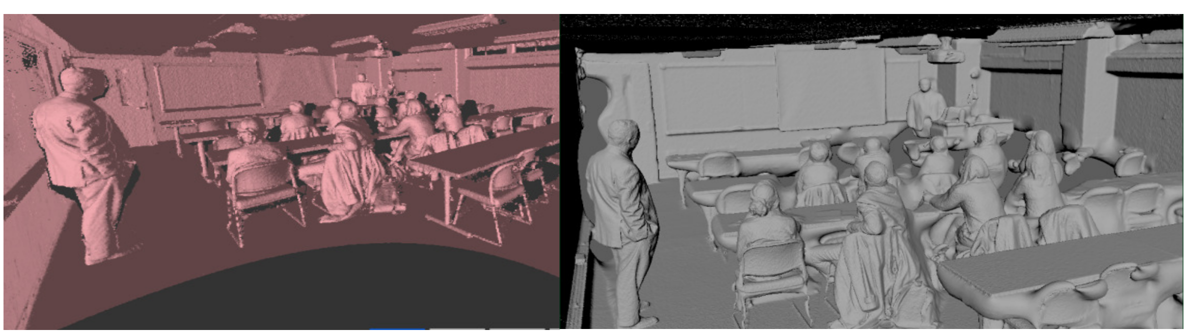

Figure 9: Comparison of point cloud visualization in LIDAR software (left) to mesh visualization in animation software (right).

The animation software can also add numerous lights to the scene. In Figure 10, the circular icon close to the wall on the right side of the image represents a point light. The cone shape close to the ceiling on the left side of the image represents a spotlight. Point lights are light sources that emit in all directions (similar to light bulbs) while spotlights emit a cone of light in one direction (similar to a flashlight). Notice in Figure 10 that the spotlight is emitting a bright green light directly downward while the point light is emitting a blue light that gradually fades as it gets further from the light source. Another notable light in Maya is a directional light which could be used to emulate the sun. All three of these light types could be used in one scene to replicate different lighting conditions within an environment. The notable light attributes that can be customized and animated include color, cone angle (only for spotlights), intensity, falloff, and shadows.

