LIDAR OR IMAGERY – WHICH TO CHOOSE?

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ABSTRACT

Over the past few years there has been extensive innovation in Geospatial technologies that can be used in revolutionary new ways in order to accurately and efficiently map and assess transportation assets. Significant investments in R&D and the race amongst auto manufacturers towards making connected and autonomous vehicles a reality has been instrumental in facilitating a rapid evolution of how spatial data is collected, processed and turned into usable intelligent transportation asset information.

There are a number of sensors and information systems that transportation asset managers can leverage in order to manage their assets. Amongst this plethora of technologies, both LiDAR and Imaging provide some of the most important and accurate foundational mapping information regarding the assets and features in the transportation sector.

Advanced sensor technologies in combination with artificial intelligence, machine learning and integrated information systems provide significant opportunities for improvements and efficiencies in the collection of data as it relates to transportation asset management.

This presentation will discuss some of the differences between LiDAR and Imaging, some of the different systems that are being used to collect these different types of spatial data and how transportation asset information is accurately and effectively extracted and derived from each type of data that these respective technologies produce.

The presentation will provide a high level overview of the technical differences between the two technologies and data they produce along with some insight on the fundamental differences in how asset data is then produced.

With this insight, transportation asset managers will have deeper understanding of which technology should be chosen for a particular application or in different settings. Ultimately the transportation asset manager will come away with more perspective on how and where these technologies fit within the overall full asset management life cycle and how to effectively leverage these technologies within their asset portfolios.

As part of a comprehensive discussion, price and cost must also be included. Insight will be provided for why quotes can vary significantly from one vendor to another for the same scope of work. From this, transportation asset managers will be equipped with more insight and understanding of what the drivers are for pricing of these services.

The presentation at the conference will provide a concise overview along with thought provoking visual aids. The transportation asset manager will leave the presentation with a clear understanding of the principles and concepts discussed in this paper.

NOMENCLATURE

LiDAR – Light Detection And Ranging
AI – Artificial Intelligence
ML – Machine Learning
UAV – Unmanned Aerial Vehicle
IMU – Inertial Measuring Unit
DGPS – Differential Global Positioning System
BIM – Building Information Modelling

LIDAR

A technology that was initially developed in the 1960s, Light Detection and Ranging or Lidar as it is commonly known did not have widespread usage and remained relatively unknown until well into the 1990s and 2000s. Lidar involves shooting a pulse of light at an object and recording the amount of time it takes for that same pulse to reflect off of a surface and return to the source sensor. Modern systems will shoot millions of pulses a second and record millions of return signals. Differential Global Positioning Systems (DGPS) and Inertial Measuring Units (IMUs) are used to determine precise location. What you end up with is a very rapid means of accurately measuring objects. Most systems have settings that allow the operator to control the intensity of the pulse which either increases or decreases the number of points collected and how much detail is recorded for an object being mapped.

Today, Lidar has become a very common and highly available commercial tool. It is a well-developed technology from the acquisition sensors to the processing software and output products and solutions. Most recently, connected and autonomous vehicle systems manufacturers that utilize vehicle mounted onboard Lidar sensors to map transportation corridors have been investing large amounts of capital into streamlining the sensor instruments for ease of use, size and increasing processing efficiency and accuracy on the data side.

In terms of data collection, there 2 primary options for how Lidar can be deployed. They are airborne and terrestrial systems.

Airborne sensors are mounted on a variety of manned fixed wing aircraft, helicopters and Unmanned Aerial Vehicles (UAVs). Terrestrial on the other hand are mounted on stationary platforms like tripods or mobile ground based platforms like vehicles. Of course connected and autonomous vehicles are fast becoming popular forms of mobile Lidar data collectors. This is particularly influential in that it will have a significant impact on the frequency and means by which transportation assets get mapped and recorded in the future.

Regardless of the acquisition platform, the output data from a Lidar system is a dense group of points known as a point cloud. It is actually quite a simple data structure that involves 3 pieces of information - a geographic x and y coordinate location and an associated z value at that location. The points collected with Lidar are so dense on a surface that an actual picture like image is formed of the object being scanned. If ultra-high density scans are used the point cloud can sometimes almost resemble an actual photograph of the feature.

