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MAGAZINE FOR SMART 3D MAPPING

TRENDWATCHER

Mobile Mapping to create Autonomous Vehicle Maps in Singapore

SPOTLIGHT

Changing the game for Telecommunications with 3D Mapping

SOLUTIONS

3D Mapping in Switzerland, Arizona and Ohio

CONTENT

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SPOTLIGHT

COLOPHON

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EDITORIAL

Dear Reader,

We find ourselves at a pivot point in time, where mass 3D data collection has become the standard and we need to find ways to adopt hundreds of years of map making, a century of aerial photogrammetry, and a few decades of digital 2D mapping to this new standard.

3D technologies have been developed since the dawn of the computer. Computer science has brought it the level we are now, thanks to the development and commercialization of new sensors, 3D computer animation and movies, and above all games that forced the visualization of 3D content to major innovations in computer hardware which we today take for granted.

So here we are. Scanning and mapping in 3D is all around us and is here to stay. No single person on our business that doubts this. However, there is still some work to do to convince our customers about its values and advantages.

Let's pick one industry to use as an example: telecommunications. The telco business is in revolution with innovations as FTTH (Fiber To The Home) and 5G wireless networks. To deploy these networks, there's an immense volume of work ahead of us. Physical networks that might have been there for 100 years, are obsolete and need replacement by Fiber. 5G can become the city or country wide hi-band wifi.

A similar process is revolting the car navigation business. From basic road information, global navigation databases are being converted to much richer datasets that must allow for autonomous navigation. Here too, old databases must be completely renewed, and which better way to do that than by Mobile Mapping?

At Orbit GT, we continuously search for solutions that improve workflows, change the way of working for the better, and sometimes it needs a full revolution to step down from obsolete methodologies that date back a century.

The stories in this magazine, written by some impressive people and companies we're proud to have as partner and customer, prove that this 3D mapping business we share with you is just getting started. I hope you may find inspiration and ideas in these stories and that we may help you in your way forward.

Enjoy !

Peter Bonne

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ROAD MANAGEMENT IN BERN, SWITZERLAND

THE OPTIMAL MAINTENANCE AND MANAGEMENT OF THE 2200KM LONG CANTONAL ROAD NETWORK OF THE CANTON BERN (SWITZERLAND) REQUIRES REGULAR ROAD CONDITION MONITORING. FOR THE FIRST TIME GRUNDER INGENIEURE AG, USING THE 3D MOBILE MAPPING SYSTEM LEICA PEGASUS: TWO ULTIMATE, WAS COMMISSIONED TO PERFORM THIS MONITORING, INSTEAD OF A COMPANY WITH A CONVENTIONAL MEASURING VEHICLE. INSTEAD OF SCANNING ONLY THE ROAD SURFACE WITH A BAR, A HIGHLY ACCURATE 3D POINT CLOUD AND HIGH-RESOLUTION 360°-IMAGES WERE CAPTURED. THE ORBIT 3DM PUBLISHER WAS INTEGRATED INTO THE EXISTING ROAD-GIS SYSTEM OF CANTON BERN TO DELIVER THE BENEFITS OF THE NEW TECHNOLOGY TO THE CUSTOMER.

All employees of the different departments of the cantonal authority now have the possibility to move along the whole road network and retrieve the desired geoinformation safely and without any restrictions. Until the realisation of the herein presented solution, it was inconceivable to view several thousand kilometres of point cloud and over 1.4 million images using standard computers at a public authority. Any obstacles were overcome successfully thanks to the close collaboration of the responsible engineers of Grunder Ingenieure AG and Orbit GT.

Introduction

Switzerland is divided into 26 cantons, Bern being the second largest in terms of area. Switzerland's capital Bern is located in the heart of the canton of Bern. The road network in the sovereignty of the cantonal authority comprises a total length of 2200 km. To optimally maintain and manage the road network, a condition analysis of the entire road network is carried out every 4 years. For the analysis in 2018, for the first time Grunder Ingenieure AG using the 3D Mobile Mapping System Leica Pegasus: Two Ultimate was commissioned. A highly accurate 3D point cloud and high-resolution 360°-images were captured.

Although this new and innovative method initially has brought major challenges for the project team, it delivers a lot of added value. Many added values however require additional computer power, so Grunder Ingenieure AG decided to build a new computer centre at the company's headquarters in Burgdorf to store the over 4400km of point cloud data and over 10 million images. Beforehand, no one was aware of the huge challenge to sensibly provide the acquired data to the customer. Furthermore, the strict time schedule was challenging: only six months were available to complete the whole project as the results of the condition analysis were to be included in the annual report and the new budget proposals of the customer.

The project perimeter of the project Kanton Bern in the GrunderMapsViewer of Orbit GT

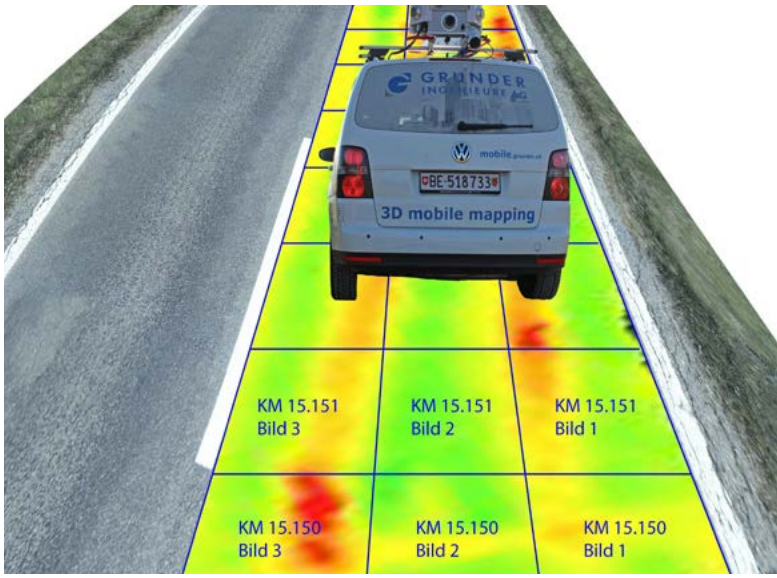
Data acquisition

The entire road network was acquired within 30 days in autumn 2018. To guarantee that the entire road surface was captured without visual obstructions, all roads were driven back and forth. The measurements could be carried out without obstructions by the normal traffic thanks to the installation of the measurement system on a standard car. The daily recording performance led to several 1TB internal memory hard disks of the 3D Mobile Mapping system being filled. In parallel to the data acquisition, a second team at the headquarters of Grunder Ingenieure AG developed the basis for a new evaluation method. Within less than 2 months a software was developed which enables the import of road surface orthophotos for the analysis and evaluation of each square metre.

Data processing and data delivery

The data was divided into 100m long

Measurement run in the Swiss Mountains



Road condition analysis, with georeferenced damage patterns

sections. Three different indices were evaluated. The visual evaluation (i1) was carried out according to the German standard (ZTV ZEB-StB 2006), the computational evaluations in longitudinal and transverse direction (i2 and i3) according to the Swiss standards (SN 640 520a and SN 640 925b).

The Grunder Ingenieure AG chose Orbit GT's services and software to provide full access to the acquired data according to the motto " We bring reality into the office". The chosen solution offers the unique possibility to provide the immense amount of data via browser without any loss. A remarkable point is that the public authority of the canton Bern already operates a road management software which plays a key role in the daily work of the civil engineering office. The viewer had consequently to be integrated in this software. Thanks to experiences of similar projects, this proved to be no problem. However, the real challenge was only revealed during in the daily routine: the employees of the Bernese administration work in a virtual environment which they access via Citrix. This challenge required an update or the Orbit GT technology to meet the high consumption demands of the customer. Thanks to the close collaboration of the responsible engineers of Grunder Ingenieure AG and Orbit GT, the civil engineering department of the canton of Bern now have "The reality on their screen".

Added value through 3D mobile mapping

Thanks to the 360° scan and the 360° images of the entire road space, the data can now be used for an uncountable number of other projects. Exemplarily, three examples are explained in brief:

- *Evaluation of retaining walls:* the department of civil engineering used the newly acquired data to create an inventory of all retaining walls along their streets.
- *Terrain models for road construction projects:* in order plan out road construction projects it is no longer necessary to carry out surveying works on site. The breaking edges can be derived from the point cloud and the terrain model is easily calculated. This offers a higher level of safety as there is no need for surveyors being on the road under traffic.
- *Clearance analyses:* to plan heavy or overload transports, the clearance of bridges and tunnels can be analysed.

