DOI: 10.2352/ISSN.2470-1173.2016.7MOBMU-297

Supplementation of Lidar Scans with Structure from Motion (SfM) Data

Fabian Gassen, Eberhard Hasche, Patrick Ingwer, Reiner Creutzburg
Brandenburg University of Applied Sciences, Department of Informatics and Media, P. O. Box 2132, D-14737 Brandenburg, Germany

Abstract

Lidar (light and radar or light detection and ranging) and SfM (structure from motion) are valuable tools for generating meshes from real world objects. In the entertainment sector these technologies come in convenient for the production. Since both methods have their advantages this paper examines the process of using both technologies in combination. Point clouds are generated using both methods and combining the results into one point cloud and creating a mesh. This generated 3D object can be used in VFX.

Introduction - Problem Statement

In film industry new technologies continuously push image and visual effects quality to new levels. 3D techniques for visual effects are present in almost every recent movie or TV series. Nowadays, most movies and TV shows only build parts of the set in real life while the rest is inserted digitally in the post production process. Therefore, it is a big advantage if the film set is digitized. Lidar scans offer one opportunity but are not suitable for arbitrary environments.

In those cases SfM provides an alternative to produce good quality point clouds [5]. For the SfM method consumer cameras are sufficient and due to their light weight they can be used in combination with drones, cranes and other high mobility equipment. Therefore, they are suitable for narrow and aerial spaces such as difficult accessible roof structures [6].

This paper deals with the workflow and methods to supplement lidar scans with additional Stucture from Motion (SfM) data to improve the results. Lidar scanners such as those produced by the company FARO generate highly detailed and accurate point clouds. On the downside, these scanners are big and heavy, thus not practicable or usable in every situation as mentioned above.

However, when scanning a building lidar is perfect tool for instance, scanning facades and large areas and structures. In thoses cases normally there is enough room for setting up a lidar scanner, providing the better and more convenient way to scan. Nevertheless, there are situations where not all structures and details can be scanned with the lidar technology. At this point other devices are needed in order to scan for instance the roof of a building. Such a device might be a drone or a crane. Using such equipment, dimensions and weight of a scanner have to be taken into consideration. There SfM appears to be a good alternative.

For the experiment in this paper two point clouds of the same object have been generated. One point cloud was recorded with a lidar scanner, the second one has been created using the SfM method and a consumer camera. Both are merged into one point cloud. For testing purposes, parts of the lidar scan have been deleted in order to simulate an incomplete scan which can be supplemented with SfM data. The new, resulting point cloud is then remeshed for use in a 3D software such as Autodesk Maya.

History of Lidar technology

Lidar (light and radar or light detection and ranging) dates back to the 1930s where it was first used to measure air density. This was accomplished by determining the scattering intensity from a searchlight beam. In 1938 light pulses were used to measure cloud base heights. With the use of light pulses it was possible to replace a bistatic with a monostatic setup. The acronym lidar was introduced by Middleton and Spielhaus in 1953.

With the era of laser technology which developed rapidly, lidar evolved too. Lidar and laser technology did benefit from each other over the time. Lidar researchers also worked in the field of laser technology to meet the requirements for the lidar scanners such as beam power, shape and wavelength [1].

Lidar

The basic setup of a lidar scanner is a transmitter and a receiver. Light pulses are generated using a laser. They last from a few up to hundreds of nanoseconds with specific properties. Some systems use a beam expander to reduce the divergence. The receiver consists of a telescope, a field stop and an analyzing system depending on the application. The telescope collects the backscattered photons from the laser beam. The analyzing unit selects the relevant wavelengths for the purpose and sends them to a detector which converts the optical signal into an electrical one [1].

SfM

Structure from Motion or short SfM is a method to retrieve 3D information from a series of images. A camera maps a 3D object from the real world onto a 2D camera sensor.
Within this process the third dimension gets lost. Photogrammetry is basically an inverse process to recover the third dimension again. From one picture it is possible to reconstruct the camera position by identifying three features. This locks the camera in two dimensions. But the photo could still move in the third dimension because there is no reference of how small or big the objects in the image are. To recreate the scene or object every photo has to

DOI: 10.2352/ISSN.2470-1173.2016.7MOBMU-297

contain a certain number of identical features from a different perspective. When all cameras are arranged in 3D space, rays can be shot from the cameras through those features. At a certain point different the rays of all cameras will intersect. This point of intersection reveals the z location of this particular feature. If repeated several times a point cloud can be generated.