LIDAR CHALLENGES

During acquisition, mapping something with Lidar requires that the object is visible to the sensor. An unobstructed line of sight between the sensor that is sending and receiving the light pulse is required. Generally, if you cannot see something in your line of sight with your eye, the Lidar sensor will also not be able to map it. Using Lidar effectively will be highly dependent upon what objects might block the scan. In some cases, taking multiple scans from different angles is effective in overcoming this. However, this can add to the number of point clouds that need to be collected to map something and increases the overall volume of data.

Where most of the difficulty with Lidar is encountered is with the volume of points. A single Lidar file will typically contains millions of points and can easily exceed tens or hundreds of millions. To accurately map a particular feature or object, several scans that were taken from different angles are sometimes required to be combined which makes the resultant point clouds even larger. This can produce point clouds that are billions of points.

Although it is simple data structurally, most traditional software tools that are used to handle point clouds are not capable of handling the volume of points in a typical Lidar file. Specialized software and tools are available to process and handle point clouds. Unfortunately these tools are generally expensive and technically complicated requiring specialized skills and knowledge. Working with a vendor that has these resources can significantly reduce some of the frustrations that can be encountered when working with Lidar data.

LIDAR FOR ASSET MANAGEMENT

In the context of transportation assets, Lidar can very accurately map any kind of asset with the above mentioned limitations in mind.

Understanding the desired level of detail that is required, how the data will be used, where the assets are, type, number and size are all factors in determining how best to capture the Lidar data and what kind of sensor platform to use for collecting the data.

Once data has been collected and processed a variety of outputs can be created. From simple CAD plans to 3D models or representations of the assets. Those outputs can then be taken into immersive visualization systems like virtual and augmented reality platforms.

It is important to keep in mind that unlike a photograph that is an exact digital copy of what the eye sees, Lidar data is at its base a dense group of points. 3D models are based on computer generated objects and surfaces that are designed to only represent real world objects. This is a key differentiator and can be a limitation.

Depending on the density of the scan, the ability to model or visualize an asset within Lidar data can vary significantly. This also creates difficulties for doing inventories of assets from large Lidar datasets. Being able to identify assets, or more importantly discrete differences in types of the same asset can be quite challenging if the Lidar data is not dense enough or was not processed properly.

IMAGERY

Imagery or involves capturing an exact copy of an object or feature. There are a number of different imagery options including standard photography which captures what the human eye sees. Other imagery products involve capturing images that depict things that are outside of the capability of the human eye to detect. Multispectral, hyperspectral and ultraspectral data as well as thermal infrared imagery are examples of this.

Traditionally, film was used but most systems today use digital sensors to capture and record imagery data.

Imagery can be collected from any of the airborne or terrestrial platforms that are used for Lidar. Imagery data is stored as pixels which are tiny square units that are the smallest controllable element of a picture on a digital screen. The squares all blend together when zoomed out to form continuous and smooth shapes. Each pixel represents a particular shade of red, green or blue and blend into lifelike copies of the real world when zoomed out on an image. An image will always have the same size of pixels throughout. Pixels are recognizable on most digital devices by zooming in on an image until the image itself becomes a series of squares. The term “pixelated” is used to describe this.

Digital imagery data is stored as raster data files. The pixel is the basic building block of a raster image. Based on DGPS, IMUs, camera lenses parameters and distance from an object being imaged, a pixel will have a known measurable size or pixel resolution.

With knowledge of the size of the pixel geographic coordinates can be used to determine the corresponding real world geographic location for every pixel on an image. With this information, the entire image can be placed in the proper geographic location which is helpful for analyzing the image in combination with other geographic data.

The number of pixels that an image has will determine how much the digital image represents a copy of the real world and how far one can zoom in before pixilation occurs. This is also what is meant by the term pixel resolution. High definition images have more pixels (high resolution) which is what makes them sharper and allows for more ability to zoom in to see finer details before pixilation.

Higher resolutions are obtained by either bringing the sensor closer to what is being imaged or by using zoom lenses to capture more detailed data without getting closer to the object.