Orbit GT's web-based viewer has also a high importance for additional projects. Often, companies planning a road project, or a heavy vehicle route are not familiar with the location. The viewer offers all project stakeholders the possibility of a virtual on-site inspection and, if necessary, to measure objects and distances. This way of working is a real time-saver as it can avoid numerous on-site inspections, and thanks to the 'Reality in the office', no details are overlooked.

Conclusion

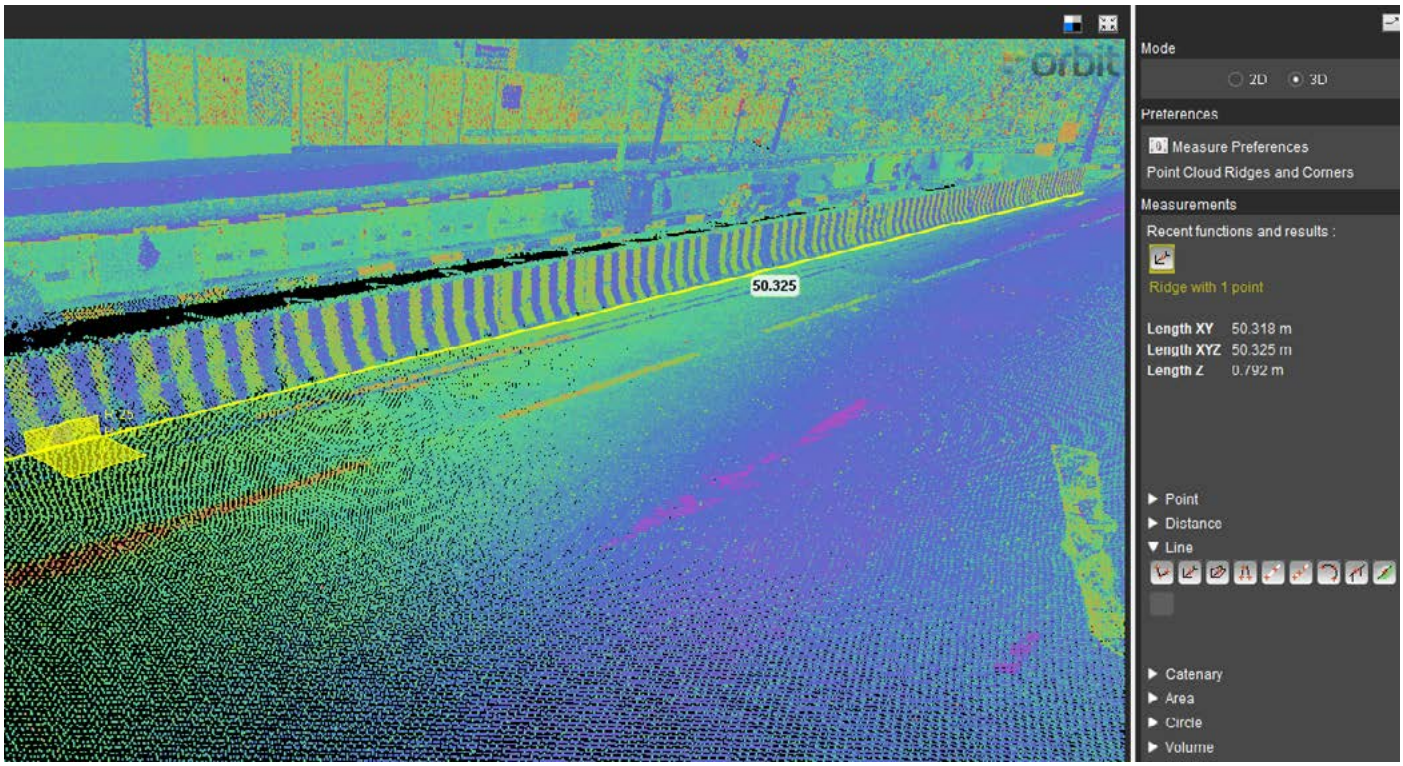
Thanks to the innovative data acquisition method and the powerful viewer, the client can be provided with a result that covers many other needs in addition to road condition analysis. Grunder Ingenieure AG is convinced that this combination will bring great added value to many cantons, provinces, cities and municipalities in the future.

ABOUT THE AUTHOR

Marc Keller is Geomatics Engineer and has been working for Grunder Ingenieure AG for over 10 years. Since the acquisition of the mobile mapping system in 2015, he has been working as project manager for many different projects, such as the road condition monitoring of the Canton Bern.

ABOUT GRUNDER INGENIEURE AG

Grunder Ingenieure AG, based in Burgdorf, is one of the market leaders in Switzerland in the fields of engineering, railway, cadastral and special surveying. Using drone surveying, laser scanning and 3D mobile mapping, they work highly efficiently. Not only innovative spirit and quality awareness are part of their philosophy, they are also one of Switzerland's largest training companies in the field of geomatics.



Ridge measurement on road curb

MOBILE MAPPING TO CREATE AUTONOMOUS VEHICLE MAPS IN SINGAPORE

WITH THE RISING OF RESEARCH AND DEVELOPMENT ON AUTONOMOUS VEHICLES, A DETAILED AND PRECISE MAP FOR THE VEHICLE IS REQUIRED. GPS LANDS SINGAPORE TOOK ON AN INITIATIVE TO PRODUCE A HIGHLY DETAILED MAP FOR AN AUTONOMOUS VEHICLE TESTING AREA IN SINGAPORE USING 3D MOBILE MAPPING SYSTEM TO COLLECT THE DATA AND PERFORM FEATURE EXTRACTION USING THE 3D DATA.