Application of Lidar and SfM

The use of lidar technology has emerged since its invention. Today this technique is used in a wide variety of business fields.

In aviation lidar is used to observe the visibility conditions at an airport. For approaching aircrafts it is important to be aware of the fogginess on the ground and on a lifted level. This can be accomplished using lidar scanners.
Another vital condition in aviation is the determination of the base cloud height which is measured by ceilometers that also take advantage of lidar technology [1].

On construction sites lidar scanners are used to keep track of the building progress [7]. Usually survey teams would take a lot of time to measure a construction site which is extremely expensive and time-consuming. On a $100 million project between $500,000 and $1 million are spent on surveying the site [4].

Google has developed its self-driving car which requests highly accurate data of its surroundings to be able to detect obstacles and possibly dangerous situations. The Google car features a variety of sensors. One of them uses lidar technology to scan the environment in real-time and generate a mesh that is used to detect those hazards as seen in figure 1 [8]. The incident report provided by Google (Figure 2) shows that the use of self-driving cars is not unrealistic in the near future. In recent tests, the car had one disengagement per approximately 6000 miles [10].

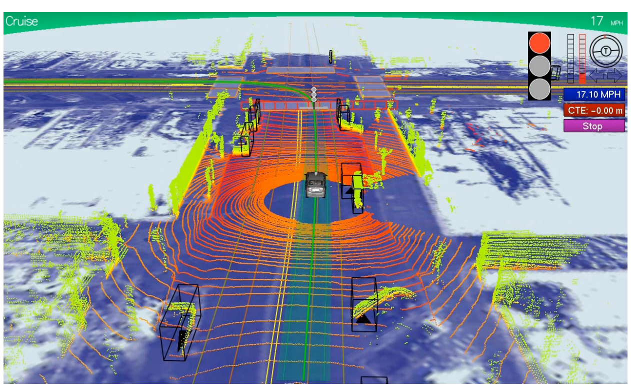

Abbildung 1. *View of the Google Self-Driving Car [11].*

In the automotive industry there has been a recent innovation equipping taillights with lidar technique. Under poor weather conditions a lot of accidents happen due to bad visibility. Fog, rain or dirt affect the perception of lights in traffic. Therefore, a system is in development that captures not only the visibility parameters, but also measures the distance to the following car and its speed. A computer can then adjust the taillight's brightness.

In the entertainment industry lidar and SfM have become a key technique to scan sets, environments or faces, either for games or for movies or TV shows. Movies have a huge production pipeline, preproduction starts way before a scene is filmed. Often previzualisations are required and laser scanners are suitable tools for that. Even later in the pipeline those scans can be used or retaken to augment a set or use the data for colliding geometry in simulations.
The SfM method can be used for the scanning of faces, setting up multiple consumer cameras that are attached to a rig (Figure 3). The cameras are set up in a way, that every angle is covered and their pictures overlap.

Setup - Workflow - Software

The object used in the experiment described in this paper is a university building.

For the SfM point cloud a RED Scarlet-X was used in 4K mode. The shot was dollied and filmed parallel to building to get parallax. In the Foundry's Nuke every tenth frame has been rendered as a jpeg image. The result were about 60 images for the SfM reconstruction. In Agisoft Photoscan all images were aligned without using any masks. Agisoft Photoscan offers the