The higher the resolution, the large the raster data file. While the level of detail is better with higher resolution data, the resulting raster file size can become difficult to manage. It is not uncommon for imagery files to exceed hundreds of gigabytes or even in the case of large mosaics, be terabytes in size for individual raster files.

IMAGERY CHALLENGES

Like Lidar, imagery is only practical if there is a direct line of sight between the sensor and the feature that is being mapped. In some instances, taking multiple images from different angles and positions can overcome this. A good example is aerial imagery and scattered cloud cover.

By utilizing the overlap between one photo and another a processor can sometimes remove clouds and/or the associated shadow on the ground from one image by using the data from an adjacent image that was collected from a different angle. This is only marginally effective in most cases and tends to require a lot of human intervention in the processing which adds to costs and timelines.

Multispectral, hyperspectral and ultraspectral sensors that collect data not visible to the human eye are also limited by the same requirements for visible lines of sight. While these sensors collect information that the human eye cannot see, they still need a direct line of sight to the object or feature being mapped.

Infrared imagery has been around for many years but its use is not as widespread as standard imagery. The sensor systems are more complicated and thus more expensive, as are the processing requirements and software tools needed to derive useful information from the source imagery. Automation and pre-programmed algorithms are making the use of infrared imagery easier, however an understanding of what the algorithms are doing is necessary and requires specialized knowledge.

IMAGERY FOR ASSET MANAGEMENT

Like Lidar, imagery is very effective for mapping and inventories of transportation related assets. It is also limited to visual line of sight just like Lidar.

As is the case with Lidar, understanding the desired level of detail that is required, how the data will be used, where the assets are, type, number and size are all factors in determining how best to capture the Imagery data and what kind of sensor platform to use for collecting the data.

With Imagery there are different levels of processing effort that correspond to the desired output. If simple photos are required for the purpose of creating a visual record, then very little processing is required post data capture. Perhaps some mosaics need to be created but if spatial location is not required then the data can typically go right from the sensor and into whatever destination workflow is required.

If spatial detail is a requirement, there are a few more steps that are required depending on the data acquisition sensor platform. For aerial data, typically the imagery is orthocorrected. In most cases this has become an automated routine and software does all of the hard work. Basically the positional information from the GPS, Ground control and IMU is all used to remove distortions in the imagery, add accurate spatial location to all areas of the images. The software then does whatever mosaicking and consolidating of the data is required and outputs a refined product that can be easily brought into any number of subsequent workflows.

As mentioned, imagery data can be very large, requiring significant storage disk space and making it difficult to distribute. Compression technologies exist and can be used to reduce file sizes. There are limitations however in the use of compression technology. Some compression options will reduce quality of the data. Others will preserve the quality but generally in doing so will be less able to compress the data. There is relatively small niche where imagery can be both compressed and the quality of the data preserved adequately.

The key in understanding how to use imagery, whether to compress or not really lies in the intended use of the data. If fine detail is going to be extracted from the imagery, likely it will be advantageous to have no compression so that the full range of detail available in the original image can be accurately observed. In the case of identifying and cataloguing assets and asset details, this is most often going to be the best choice. The challenge is that the data storage requirements and handling efforts are greater.

As sensor systems continue to improve, zoom lens technology innovates and acquisition platforms evolve higher and higher amounts of detail can be captured using imagery. The tradeoff with more detail and higher resolution, is much larger file sizes and storage implications.

It is common to see imagery acquisition vendors advertising very high resolution capabilities and marketing how finely detailed they can capture imagery. This has become particularly prolific with the use of drones. Since they can fly much closer to the objects it is tempting to collect very highly detail. Just because it can be done though does not always mean that it should. With imagery this cannot be understated.

The rule of thumb is to align the resolution of imagery data with the end goals of the project. If a 10cm x 10cm object or asset feature on the ground is the finest detail that you need to identify based on your goals and needs, then it does not make sense to collect 5cm resolution data. All you end up with is double the amount of data that you need to store, manage and distribute. The exception to this is if the imagery will be used for another purpose at a later date. In this case it may be more cost effective to collect data once and use it for multiple purposes over a period of time. The only caveat to this is that things tend to change over time. Depending on your timeline and the subject matter being imaged, the data will have a life expectancy after which new data will need to be collected as changes will have occurred in the features being mapped.