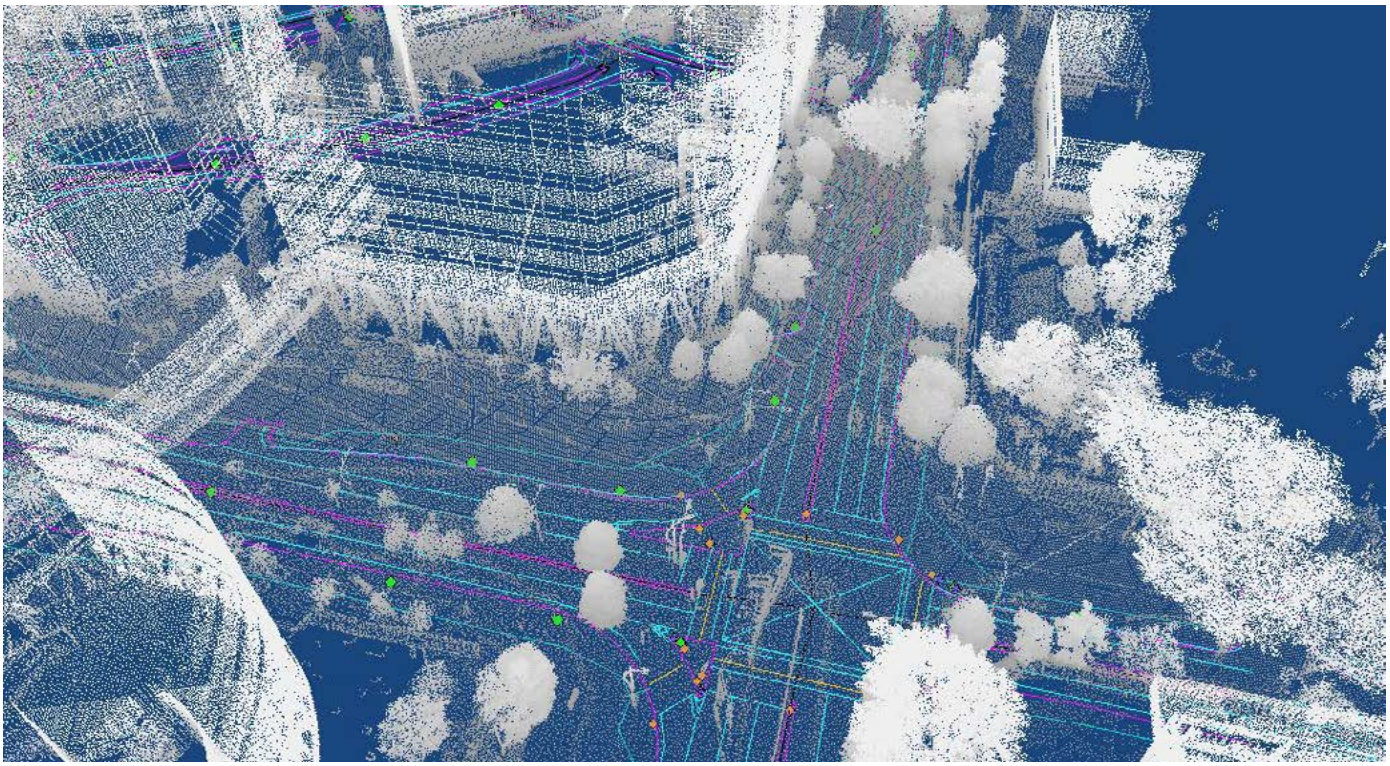
Introduction

In Singapore's quest to be a Smart Nation - https://www.smartnation.sg/what-is-smart-nation/initiatives/Transport/autonomous-vehicles - one of the core pillars for this initiative is the development and implementation of self-driving technology by putting Autonomous Vehicles (AV) on the roads. This is in part to revolutionise and transform our transportation system and to improve our living environment.

Since January 2015, Singapore's Land Transport Authority (LTA) - https://www.lta.gov.sg/, in partnership with Jurong Town Corporation (JTC) - https://www.jtc.gov.sg/, has designated One-North, a tech hub located in the western part of Singapore, as the first AV test-bed in Singapore. This test bed provides 55km of routes with various possible scenarios to support robust tests of AVs.

AVs that passes the safety test are able to submit application to allow on-road testing in the designated area of public roads. Since then, the development of AVs has been rapid and there are already 14 AVs registered for public road trials and even in some tourist spots like Gardens by the Bay and Sentosa Island resort. Tourist will be able to take a ride in these AVs while touring these places of interest.

With the increased awareness and a global push to move into all things robotics and dynamic platforms to be autonomously guided, the demand for safety and high accuracy information is on the rise. GPS Lands Singapore took on the initiative to produce highly detailed maps for AV



Extracted features 3D view

trial areas in Singapore in order to support the Smart Nation initiative. A highly detailed map can support AV development in terms of localization and simulation and these information are critical also to the safety aspects by travelling in the correct direction and slowing down or stopping on traffic junctions, pedestrian crossings and a whole host of potential scenarios that an AV needs to "function" safely and efficiently.

Data capturing

GPS Lands Singapore deployed a Mobile Laser Scanning (MLS) system to capture the roads & surrounding elements of the autonomous vehicle testing site. The accuracy of the trajectory and the resulting pointcloud relies heavily on correct mission planning. Satellite coverage, structural conditions and the size of the project area need to be considered before deploying the system.

Satellite images or street photographs help to get a first impression of the mission site. Commonly known and free available tools can be employed for this purpose. Detailed planning of the route to be followed during data acquisition helps the driver and operator team in the field to fulfill their tasks. Route objects are imported into the acquisition software and are used to aid the team's navigation during the capture process.

Road features extraction

After the data has been captured and processed, the pointcloud data is then imported into Orbit's 3DM Feature Extraction Pro for extraction of road features. Using the 3DM Feature Extraction Pro allows semi-automated extraction of road features such as lane markings and curb lines, using the automatic detection of traffic signs and poles helps in identifying the location of all the traffic signs and traffic light poles where the operator is able to extract all the accepted detections.

The update in the hover display tool to detect ridges greatly assisted the accurate extraction of curb lines as it assist in finding the lower curb edges and with a single click, the curb line is extracted easily.

Action review

The whole exercise took about 4 months to start from mission planning to completion of extraction. There are still challenges in extraction of way points and the road links needs to be created manually to identify the direction and also the linked roads at a road junction where the AV is allow to turn into. The reviewing of the auto-detection tools also took some time to filter out the false detections but in return, it reduces the time required to manually search for the features in the data.

After the completion of the first AV map that GPS Lands Singapore created as an initial trial to showcase the strength of Orbit GT's solutions in this fast growing space globally, the next plan would be to provide potential map providers or even AV companies Orbit GT technologies for them to extract and create their own AV map data to meet their unique needs.

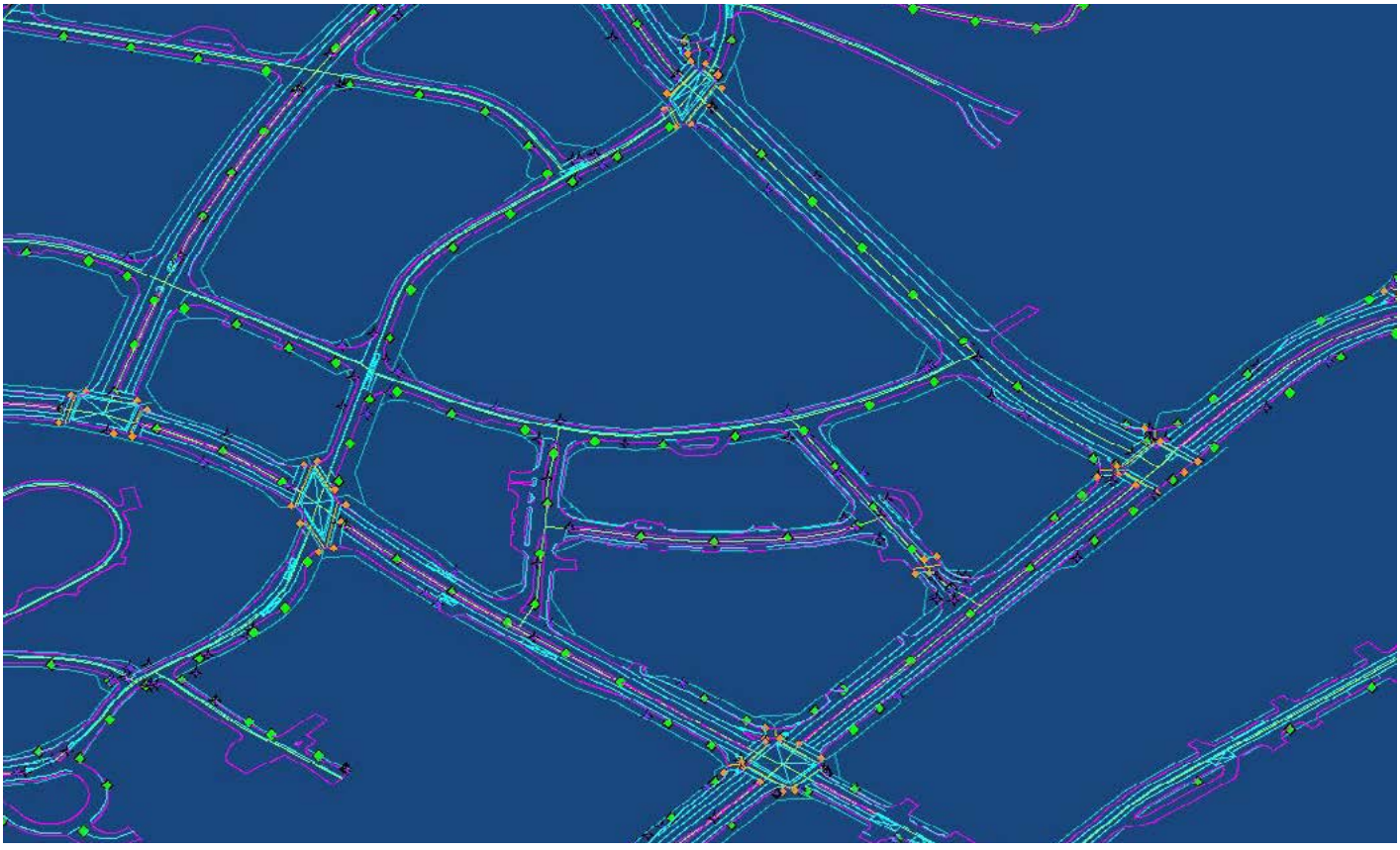
ABOUT THE AUTHOR

Eric Low is the Project Manager for GPS Lands (Singapore) with 10 years of experience working in the land survey industry. He was formally from Singapore Land Authority (Land Survey Department) and has good working knowledge with laser scanning and mapping. His role in GPS Lands is mainly to craft solutions or workflow utilizing scanning to fulfill client's needs such as feature extraction, 3D modeling, indoor mapping and visualization, and so on.