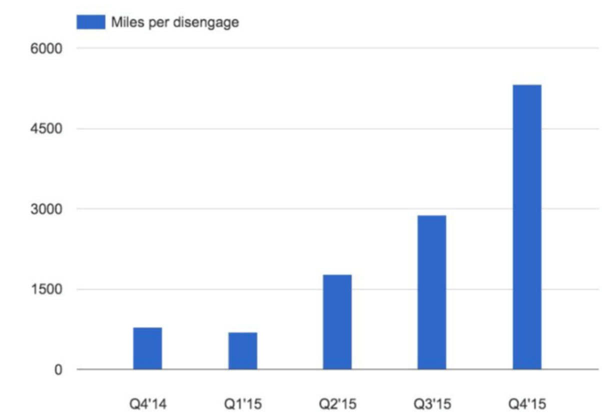

Abbildung 2. *Mileage per disengagement by the driver [10].*

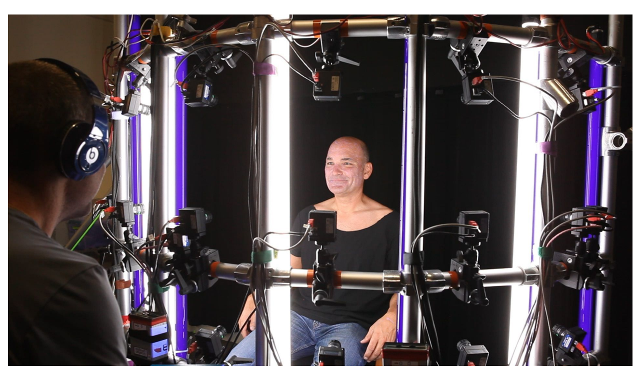

Abbildung 3. *Setup to scan a face [9].*

functionality to build a dense point cloud, applied in the next step. The dense point cloud was exported for the alignment process with the lidar scan.

The lidar scanner in use is produced by the company Faro. For the point cloud of the building two scans were recorded to capture the whole building. In the software Scene, provided by Faro as well, the two scans were merged into one large scan and exported as well.

In the free software Cloud Compare both point clouds, the one from the lidar scanner and the point cloud reconstructed with the SfM method were loaded. While both point clouds feature the whole building, for proof of concept parts of the lidar scan were deleted to supplement the lack of information with the SfM data.

Cloud Compare comes with a feature that allows to align both clouds by picking four points. The aligned point clouds were then merged into one new point cloud containing the lidar scan and a small part of the SfM cloud. This new cloud was then exported to Meshlab for the remeshing process.

Meshlab is a free Software as well which offers many filters for remeshing and sub-sampling. At first, face normals are calculated for the point cloud. Hereafter, Meshlab offers a sub-sampling to thin out the cloud and speed up the remeshing process. In the final step the remeshing algorithm is applied.

Results

The initial point cloud generated by Agisoft Photoscan is a spatial point cloud which would be sufficient for the use in previsualization or as collider geometry in fluid simulations. In combination with a lidar point cloud it turns out, that the remesher in Meshlab has problems meshing the cloud. This issue might be caused by the different point cloud densities. The final mesh generated by Meshlab only used the points provided by the lidar scan and ignored the ones from the SfM point cloud. Probably because the lidar scanner has a higher resolution.
Sub-sampling the lidar point cloud to a lower level resulted in an edged mesh which is not the desired result.

Fortunately, Agisoft Photoscan offers the option of generating a dense cloud. With the dense cloud generated, it is possible to process the point cloud with lidar and SfM data at the same time. The computer used for the calculations is an iMac with a 2,8GHz i5 and 20GB of RAM storage. Generating the spatial point cloud in Photoscan took about 30 minutes which is relatively quick. Howerever, calculating the dense cloud took about 30 hours.

During the experiment, the meshing process in Meshlab had been very slow and the program crashed very often. Therefore, the cloud of the scanned building which was remeshed was reduced to a minimum.

Even though the SfM point cloud seems to be good for generating a mesh (see figure 4), it turns out that the density is still not sufficient to be processed along with a lidar cloud. Either, more photos have to be taken or the lidar scan and the SfM scan have to be processed separately, so the parameter can be adjusted to the right cloud resolution. Figure 5 shows the final mesh generated with Meshlab.As figure 5 shows, the difference between where the lidar scan ends and where the SfM cloud starts is immense.

To show that it is possible to generate a point cloud comparable to the density of the lidar scan, a much smaller object has been used. This object, a baseball, was placed on a turntable which made it possible to take more images from various angles for the construction of the point cloud. This experiment resulted in a much higher resolution mesh. The final result of a rendering in Autodesk Maya with Mental Ray can be seen in figure 6.

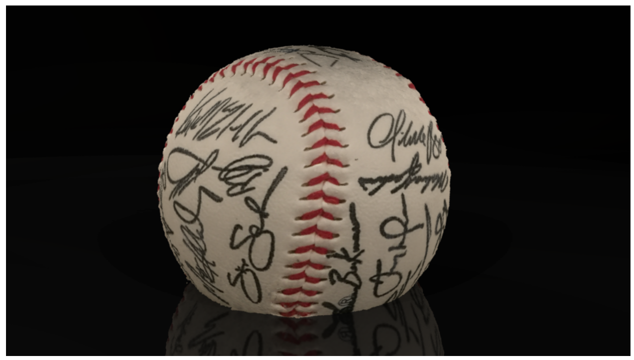

Abbildung 6. *Rendering of a mesh generated with SfM in Agisoft Photoscan.*

Conclusion

All in all, the results of the scanned building are not satisfying for the time being. However, as this is an ongoing research and the issues concerning point density can be fixed with more pictures taken of the object. This will result in more computational power needed and/or longer render times.