Timeliness of the data be it Lidar or Imagery, can be an overlooked but very important part element of these data sets. It is critical to remember that data is collected at a single point in time. Things change over time and therefore it is imperative to understand the chronological parameters of the data in order to make sure it is relevant for the task at hand. In the case of asset management, where capital budgets are based on life cycles and changing asset conditions over time, timely data is imperative.

POINTS OR PIXELS - WHICH ONE?

Suffice to say, between Lidar and Imagery there are a lot of similarities and some differences too.

So how does a transportation asset manager determine which is the best alternative for leveraging these technologies? Once a choice has been made between Lidar or Imagery how is one to know what the best platform is for acquisition. Is it Aerial or Terrestrial, or both? Maybe neither are appealing? A lot of questions arise and need to be answered, all of which can have a significant impact on what it is that is to be accomplished, costs, timelines and risks.

In order to make things easier, it is best to apply a logical approach to the decision making.

The first decision is whether or not a line of sight will be available to whatever is being mapped. If there is not line of sight and the obscured areas cannot be mapped from different angles, then both Lidar and Imagery are likely not going to be the right tool.

This is an important first decision that often gets overlooked. Of course there are vendors in the market who profess to be experts and will say they can collect anything, this in fact we know is simply not true. Unfortunately once the data is collected there are bills to be paid and if the data does not meet the need, well that is not a position anyone wants to be in.

There tends to sometimes be a lot of mystery around what Lidar and Imagery platforms are capable of. Perhaps we can attribute this to some of this to science fiction shows on television. The reality is, to decide on whether Lidar or Imagery would work one only needs to think about whether or not they could take a photograph from whatever platform or platform vantage point is available and be able to capture every amount of detail that is needed from that photo.

Once Lidar or Imagery has been decided upon as viable, which to use involves a few more considerations.

The next step would generally be the type of platform that is to be used. Will it be Aerial or Terrestrial? This will depend mainly on the size and type of objects that are to be mapped. Also important are the logistics involved in getting close enough to them with either technology to effectively capture the level of detail that is required.

Airborne platforms will generally be used for large areas and linear infrastructure. Highways, rail and transit corridors and airport runways for example are often mapped with aerial platforms, both Lidar and Imagery alike.

In the case of long linear asset like highways, mobile Lidar and imaging systems on a terrestrial platform could also be options. In order to determine which is the best tool one, would want to consider things like whether or not the highway can be shut down during mapping, weather conditions and timeliness of the data that is to be collected.

Terrestrial systems will have more of an impact on the ongoing operations of the transportation assets being mapped. Terrestrial systems are getting better and more capable of collecting data while integrating with the operating assets but any hiccups in the data collection will be more challenging to deal with. If it is impractical or costly to shut down an asset for a length of time while a terrestrial system is used, then aerial platforms become the preferable choice.

In deciding between Lidar and Imagery, the choice is also dependent to a large extent on what the desired outcome is and how the data will be used. For aerial acquisition platforms, Lidar will be able to penetrate a certain amount of vegetation cover. The pulse of light will be able to reach the ground in some places amongst the vegetation and map features there. Imagery cannot penetrate the vegetation enough to map features. If there is light vegetation cover, Lidar would be the better choice over imagery. There is a limit and Lidar will only be effective with relatively light vegetation cover before the light pulses cannot reach the ground with enough consistency to map anything accurately.

A few other significant differences exist between Lidar and Imagery. The nature of Lidar data allows for very easy 3D mapping of features. Precise detail can be collected which enables measurements to be taken and dimensions of assets to accurately be obtained. Individual images by themselves cannot be used in this manor however, photogrammetric workflows can be used to obtain x,y,z points from the stereo overlap in photos. Producing both the imagery products and an associated point cloud from photogrammetric workflows has become quite common. The difference is that there is high quality imagery that goes with the point cloud however the point cloud will not have the detail or density of a Lidar point cloud.

There is a common perception that Lidar is by far the best data that can be collected. In actuality, there are many factors that influence the quality of these two types of data. In certain instances the point cloud produced from photogrammetric methods, can be of higher detail and accuracy than Lidar. The type and brand of sensor, be it Lidar or imagery, can also have a significant impact on the quality of data that is produced. Not all sensors are alike in capabilities.