ABOUT GPS LANDS (SINGAPORE)

GPS Lands (www.gpslands.com) was Founded in 2000 and headquartered in Singapore, GPS Lands focuses on providing the Mapping & Surveying and Geomatics Engineering sectors with modern Hardware & Software technologies.

The past 10 years, GPS Lands has focused much on technologies related to Smart Cities and Digital Twin content creation. With Orbit GT Technologies within the solutions offerings portfolio, GPS Lands is well positioned to enter new markets and adding to the value creation of clients, governments and stakeholders.



Extracted features overview

OPTIMIZED PROCEDURES FOR SLOPE INVENTORY IN PHOENIX, ARIZONA: "Y=MX+BPG – SOLVING FOR M"

WITH THE HELP OF ORBIT GT, ESRI AND THE TRAINED STAFF AT BPG, WE HAVE MANAGED TO CREATE A SLOPE TOOL THAT IMPROVES PRODUCTION, IS REPEATABLE AND DOCUMENTED, AND CAN BE USED FOR MANY PROJECTS TO COME!

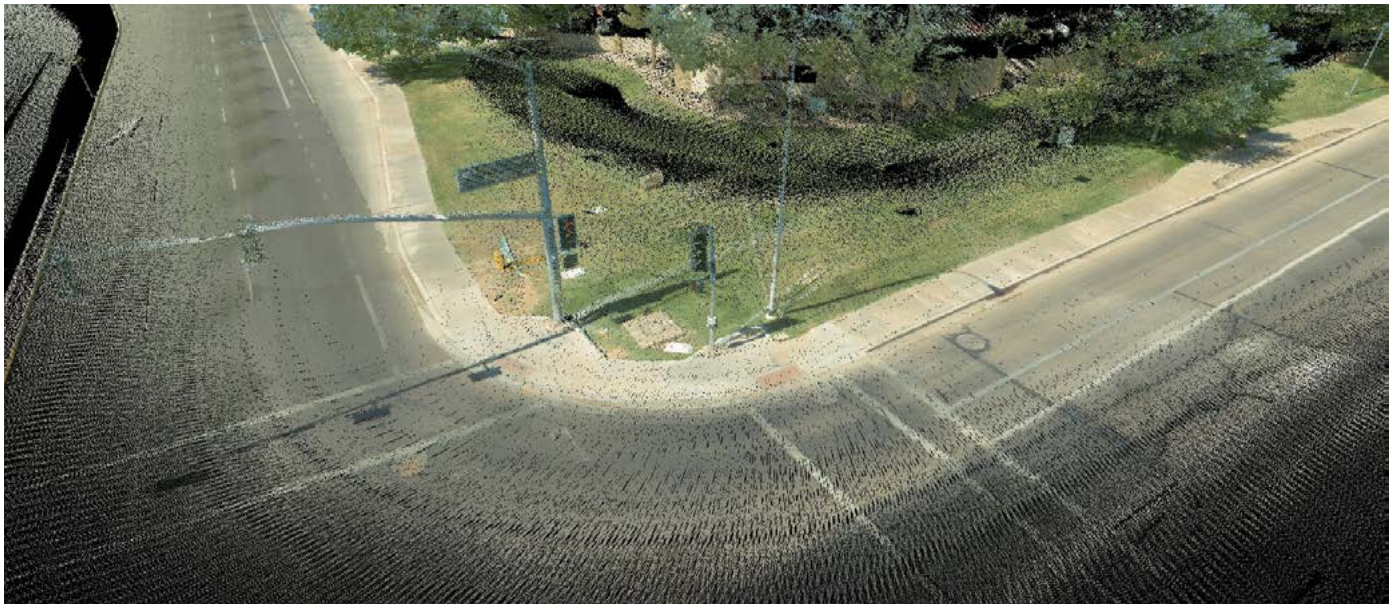
Background

A typical motorist often overlooks the importance of a maintained traversable path. This specific driver normally commutes from point A to point B with ease and in the comfort of their own vehicle. Their worry lies mostly on the influx of traffic and approaching E on the fuel gauge. There is little thought on the potential trials and tribulations of commuting via pubic sidewalk to their destination.

Unfortunately, not all have this same sense of effortlessness in their commute. The United Nations reports over 15% of the world population live with one or more disabling conditions, and more than 46% of the population aged 60 years or older have disabilities. According to US Census data compiled by the American Community Survey (ACS), population aged 65+ is growing at a higher rate than the total population by a ratio of 2.5:1. With the growth rate there will be an increased number of mobility–impaired individuals who will need to navigate public right of way paths with the same ease as the everyday motorist. Luckily, the American Disabilities Act (ADA) recognizes the significance of a city's pathway infrastructure and is set out to make certain they pose no barrier to the mobility-impaired pedestrian by implementing a Public Right of Way Accessibilities Guidelines (PROWAG).

BPG Designs, LLC and their strategic partner paired with a large municipality to ensure ADA PROWAG were met throughout the project area. The ADA Self-Evaluation was used to help mitigate the city's risk as well as allow the city to efficiently respond to requests for ADA improvements from the public.

The evaluation called for BPG's advanced, high-accuracy mobile LiDAR technology to be at the forefront of this project. BPG collected over 630 arterial and collector road centerline miles using the state-of-the-art IP-S3 mobile mapping system, creating a 3D model of the city's street assets. The IP-S3's high density, high precision point clouds combined with high-resolution panoramas allow the Orbit GT user to access an array of data for the surveyed area. The IP-S3 positioning system is an integration of an Inertial Measurement Unit (IMU), GNSS receiver (GPS and GLONASS) and a vehicle odometer allowing the system to maintain positional accuracy within a dynamic



Colorized point cloud from IP-S3

environment. The rotating LiDAR sensor captures the environment with a rate of 700,000 pulses per second at a range of 100 meters. This point density provides a picture-perfect 3D model of the scanned area. The six-lense digital camera system provides 360-degree high-resolution spherical images that allow for feature recognition and precise measurements. After the LiDAR data were collected and processed, trained BPG staff utilized Orbit GT software to extract the necessary ADA assets. These assets included: polygons that were traced over sidewalk panels ~50ft, all ramps and driveways, a point for any surface discontinuities (cracks, gaps, heaving, and obstructions in the traversable pathways) and slope lines for all surface polygons. Each feature has its own set of classifications and measurement attributions, which led to a robust amount of data collected.

The ADA compliance guidelines state sidewalk running slopes over 5.5%, driveway running slopes over 8.8%, ramp running slopes over 10.5%, and all cross slopes over 2.5% would be deemed non-compliant and sent to the city for further review. Each ramp, sidewalk, and gutter had its own set of cross slopes and running slopes. Sidewalks and gutters have 2 slope lines, ramp features have anywhere from 6 to 8, and driveways have 4 total slope lines. This meant the bulk of the data collected in Orbit GT software were slope lines associated to each polygon feature. Using Orbit GT's 3DM Feature Extraction package, the BPG team manually drew these slope lines over each polygon feature, as well as documented the slope measurement that represented the slope grade of the surface feature. Ultimately, BPG was responsible for the creation of hundreds of thousands of slope lines that would dictate whether the polygon feature was within ADA compliance.

The first square mile of data that BPG collected and extracted was sent off to our strategic partner for review and the results were undesirable. It was brought to BPG's attention that the manual slope measurements did not match the slope measurements they had taken in the field. About 50% of the slope lines were inconsistent with the field readings and failed to meet ADA standards. This forced a halt any further production until the inconsistencies were resolved.

The BPG Team quickly faced the realization that the manual creation of the slope lines which had occupied much of the time and energy spent on the project was not effective. Finding an efficient solution for collecting the slope lines and their measurements was crucial to the integrity of the project. In hopes of gaining a solution to this slope line conundrum, the BPG team reached out to its partners at Orbit GT for advice and technical help.

Technical challenges

ADA had allowed a 0.5% tolerance on all slope lines for the polygon features, meaning the team was fighting against the resolution of the IP-S3 to reach complete slope accuracy. Even using the most advanced mobile mapping system the machine still left BPG with a +/- 3.3% tolerance, which was well over the 0.5% allowed by ADA standards. The staff at Orbit GT quickly partnered with BPG and, through multiple phone calls and virtual collaborations per week, guided the team through different functions of their software that were relevant to accomplishing this type of precise measurement.