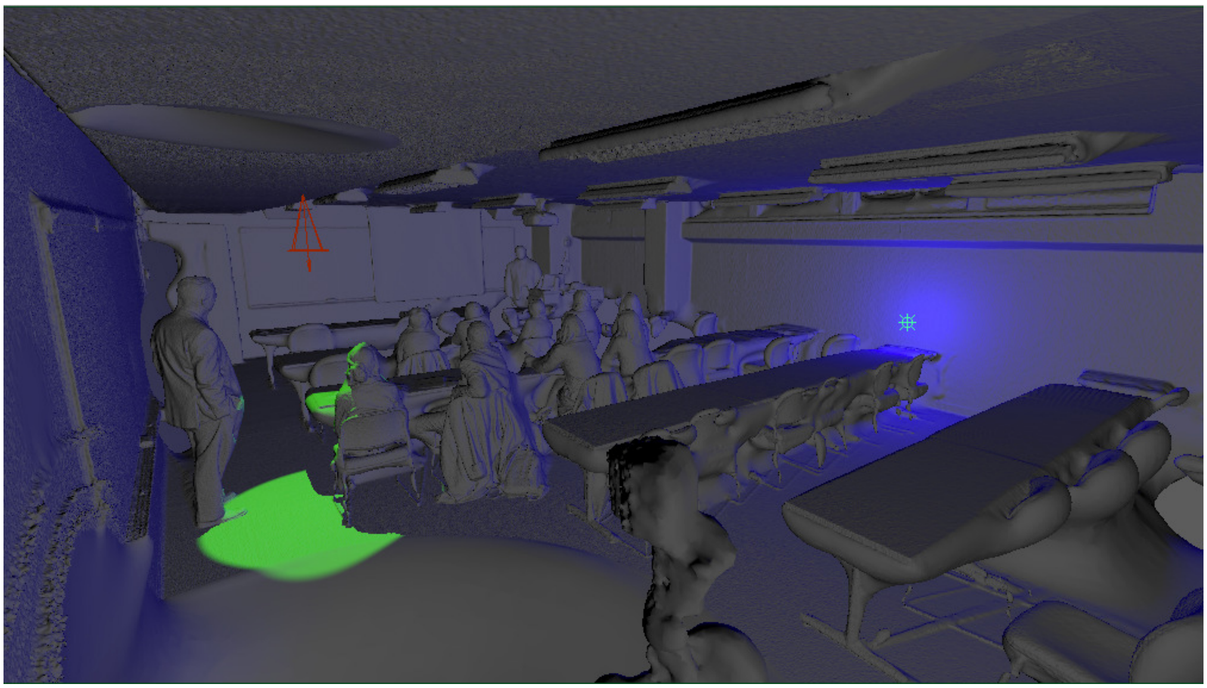

Figure 10: Visualization of two different light sources in Maya: spotlight (emitting green on left) and point light (emitting purple on right).

The third advantage to incorporating a LIDAR scan in animation software that will be highlighted in this paper is animation of objects. Practically any object or attribute in Maya can be animated. This could be useful in visually demonstrating camera movement as mentioned previously. Animation would also be useful in showing typical movement in a captured scene. For example, if a person typically walks into a room from a certain location and has limited locations to move based on the room setup, a digital character can be animated to walk in common paths. This can be useful in identifying blind spots for camera positions and optimizing key components of surveillance (Figure 11). Animation can also be applied to any model such as cars or any other object of note. Similarly, if a certain subject in