For these reasons, working with an acquisition partner that has many years of experience and can provide examples of successful deliverables as well as validation reports is important.

In terms of innovation, much work is being done on the use of Artificial Intelligence (AI) and Machine Learning (ML) for automating the interpretation and extraction of assets and related details from both point clouds and imagery data. Much of the research has been focused on Lidar data however imagery research in this regard is catching up quickly.

With regard to either technology, the potential of AI and ML to automate the process of building asset inventories from these types of data and monitoring and assessing the condition of existing assets stands to revolutionize the way transportation assets are managed.

It will become significantly easier, faster and less costly to build inventories of assets and manage them ongoing. Further, there is a convergence of these technologies underway. In both the aerial and terrestrial platforms, systems that collect both imagery and point clouds simultaneously are becoming increasingly common. Additional sensors are also being added to these platforms like Ground Penetrating Radar to collect even more data in one pass.

PRICE CONSIDERATIONS

An examination of which of these technolgies to use would not be complete without a discussion of price. When it comes to selecting one of these technolgoies over the other, price should not be used as a deternmining factor in choosing one over another. There are many techncial variables that need to be considered that are far more influential in a good outcome than price.

When looking at it on a technology specific basis, there is a wide variance from one vendor to another and from project to project. A significant number of factors need to be considered in determining what an appropriate price is.

There are some consitencies from one project to another. Cost recovery on the capital costs associated with the sensor systems and platforms, staff wages and labour rates and insurance for example remain somewhat consistent within short timeframes over a period of a few months.

It is the variable items that cause the most uncertainty and are primarily responsible for the variances from one vendor to another. Some of thse can vary with one vendor from job to job and can also vary from vendor to vendor. These can include mobilization costs, fuel, labour rate differentials from one geography to another, different platforms and sensor systems, diferent processing and workflow methods as well as office overhead.

Generally, larger organizations will carry higher management overhead and the recovery of that is built into the pricing. That being said, the larger service providers also usually have more financial resources at their disposal and therefore often have better equipment as well as more redundancies in both equipment and staff. The larger firms will also have more refined processes, health safety and environment policies and formal quality management programs. All of these items will factor into the price. For some consumers, usually larger corporate entities, these items are important and for others less so but important and sometimes overlooked influencing factors on price none the less.

Smaller service providers can optimize on many of the above mentioned items in order to offer a lower priced service. Sometimes that is ok and other times it can introduce unnecessary risk into a project. Each client and consumer will have their own tolerance level for how much risk they are willing to accept.

There are customers that will always go for the lowest priced option every time. Businesses are always on the lookout for cost saving opportunities, this is understandable. The challenge with this approach in this context is that there are simply too many variables that can influence these technologies and the associated products, both in the context of the technologies themselves and also from one vendor to another.

With this in mind, comparing one vendor or solution based on price alone is not an effective means of assessing one option over another. This can introduce unnecessary risk and leave you unsatisfied with a product that you pay good money for.

Instead options need to be considered using a feature-for-feature comparison, taking into account as many of the technical and vendor specific details as possible. In addition, the use and intended workflows for the data need to be factored in. If a true and even comparison can be made between all of these factors, then and only then should price become the determining factor in the decision making process.

CONCLUSION

As has been discussed, when it comes to the question of pixels or points, the decision can be challenging. There is an abundance of information in the market. Some of it reliable, some of it not or provided with a marketing and sales based slant such that one is left thinking these technologies are dead simple and will revolutionize everything with little or no input from humans.

While these technologies continue to evolve and realistically do get a little easier to leverage across a wide range of situations as time goes by, understanding at a base level all of the factors that combine to produce a particular deliverable from a specific platform at a given price point is paramount. Sifting through to gather the insight needed to make an informed decision quickly becomes overwhelming, even more so for those that are new to these technologies and have not been exposed to them previously.

Using a logical and well thought out decision making process, based on technical facts, reliable information and solid business principles will help transportation asset managers with deciding on which of these valuable technologies will be their best choice on a project by project basis.

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