Of the functions, the Slice View function was exceptionally helpful in recognizing the inconsistencies within the point cloud data. The Slice View function allows the user to slice of the point cloud and examine its thickness, as well as any extra noise in the data due to multiple passes in the road or any miscellaneous interference. After extensive data collection, assessment,

Ramp and sidewalk features with running slope and cross slope lines

and evaluation the teams were ultimately able to identify the primary reason for the inconsistency in the slope line measurements was this noise.

The original failed slope measurements were produced from sections of the point cloud that were not representative of the entire data set – the outliers. When drawing the slope lines on top of a sidewalk panel, the user might grab the first point directly on the sidewalk, but their second point may be placed in a small area of the point cloud with outlier points, leading to a misrepresentation of the actual slope value of that sidewalk panel.

Using the Slice View function, BPG could identify the level of noise in the section of point cloud for that specific ADA feature and take the slope measurements in an area that was a true representation of that surface. However, though this was an accurate solution, using the Slice View function for all slope line measurements was simply not feasible due to the numerous amounts of slope lines that were eventually going to be extracted throughout the entire 630-centerline miles of the project. BPG and Orbit GT were sent back to the drawing board. With the newfound realization of the direct correlation between the level of noise in the point cloud and the slope measurements, both BPG and Orbit GT were determined to find a speedier solution that would produce precise slope measurements in a timely fashion. The Orbit GT team focused their resources on creating a script that could eliminate any point cloud noise and automate the slope line collection process, eliminating any variability in slope line length and placement within the polygon feature.

Solutions

Over the next several weeks of slope line research between BPG and Orbit GT a few assumptions were made to aid with the scripting process:

- The features with slope lines associated to them require a running slope and cross slope. The running slope dictates the direction of travel on the sidewalk, ramp, or driveway panel and the cross slope bisects the running slope to form a cross in the middle of the polygon feature.
- It is imperative the slope line measurements are extracted from a point cloud that is dense and free of any noise or data discontinuities to truly represent the slope grade of the surface feature.
- The projection in which the slope line measurements are extracted requires metric meters instead of imperial feet to further tighten the measurements.

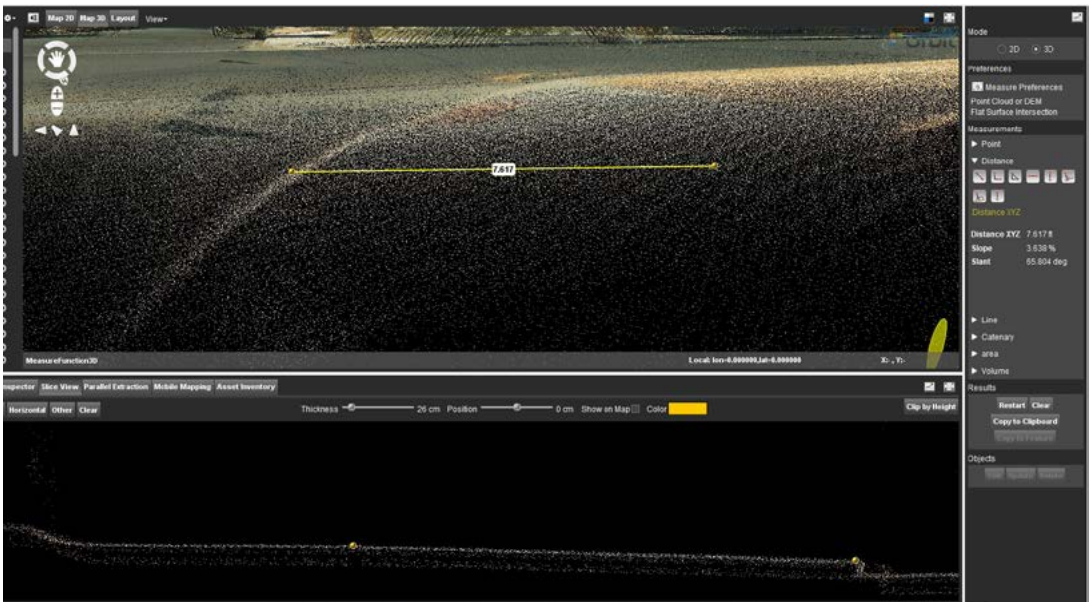
Orbit GT developed the final version of the slope script that encompasses all the parts needed to collect precise slope lines and measurements.

Script 1: Line Segment Bisector

The first script creates a line segment bisector, the running and cross slope, for each feature within the original polygon feature exported from Orbit 3DM software (sidewalks, driveways, and ramps). The first line segment is created parallel to the longest side of the polygon. The second line segment is then created perpendicular to the first line segment. The result is systematically replicated cross and running slopes identical in length and placed at the centroid of the polygon, improving length consistency and eliminating human error variability.

Script 2: Slope Value by Linear Regression

For each line segment the second script calculates the true slope value and the Mean Square Error/Deviation (RMSE) using a linear regression model. To take advantage of the high relative accuracy and the millions of points generated by LiDAR, the script produces a count of the points used for the slope line within a well-



Slice view showing two points on the true surface and the noise below. The true surface is the dense line on top, the noise is the clutter underneath.

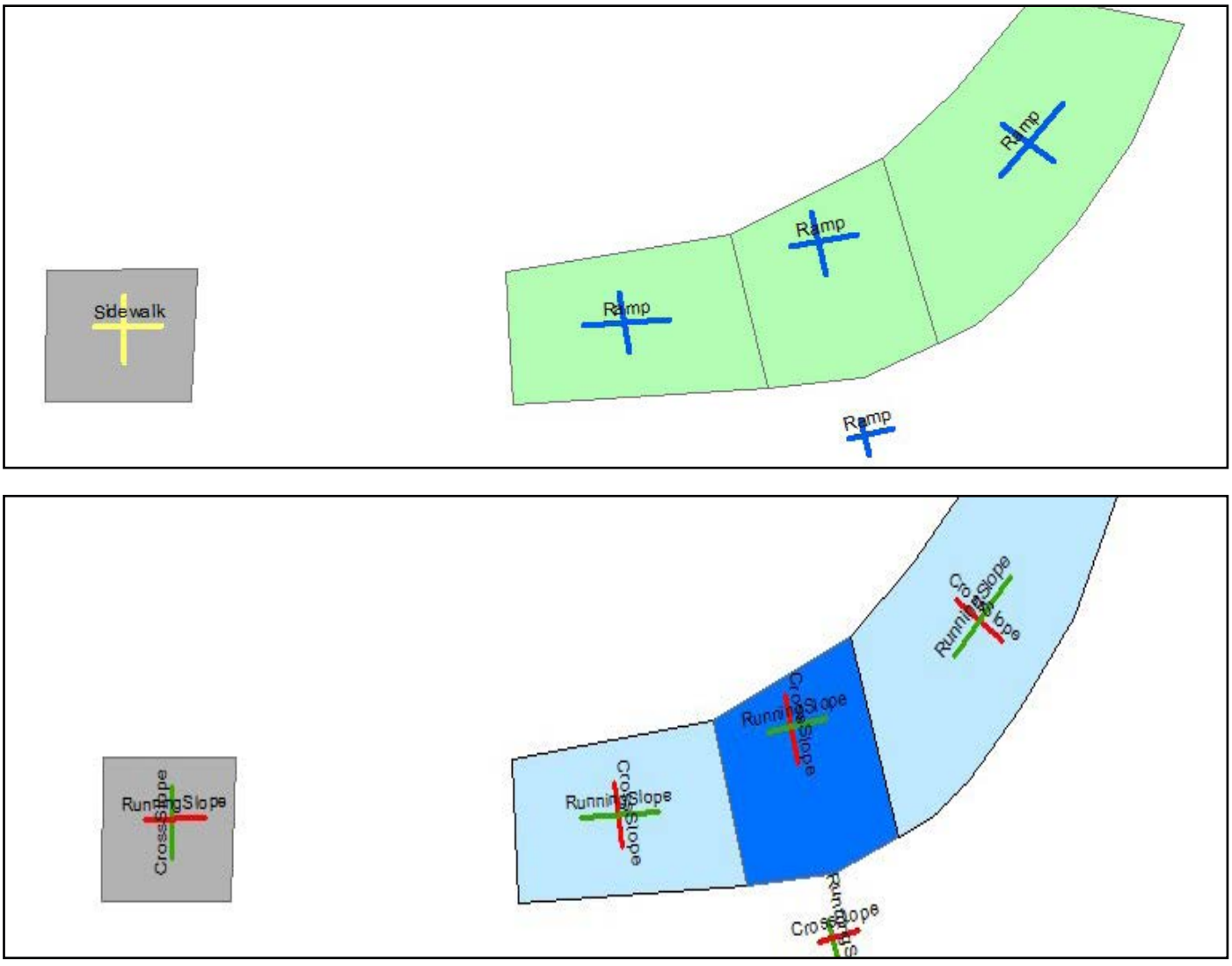
defined section of the point cloud. Using a multiple linear regression model, the script removes statistical outlying points, the miscellaneous noise, and uses a weighted average to help best fit the slope plane using 3 factors: the segment's length; a given width defined as the buffer of points around the slope line; and a positive, or negative, offset of the slope lines CenterZ (Z-Range). These settings all define the point cloud selection used for the measurement. The script allowed for BPG to manually fine-tune these preferences to find the best fit for the data collected. BPG added an additional quality check to eliminate additional variability in the slope line data by manually checking all slope lines with measurements greater than 4% slope and with an RMSE greater than 10. The slope lines that fell into this category were manually cross referenced for measurement verification.