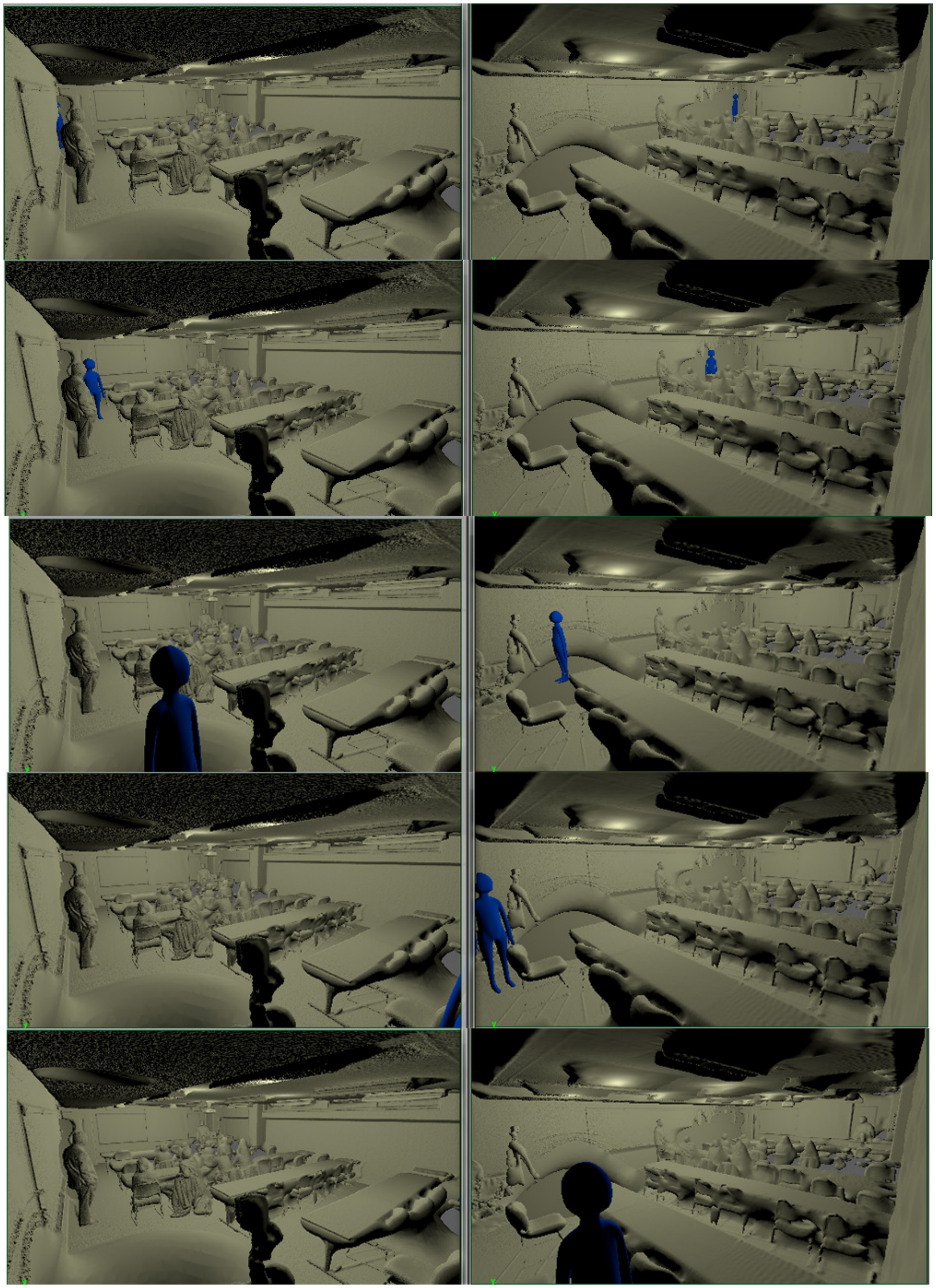

Figure 11: Camera position 1 (left column of images) appears to be covering the room, but Camera position 2 (right column of images) demonstrates the blind spot from the first position.

the captured scene was the purpose for the surveillance, such as securing the safety of artwork, monitoring entrances and exits, or capturing movement at an intersection, this could all be simulated prior to the decision of surveillance camera location. Animations can be viewed within the software or can be exported as movie files such as *.avi and *.mov.

Establishing Surveillance Strategies

Combining the use of LIDAR scans and animation software provides extended capabilities of surveillance camera placement. This combination provides true 3D representation of the region of interest and the capability of inserting a camera, with specific camera parameters, into the scene to evaluate the field of view. Figure 12 provides a 3D image showing the field of view of a camera (shown in dark pink) placed in the scene. In addition, the animation provides the capability of inserting light sources to simulate how the camera is functioning with variable lighting conditions and how moving objects into the scene may impact the field of view.

