Mapping the world with LiDAR

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Abstract

To map the world TomTom/Tele Atlas is continuously looking for new source material to improve the quality of the geographical database, to extend the coverage more quickly, to keep it up to date and all this with an acceptable cost. Hereby point cloud data is becoming more and more a source of interest to reach those goals. Mapping reality means modelling hundreds and thousands types of features/attributes and in this paper an overview will be given where point clouds can become an added value and another part of the paper will highlight that cloud data is not a silver bullet and brings along some challenges if one want to industrialize the process and make it more cost efficient, which of course introduces new business opportunities and challenges academically.

1. Opportunities

Point cloud data can be used to create and maintain several features or attributes in a geographical database. The following subsections will give an overview of several feature/attribute groups where this data could and is being used.

1.1 Road geometry

An obvious domain where point clouds can be an added value is related to road geometry. It could help us in modelling new road geometry or help us in improving the absolute and relative accuracy. Although it must be said that so far this domain has not been studied in a large extend. Certainly the relationships between the point cloud accuracy, relative geometry accuracy and absolute geometry accuracy contains a set of interesting unexploded academic research topics.

Further more the point cloud data can also be used to capture and maintain new geometry related information which is crucial for Advanced Driving Assistance Systems (ADAS) such as road curvature, road slope and road width. Curvature and slope challenge our academics to come up with new algorithms and arithmetic paradigms to for example derive splines from the point clouds. Splines are functions defined piecewise by polynomials and are used frequently by road construction engineers to model road curvatures.

1.2 Road attribution

Once the road geometry has been captured one can start thinking about which attributes that could be captured or maintained with point cloud data. And without too much brainpower one can come up with examples such as pavement, lane information, tunnels and bridges.

The pavement includes the detection of different pavement structure or material such as asphalt, concrete, cobblestone, etc. But it can also look at the pavement conditions, so basically how good the road is maintained.

The lane information is again an information set that could be derived from the point cloud data. One could extract the number of lanes, the lane divider type (e.g. solid line, interrupted line, single, double, etc), the lane type (e.g. exit lane, parking lane, shoulder lane, etc) and even manoeuvre information based on the arrows on the road surface.

Another interesting and obvious feature one could extract from the point cloud data are the bridges and tunnels. And one can not only determine where they are but could also extract some attributes from it such as the length or the height of a tunnel. This information can of course not be derived from laser-alt but from terrestrial lasers, e.g. mounted on mobile mapping vans.

1.3 Road furniture

The next level we can use the LiDar for is any features or attributes along the road geometry. There is still a huge amount of interesting data along our roads that are very important to be captured within a geographical database. The list below gives an idea of features that could be captured via this data; some are more exotic, read challenging, then others. For all of them one can again detect the presence of the features but for some of them one can also extract attributes.

- *Side walks*. Determine the presence of a side walk but also attributes such as the width, pavement type, etc.
- *Curbs*. Determine the height of a curb.
- *Signs*. Determine the position of a sign but also the dimensions. And perhaps it is even feasible to categorize signs (e.g. sign post, speed restriction, stop sign, advertisement panel, etc.).
- *Trees*. Determine the position of a tree and also here perhaps the dimension.
- *Road lighting*. Determine the position and dimension information.

1.4 3D information

In the literature one can find a tremendous amount of material on how LiDar can be used to model buildings, to determine roof structures and of course also the height of a building. Point clouds can assist to build real 3D volume-tric objects and not only 2.5D (= building footprint with height attribute).

The buildings need to be also integrated within the environment and hereby is the alignment with for example road geometry instrumental, of course point clouds can assist here.

Finally the landscape should also be modelled in 3D and also here point clouds can help in creating a Digital Terrain Model (DTM) and assist in integrating the 3D buildings and road geometry within the DTM.

2. Challenges

When one has a geographical database which needs to fulfil different market segments one immediately gets in competing and conflicting requirements. Because each market segment has different priorities and focus, personal navigation is perhaps today very interested in road attribution, where in-car navigation can be more interested in ADAS related features and finally the online community is more into 3D City Models. Nevertheless they have one thing in common they all want to model the reality with a certain level of detail and each of them have there own challenges, personal navigation devices have a small screen, in-car navigation systems are not yet online and finally the online customers have still bandwidth restrictions.

Figure 1. Market - Focus and Importance shows some examples of the continuous clash between different markets and what those markets determine to be important and what they are focusing on.

All those requirements result in the geographical database getting following requirements:

- Should be at all time in line with reality.
  Model the reality correctly related to content integrity (= capture the right objects with the right attributes) and format integrity (= files/databases are technically correct).
- Should have different representations of reality.
  The same object can be modelled several times with a different level of detail. E.g. the number of polygons used to model a 3D building can have a big impact on the final representation of the building.
- The positional correctness should be very high.
  For a geographical database x, y, z coordinates are crucial. Every object should be georeferenced with high accuracy, can go from 5 m to 1m to even 10 cm absolute accuracy.
- The data size should be adaptable based on the requesting market.