The result produced a new spatially correct shapefile of the cross slopes, running slopes, and their newly calculated slope measurements. The script also rendered separate Orbit Vector Files for every slope line that showed the specific slice points from the point that they were used for the slope measurement, the potential slope errors and the start and end points used for measurement. These OVF files hold extremely valuable data for the client. They show, based on mathematics, how the slope measurements were decided and why the measurement makes sense. By utilizing these two scripts in conjunction, the client was confident that the analysis was based on statistics, whereas field measurements taken with a manual level have multiple stages of variability based on location and equipment used.

With the help of ESRI software, BPG then performs a final process with automated QC routines that remedied any misclassified slope lines and polygon features. This resulted in a data set that was free of errors in classification, measurement, and variability.

Conclusion

Without the help of Orbit GT and the use of the Slice View function in the Orbit 3DM Feature Extraction software, BPG would have taken longer to produce the quality products our core values require. The creation of the scripts and extensive help and patience from Orbit GT helped BPG significantly reduce the number of hours that would have been



Sidewalk panel showing created slope lines (above) and labeled lines (below)

required to re-measure hundreds of thousands of slope lines across the city.

The most significant contribution that the scripts have made to the BPG process is that our projects are now consistent, repeatable, and we are able to provide detailed documentation with our results. The time savings, repeatability and documentation allowed BPG to provide an accurate, quality result for over 630 centerline miles that was delivered on time and exceeded the expectations of the clients. The city can now use the information to help improve the capability of its community to traverse the sidewalks and right of ways. The script has also been successfully used on two additional ADA projects since this project. Today Orbit GT implemented the tool into production to assist other clients and projects of similar scale in the future.

The mobile mapping system attached to a vehicle

ABOUT THE AUTHORS

Gentry Nissen is a GIS Specialist with a new focus towards data analytics. A 2015 graduate from Arizona State University, she earned her B.S. in Urban Planning but quickly fell in love with her minor in Geographic Information Science. Residing in Phoenix, Arizona, she is currently using her GIS prowess working as an independent in the Geospatial Services industry with top industry leaders.

Brandon Sisco manages a team of 20 geospatial professionals and surveyors for BPG. Brandon earned his Bachelor's degree from the United States Naval Academy in Control Systems Engineering. He has also earned Master's degrees in Aeronautics from Embry-Riddle Aeronautical University and in Geographical Information Systems from Arizona State University. Brandon has over 1000 flight hours in various military aircraft and Unmanned Aircraft Systems with over 15 years of experience with remote sensing. He is a Part 107 certified UAS Pilot.

ABOUT BPG DESIGNS

Founded in 2000, BPG Designs is a small business and limited-liability company with one-hundred and ninety employees. BPG has a simple vision that if they can provide their customers confidence in knowing they are working with the most innovative, creative, forward thinking, technology advanced companies focused on producing results, they can reach their dreams and make a difference in the community they serve.

Over the years, BPG has developed a robust Design and Mapping Department's that includes a team with a deep knowledge and passion of all facets of design development. Their team consists of multiple software programmers, CAD technicians, designers, and surveyors that collectively have over a century of design experience. This talent, along with their commitment to employ the latest technological advancement in design development, has led them to support major organizations like Cox Communications, Verizon, and Salt River Project. The team completes over 1000 miles of design for broadband infrastructure annually throughout the southwestern United States, utilizing the latest and most advanced technology on the market today. One of BPG's greatest assets is the ability to quickly mobilize and to scale appropriately for any size job. For more information, please visit their web site at bpgdesigns.com.

MOBILE MAPPING REDEFINES PAVEMENT MARKING INVENTORY IN OHIO

MOBILE MAPPING, THE ANSWER TO PAVEMENT MARKING INVENTORY STUDY CHALLENGES. A PAVEMENT MARKING INVENTORY STUDY IS A CHALLENGE TO PERFORM PROPERLY, EFFECTIVELY AND QUICKLY. IT INVOLVES A MULTITUDE OF OBSTACLES RANGING FROM IN-FIELD SAFETY ISSUES WITH TRAFFIC TO ACCURATELY TRACING THE CONTOUR OF LONG STRIPED LINES AND PRODUCING ACCURATE DISTANCE CALCULATIONS TO GEOREFERENCING ALL OF THE PAVEMENT MARKINGS.

The MasterMind mobile mapping vehicle displaying the 360° camera, multiple LiDAR units, GPS antennas, the distance measuring instrument (DMI) and the solar panel.

Pavement Marking Inventory studies are very beneficial once completed. With highly accurate lineal footage marking totals, bead and paint quantities can be easily calculated for entire roadways or even just sections. With identifying the markings materials, proper replacement can be easily planned and achieved. Proper yearly striping plans can be assembled based on inspection ratings. Striping projects can be more accurately assembled and bid. Proper t-marking can be more easily applied when striping repaved roadways. Overall, with the cost analysis benefits, government agencies can save a considerable amount of money and time and improve their budgets.

Richland County Ohio

It began with the Richland County Ohio Engineer's office. They set out to inventory and inspect all their roadway pavement markings.

Pavement Marking Examples:
- Centerline (No-Passing, Safe Passing)
- Edgeline (White and/or Yellow Edgelines)
- Auxiliary (Turn Arrows, Stop Bars, Crosswalk lines, Transverse lines, Railroad crossings)

The Richland County Engineer, Adam Gove, P.E., P.S., stated, "When evaluating the condition of our County Roads, it became clear that our pavement marking inventory was out of date. We did not have an effective way of tracking which roads had pavement markings, when they were last repainted, and what type of material was used when last applied..."

Pavement marking inventory studies are riddled with challenges, and everyday government agencies are demanding greater accuracy and more ways to visualize their asset data. For the Richland County project and all safety studies, safety is the number one priority. In addition to safely performing the study, all pavement markings needed to be geo-referenced, the contour of long edgelines and centerlines would need to be strictly traced and 347.7 miles of roadway pavement markings would need to be inventoried and inspected.

We at MasterMind, LLC were thrilled to be awarded the project and redefine how a pavement marking study would be performed. We would use mobile mapping to overcome the challenges. To dive into the field work, we utilized our custom designed mobile mapping system which was supplementary powered by solar energy and mounted on-top of a Fiat 500. We choose the Fiat vehicle because of its smaller size, which helped increase visibility of the roadway within the spherical imagery. At MasterMind, when we perform a safety study, safety really is the first concern. After all, whether it's a pavement marking inventory study or any other safety study, the result is to make our roadways safer. With mobile mapping, first and foremost, we would increase the safety of the pavement marking inventory study. We were able to map the Richland County roadways at normal highway speeds and not impede traffic flow. The pavement marking inventory study was performed without traffic backups or traffic stops which increased safety exponentially.