In the future, more software will be used such as Geomagic and VisualSFM.

Literatur

[1] Claus Weitkamp: Lidar Range-Resolved Optical Remote Sensing of the Atmosphere, Springer, 0-387-40075-3, 2005.
[2] Tim Dobbert: Matchmoving the Invisible Art of Camera Tracking 2nd Edition, Sybex, 978-1-118-35205-2, 2013.
[3] Jeffrey A. Okun, Susan Zwerman: The VES Handbook of Visual Effects, Focal Press, 978-0-240-81242-7, 2010.
[4] Geraldine S. Cheok; William C. Stone: Non-Intrusive Scanning Technology for Construction Assessment, Proc. ISARC, pg. 645-650. (1999).
[5] Patrick Ingwer, Fabian Gassen, Stefan Pst, Melanie Duhn, Marten Schlicke, Katja Mller, Heiko Ruhm, Josephin Rettig, Eberhard Hasche, Arno Fischer, Reiner Creutzburg: Practical Usefulness of Structure from Motion (SfM) Point Clouds Obtained from Different Consumer Cameras, SPIE Proc. vol. 9411 (2015).
[6] Patrick Ingwer, Fabian Gassen, Stefan Pst, Melanie Duhn, Marten

DOI: 10.2352/ISSN.2470-1173.2016.7MOBMU-297

Schlicke, Katja Mller, Heiko Ruhm, Josephin Rettig, Eberhard Hasche, Arno Fischer, Reiner Creutzburg: Investigations of Practical Usefulness of Structure from Motion (SfM) Point Clouds Obtained from Different Consumer Cameras, Research Report of Brandenburg University of Applied Sciences 2013 - 2014, Brandenburg 2015, pp. 181-187.

[7] Jenny Knackmuß, Stefan Maack, Reiner Creutzburg; Comparative Visualization of Geometry of a Hollow Box Girder Using 3D Lidar - Part 1 Cross Sectional Area, Proc. Electronic Imaging 2016 (in print).

[8] Erico Guizzo: How Google's Self-Driving Car Works, IEEE Spectrum, IEEE, 10/18/2001, Web 1/4/2016.

[9] FX Guide, Web 1/4/2016.

[10] Google: Google Self-Driving Car Testing Report on Disengagements of Autonomous Mode December 2015, Google Self-Driving Car Project, Dec. 2015, Web 1/4/2016.

[11] Hot Digital News, Web 1/4/2016.

Author Biography

Fabian Gassen received his Bachelor of Science in Media Informatics from the Mittelhessen University of Applied Sciences, Germany (2013) and is currently enrolled for a Master of Science in Digital Media at the Brandenburg University of Applied Sciences, Germany. He will finish his master studies in 2016.

Eberhard Hasche received his diploma in Electrical Engineering from the Technical University of Dresden (1976). Afterwards he studied double bass, composition and arranging at Hochschule für Musik Carl Maria von Weber in Dresden (state examination 1989). At this time worked as theater musician and in the 1990s as trainer and technician for digital music production. Since 2003 professor for Audio and Video Technology at Brandenburg University of Applied Sciences. Since then he focused on Image Compositing (certified Nuke Trainer by The Foundry in 2012).

Patrick Ingwer received his diploma (2006) and M. Sc. (2009) from Brandenburg University of Applied Sciences. Worked as sound engineer, camera assistant and cameraman for German television ARD / RBB and currently as scientific assistant at Brandenburg University of Applied Sciences. The focus of his work is camera work, above all stereo3D, 3D-scanning and processing. He publishes also albums with electronic music.

Reiner Creutzburg received his Diploma in Math from the University of Rostock, Germany (1976). Since 1992 he is professor for Applied Informatics at the Brandenburg University of Applied Sciences in Brandenburg, Germany. He is member in the IEEE and SPIE and chairman of the "Multimedia on Mobile Device" Conference at the Electronic Imaging conferences since 2005.