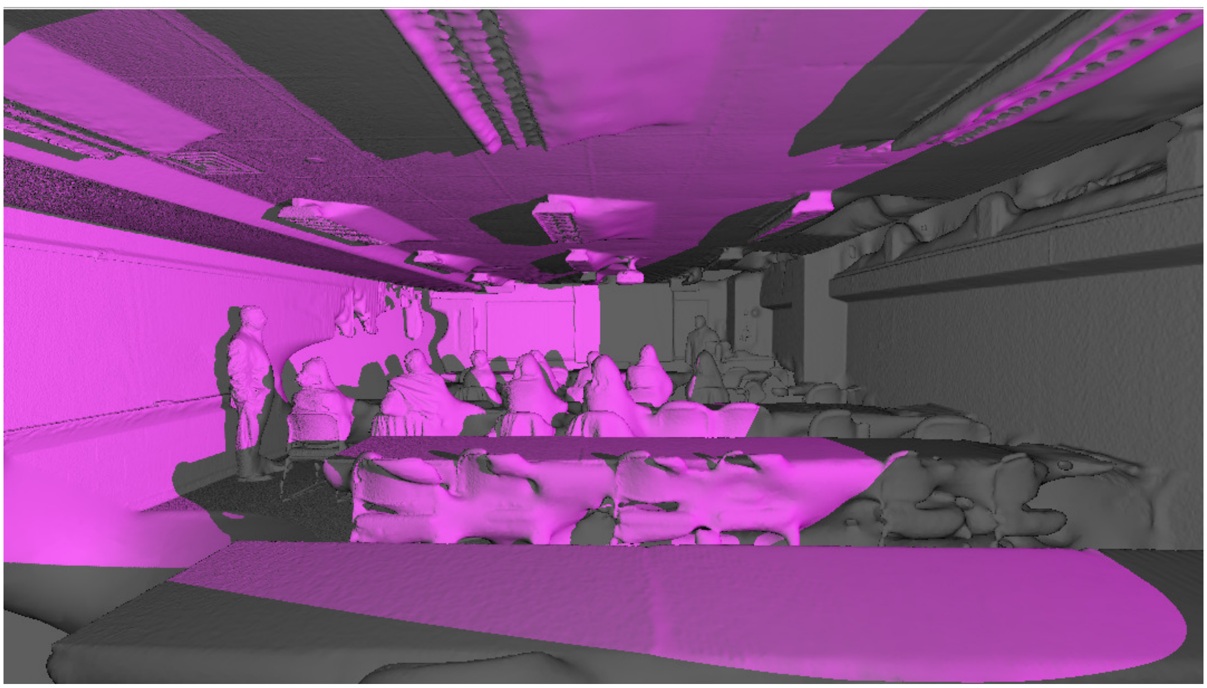

Figure 12: Camera inserted into the scene to demonstrate areas covered in the field of view.

Developing the combined LIDAR and animation package for a specific location provides a true 3D tool to evaluate current surveillance camera locations. Once the 3D scene is developed in the animation software from the LIDAR scan, cameras with instrument specific characteristics can be placed at the locations and tilt angles of existing cameras. The resulting image from each camera location can be compared to the video from the existing camera. The field of view of the camera can be modeled as a spot light and areas that are illuminated are those that are within the line of sight of the camera (similar to the spot light and green area shown in Figure 10). Applying a spotlight to each camera location provides a scene showing the area of coverage of the surveillance system. Placement positions and camera mounting angles can be changed to simulate moving the camera to obtain better coverage. In addition, animated lighting and objects in the scene can be evaluated to determine the impact of each on the surveillance area.

The design of a new surveillance system would initially identify areas that had the highest priority for surveillance and movement in the 3D image to locations that have the best vantage point of providing the necessary quality of video monitoring. Animated features (cars, trucks, people) can be inserted into the image through animation to determine if the coverage is sufficient to meet security concerns. Developing a matrix of cameras within the scene provides the ability to monitor the scene from a network of camera locations during animation. Once a network of cameras is established, testing of the network as described above in the analysis of an existing system provides assessment of the camera placement.

Conclusion

This work shows that the use of LIDAR scans to establish a true 3D scene of a region of interest for a surveillance system and the integration of the 3D scene into animation software provides an effective tool to optimize the siting of security cameras. In addition, the capabilities of the animation software provide the opportunity to assess the lighting within the scene and the movement of objects that could have an impact on the line of site of the camera. This system has been demonstrated to have potential in evaluating current surveillance systems and in the design of surveillance systems not yet deployed. The results of the application of this system can reduce the number of cameras within a region of interest while increasing the coverage within the region. This results in lower cost of the system in both camera acquisition and installation and in data storage and greater surveillance area.

References

[1] Department of Homeland Security (2011), Privacy Impact Assessment Security Management CCTV System, DHS/ICE/PIA-030.

[2] Ghanem, B., Cao, Y., & Wonka, P. (2015). Designing Camera Networks by Convex Quadratic Programming. Computer Graphics Forum, John Wiley & Sons Ltd.

[3] National Oceanic and Atmospheric Adminstration, What is LIDAR?, Website: http://oceanservice.noaa.gov/facts/lidar.html.

[4] Autodesk Recap 360 (2016), Overview, Website: http://www.autodesk.com/products/recap-360/overview.

[5] CloudCompare 2.7, 3D Point Cloud and Mesh Processing Software Open Source Project, Website: http://www.daniellgm.net/cc/.

[6] Autodesk Maya 2016 (2016), Overview, Website: http://www.autodesk.com/products/maya/overview.

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