Our MasterMind mobile mapping vehicle is composed of multiple Velodyne LiDAR units, a 360° LadyBug 5+ spherical camera, and an Applanix POS LV GPS/IMU unit with a distance measuring indicator (DMI). Our MasterMind mobile mapping vehicle LiDAR mapped Richland County roadways at 600,000 points per second and video mapped at 10 frames per second (FPS) in 8k resolution imagery. This allowed us to offer a full 360° video from the beginning to end of each roadway, along with still frame imagery.

The Richland County Engineer, Adam Gove, P.E., P.S., continued to state, "... Thanks to a grant from the County Engineers Association of Ohio, we were able to contract with MasterMind to complete an inventory and rating of all markings on County Roads in Richland County. The advanced technology utilized by MasterMind has provided us the necessary data and tools to update and track our pavement marking inventory in an efficient and effective manner."

The "Pipeline"

The next challenge was to post-process our in-field data for accuracy before the inventory could even begin. At MasterMind, we refer to the data post-processing on all in-field generated mobile mapping data, as the "pipeline." The pipeline steps include:

1) Applanix PosPac software performs multiple calculations and adjustments of the in-field GPS/IMU data to greatly increase accuracy for all imagery and LiDAR point cloud data.
2) The in-field video imagery is updated with the PosPac adjustment file.
3) Individual image frames are extracted with a movie maker software to be used as spherical imagery.
4) A specific version of VeloView software created and customized by Kitware, Inc. specifically for us at MasterMind, creates the final RGB coloured .LAS point cloud.
5) Finally, the spherical imagery frames and RGB coloured .LAS point cloud are ready to be used, but putting them together was our next challenge.

Also, the overall Richland project challenges didn't end there. A full inventory of the pavement markings was now to be performed, lineal footage of pavement marking lines would need to be properly identified, the contour of the long lines would need to be traced and the project delivered.

Orbit GT to the rescue

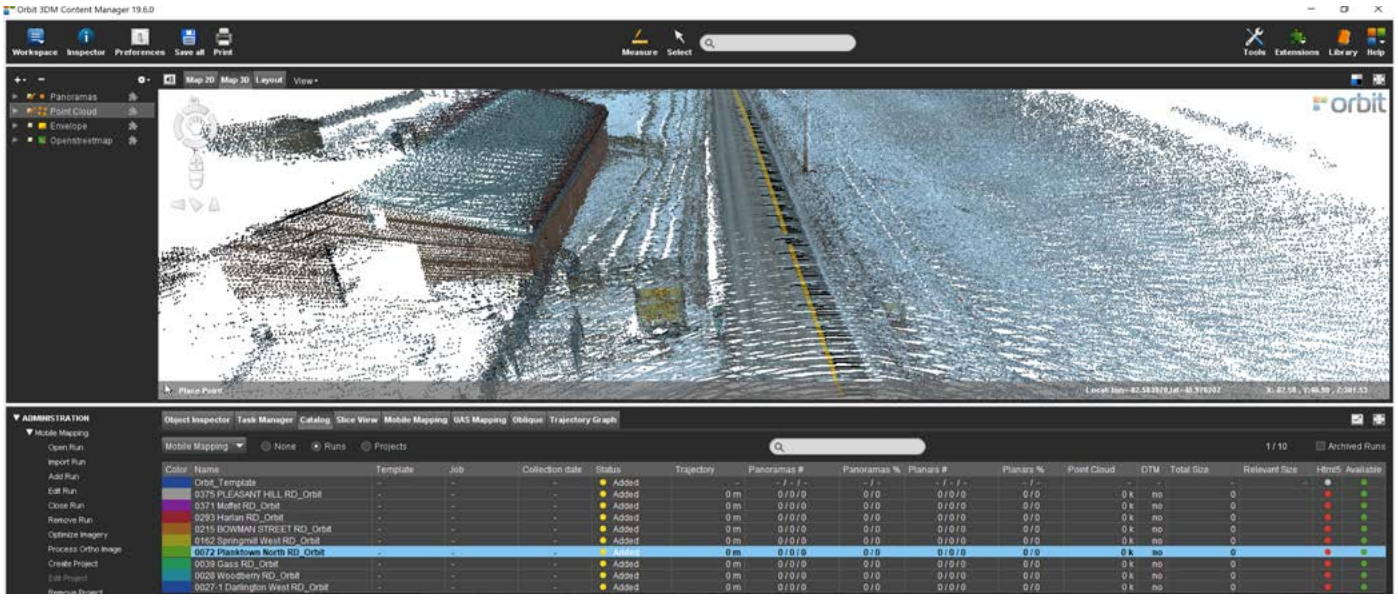
It was an easy choice for us at MasterMind to choose Orbit GT software as our go to mobile mapping software for the Richland County project. Orbit 3DM Content Manager offered ease of integration for our MasterMind custom

mobile mapping system. The Orbit 3DM Feature Extraction Pro software offered an extensive amount of asset inventory capabilities. Impressively, Orbit GT also offered a powerful yet simple delivery platform with the 3D Mapping Cloud.

First, we used the Orbit 3DM Content Manager software to import all the spherical imagery and LiDAR point cloud data. 3DM Content Manager solved our challenge for managing and preparing all 115 Richland County roads. Each road was imported into the "Catalog" section of 3DM Content Manager as a separate dataset known as a "Run." Preparation for so many roads included steps such as: Lidar to imagery alignment, nomenclature identification, metadata insertion, ghost removal and uploading into the 3D Mapping Cloud. These preparations were all more easily and centrally achieved for us using the 3DM Content Manager Catalog. We've performed thousands of miles of safety studies with multiple methods at MasterMind. We needed a new easy to use and advanced software to perform the pavement marking asset inventory. Orbit GT's 3DM Feature Extraction Pro software was our answer. We heavily utilized this software for its asset inventory features. Inside of the software, you create "Themes" which are used to create asset items such as centerline and auxiliary inventory data. We then used 3DM Feature Extraction Pro's manual and semi-automatic extraction tools to inventory the pavement markings. Thanks to LiDAR and the 3DM Feature Extraction Pro's semi-automated tool, road markings such as centerline and edgeline markings were easily extracted. The main bonus was that the contour of the lines were inventoried perfectly with altitude included. This also allowed us to provide Richland County with extremely accurate lineal footage measurements. The 3D Mapping Cloud was even more desirable by allowing the mobile mapping data to viewed on any computer (laptop, desktop, or tablet). Accurate measurements can be made in the 3D Mapping Cloud on all mobile mapped roadways. The Richland County Chief Deputy Engineer, Kevin Payne, P.E., P.S., stated, "The 360 video has proven to be valuable not only for the markings, but to see all of our County assets without leaving the office, thus saving time and money. The quality and ease of use of the video mapping will provide benefits for years to come. Although other street view mapping is publicly available through the Google platform, not all of our roads are on it and it would not be directly linked to our asset data like the MasterMind MasterSuite software. After selecting a database inventory item in MasterMind, with the click of a button you can be directed to a 360 street view of the roadway to actually see the item from the video."

In conclusion, our MasterMind mobile mapping vehicle performed the Richland County pavement marking inventory study quickly and accurately with no accidents nor resident complaints. We delivered the final asset data to Richland County in our MasterSuite asset data management software. We found that Richland County Ohio has 1,299,171.5 feet (246.055 miles) of centerline, 1,086,997.2 feet (205.871 miles) of edgeline, 45,220.5 feet (8.565 miles) of auxiliary line and 173 auxiliary symbol markings (ONLY, SCHOOL, RxR, Turn Arrows, etc). We're currently developing connection to the Orbit GT 3D Mapping Cloud from within our MasterSuite asset management software. This feat is accomplished thanks to Orbit GT's excellent software development kit (SDK).

Overall, using general pricing, the estimated cost of only materials (paint



Orbit 3DM Content Manager displaying a LiDAR point cloud of a Richland County roadway with one of Ohio's most common occurrences, snow.

and thermoplastic) to restripe all the Richland County pavement markings, would cost around $440,570.95.

At MasterMind, our clients are mainly composed of U.S. County governments and almost all of them use ESRI ArcMap software. We are very excited to now offer them the 3DM Plugin for ArcMap which allows Orbit's 3D Mapping Cloud data to be connected and used in multiple ways within their ArcMap software.