DOI: 10.2352/ISSN.2470-1173.2016.7MOBMU-297

Abbildung 4. *Point cloud with lidar and SfM data in Meshlab.*

DOI: 10.2352/ISSN.2470-1173.2016.7MOBMU-297

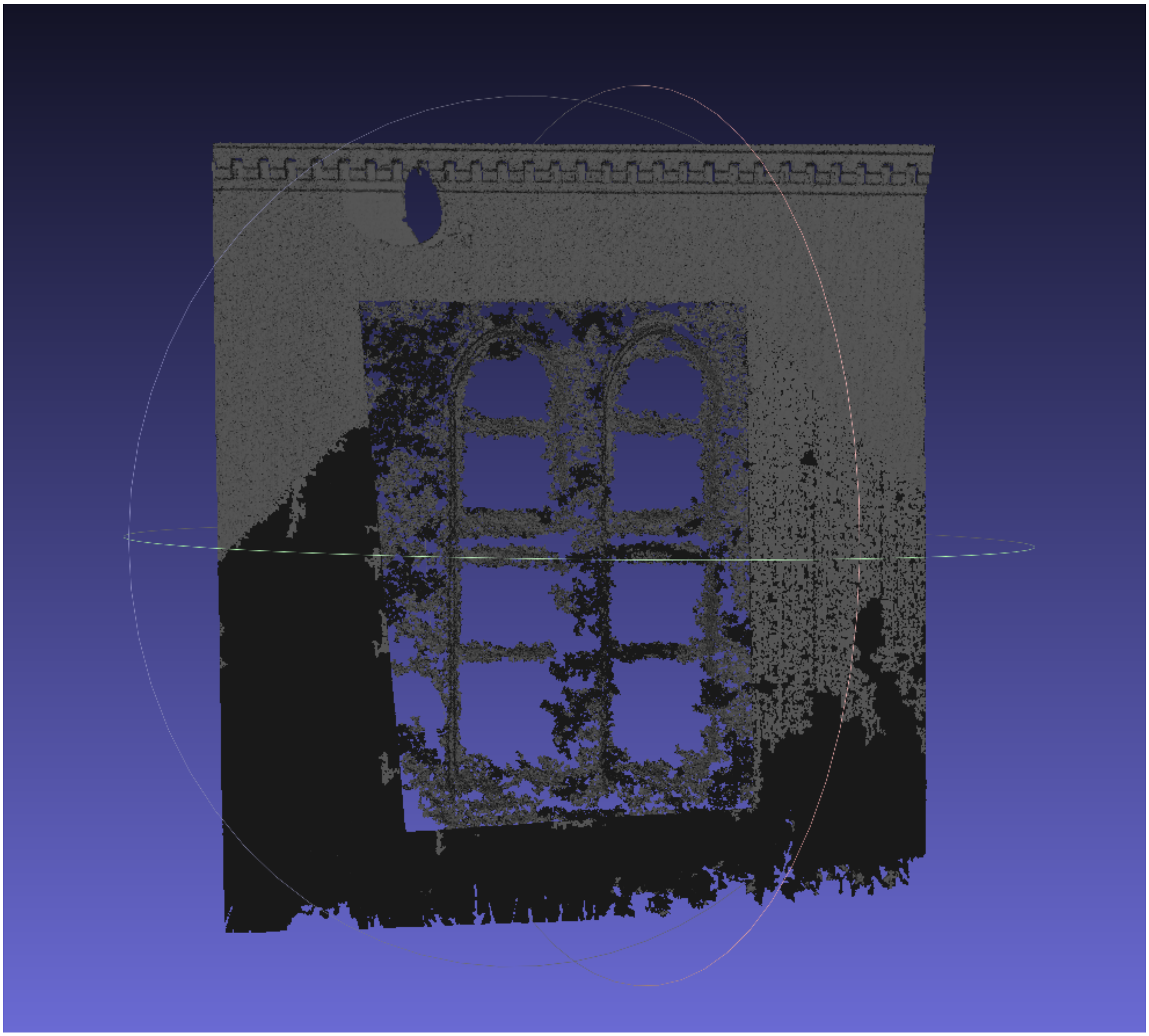

Abbildung 5. *Generated mesh with lidar and SfM data in Meshlab.*