At MasterMind, we saw so much potential for the U.S. County governments to utilize the 3D Mapping Cloud along with the 3DM Plugin for ArcMap, that as of May 28th, 2019, MasterMind teamed with Orbit GT to become an official reseller for Orbit GT software. We look forward to continually spreading the word and praise of Orbit GT's mobile mapping software, along with mobile mapping in general. Mobile mapping truly redefined how we perform a safety study, such as pavement marking inventory. To learn more, please visit our website at www.onlinemastermind.com.

ABOUT THE AUTHOR

Nicholas Hickman is the President and co-founder of MasterMind, LLC. Nick designed and built the MasterMind mobile mapping system. He also led coordination with companies from around the world to develop software which prepares the data for delivery through multiple post-processing stages.

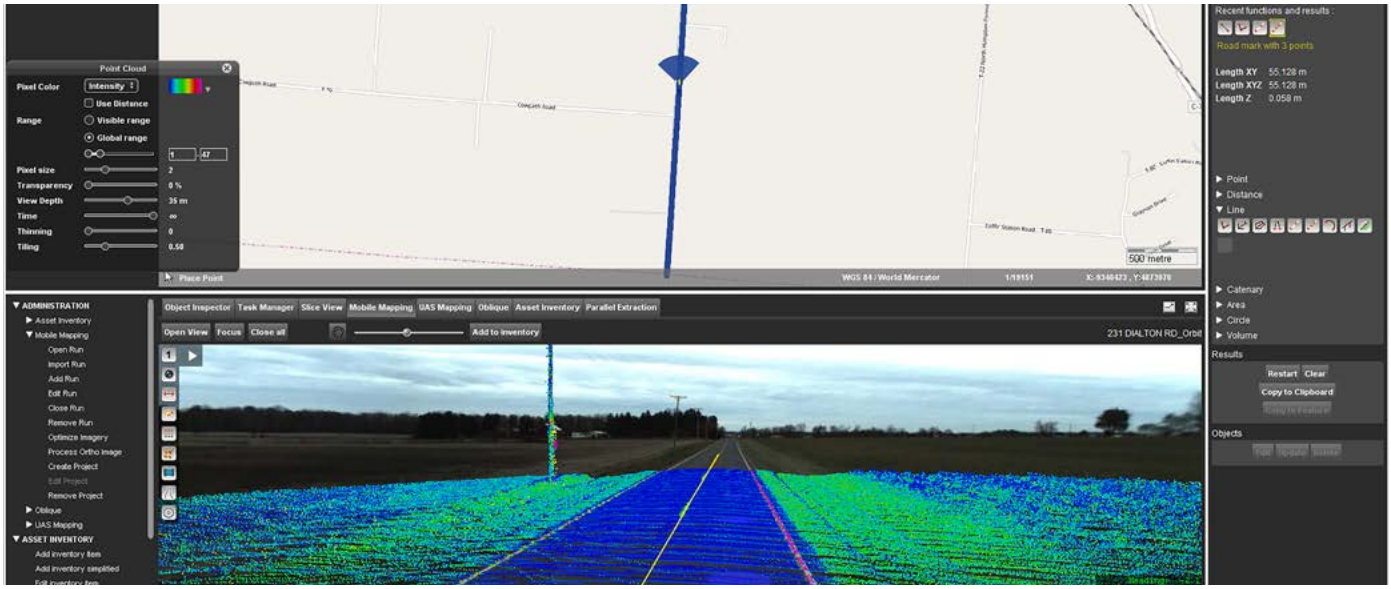
Nick grew up working on safety study projects and attending tradeshows with his mother and father. He has been working with government agencies for over 18 years. The founding of MasterMind, LLC continues a 4th generation of family businesses and Nick looks forward to continuing that tradition with his family.

ABOUT MASTERMIND, LLC

MasterMind, LLC is a traffic safety software & services company encompassing: 360° Mobile Mapping with LiDAR," No-Passing Zone, Pavement Marking Inventory, Horizontal Curve "Ball Bank, Sign Inventory, Sign Compliance, Guardrail Inventory, Right-of-Way/ Roadside Hazard Inventory, Speed Zone and Traffic Count Studies.

MasterMind was founded in 2013 by Nick & Amber Hickman. MasterMind's central office is located in Delaware, Ohio. MasterMind dove into the world of mobile mapping from its founding and created its own field based mobile mapping system.

MasterMind has performed mobile mapping and traffic safety studies on over 25 thousand miles of roadway. MasterMind also has hundreds of software clients all around the United States ranging from the great state of Ohio to Florida, New York and California. www.onlinemastermind.com



3DM Feature Extraction Pro software with the road marking 3-point semi-automated feature being utilized to extract the centerline pavement marking.

3D MAPPING FOR TELCO OPERATORS: A GOLDEN MARRIAGE

THE TELECOMMUNICATIONS BUSINESS IS IN GENERAL NOT SO FAMILIAR WITH 3D MAPPING TECHNOLOGY. IT'S ABOUT TIME THAT THIS CHANGES. EARLY ADOPTERS HAVE PROVEN THAT 3D MAPPING CAN PROVIDE A SPECTACULAR ROI ON THE DEPLOYMENT OF FTTH (FIBER TO THE HOME) AND 5G. FURTHERMORE, 3D MAPPING ENHANCES AND SPEEDS UP MANY ASPECTS OF THE DESIGN AND DEPLOYMENT WORKFLOWS.

Revolution in Telecommunications

The Telco business is in revolution with innovations as FTTH and 5G wireless networks. To deploy these networks, there's an immense volume of work ahead of us. Physical networks that might have been there for 100 years, are obsolete and need replacement by Fiber. 5G will become the city or country wide hi-band wifi.

The European Commission cited 5G as 'one of the most critical building blocks of the digital economy and society in the next decade' (https://ec.europa.eu/digital-single-market/en/towards-5g). It has set out a roadmap that will see 5G services launched in all EU Member States by the end of 2020, followed by a rapid build-up to ensure uninterrupted 5G coverage in urban areas and along main transport paths by 2025. Similar initiatives are taken throughout the world.

Regarding the roll-out of 5G, it is clear that without pervasive fiber there is no 5G. Fiber is essential to the success of 5G. And the demand for 5G is extremely high, as mobility is increasingly managed online, with real time communication and autonomous vehicles as prime requesters.

Road and Asset Databases

Most Telecom businesses around the globe suffer from bad or non-existing documentation about their current networks, locations of poles and the numerous assets along the distribution lines. In many areas of the world, there's even absence of a proper base map depicting roads and buildings. This is a huge Mapping and Asset Management problem. How are we going to solve that? Mobile Mapping has proven to be ideal for such work: by bringing the outside world into your office, and into your workflow, map creation has never been easier. And as for Assets, well, roadside assets have been triggering the early mobile mapping business – there's massive experience on that end!

Boost your First Time Right!

In Fiber deployment, it is critical to keep the costs of building the network under control. Hitting a high percentage

EU's vision on 5G

Mobile Mapping as multiplier of cost-savings

of 'First Time Right' is how you can measure that. First Time Right means that the first design makes it all the way through to the as-built. The design is thus valid for construction. This can only be achieved with an in-depth, accurate and up-to-date knowledge of the site. Without that knowledge, the contractor would receive a design that cannot be executed, hence returns to the drawing table to rework. It can take up to five iterations until the design matches reality and can be constructed, generating immense overhead costs.

First Time Right is thus a major cost saver, and the most efficient way to achieve this is by use of Mobile Mapping, by giving the Planning Department as-good-as-live footage of the site. It is visually clear where to put a cabinet, where to dig trenches, and check real life distances.

Mobile Mapping as multiplier of cost-savings

By now you've understood that Mobile Mapping is profitable for Base Maps, Assets, and Planning. On top, 3D Mapping data is very clarifying for communication with construction teams, documenting work-orders and permits, as-built documentation, and for the customer assistance team that now have clear insight in a customer's site.

5G Analysis

Equally to the deployment of Fiber, building the 5G network is boosted by use of 3D Mapping throughout the workflow. While designing and planning a fiber network is a physical thing, for 5G the wireless connectivity adds a level to the challenge. 3D Mapping is clearly the best way to analyze for line-of-sight, optimal coverage, fresnel calculations and more.

Conclusion

As this industry is just discovering the values and benefits of 3D Mapping, it is clear that Telecom operators can boost their effectiveness and ROI a hundredfold when embracing 3D Mapping in a proper way.

Cabinet placement (3D model placed in 360° image) for permit request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