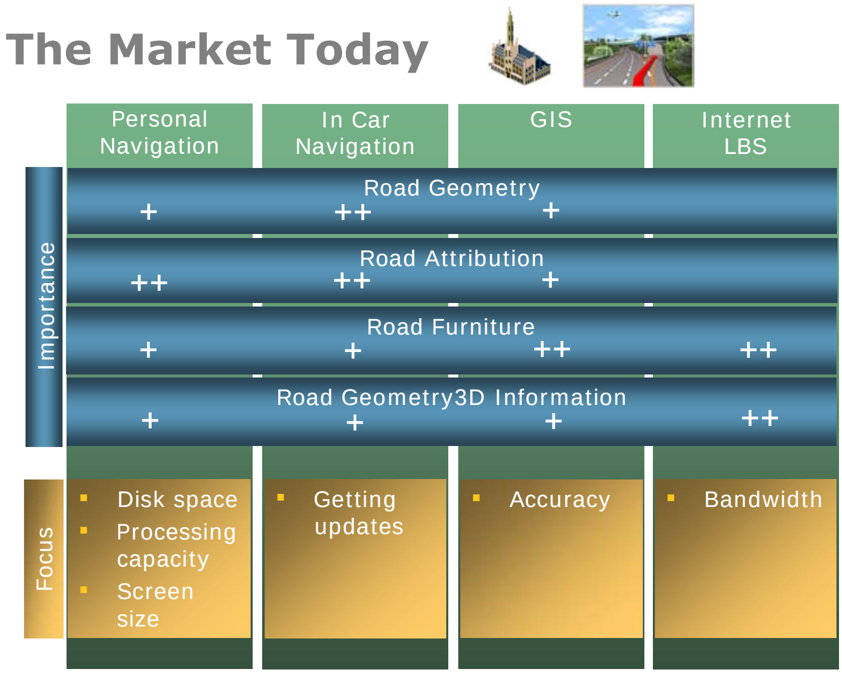

Figure 1. Market - Focus and Importance.

The opportunities section made clear that point clouds can help us in modelling the reality but if we now also take the four “simple” requirements, just listed above, into account then can we still say that point clouds can be a useful source material to create and maintain geographical databases?

Probably the last question posted just above can be answered positively but due to the fact the source material type is quite recent the production processes are quite immature and are a potential trigger of research projects.

2.1 Challenges to keep in line with reality

The main challenge with point clouds is the huge amount of data, which not only gives storage challenges but also processing/throughput challenges. Today it has been proven that one can use LiDar data to model 3D buildings but what if one has LiDar data for 40 million cities in the world and several capturing sessions of the same city? This increases of course complexity and mainly processing time tremendously. So how can we speed up processes?

– Can we extract in a more automated manner features from point clouds?
– Can we find differences between two deliveries covering the same object/area?
  Is it possible to perform change detection between two point clouds covering for example the same city? Can one have algorithms that detect the changes within a city based on those two point cloud deliveries?
– Can we combine different source materials to improve the efficiency?
– How to come to a smoother integration between DTM (Digital Terrain Model), buildings and road geometry?
– How to integrate buildings on a flat plane in the most efficient way, read as less as possible artefacts?
  Buildings on a hill will due to the slope not have a rectangle façade. However not all products have the DTM included and as a consequence one has a gap between the model and flat plane, Figure 2 illustrates this.

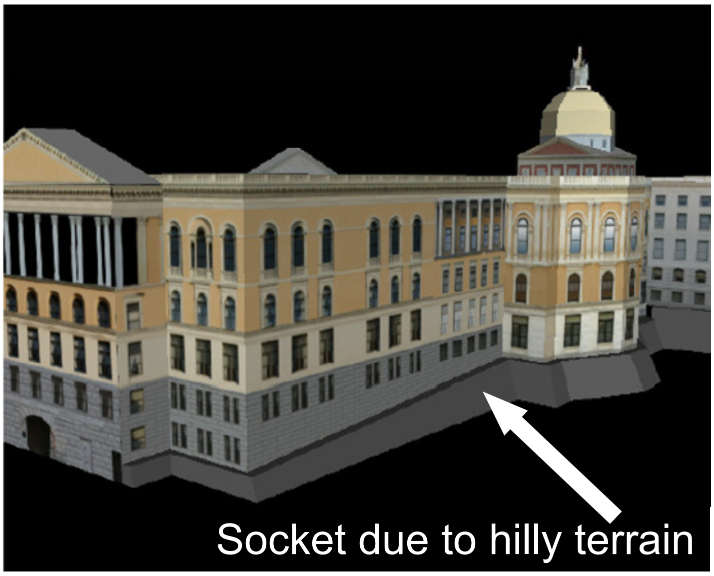

Figure 2. Socket example.

2.2 Challenges to have different representations of reality

In a lot of cases it is not a problem to have different representations of the same object. Although with the current technology it can't always be done in an automated manner.

- How can we derive less detailed representation of building from higher level of detail representation of the same building?
- How can the different models kept consistent with each other if adaptations are required?
- How can we reduce the data size for the same level of detail? Or what is the impact on data size between the different levels of detail? Can we apply any new lossless or lossy compression algorithms on LiDar data or derived features?

These challenges are mainly related to the 3D information.

2.3 Challenges to have high positional accuracy

Positional accuracy is becoming more and more important in applications, definitely for ADAS applications. Applications are using more and more the coordinates to adapt the application behaviour. For example orientation of the headlights of a car will change based on the road curvature data or the truck gear box is steered based on slope data. So we should have a clear view on how the accuracy of point clouds can have an impact on the positional accuracy of features in a geographical database.

- Are there processes to determine the positional accuracy of a point in the cloud?
  - What's the impact of reflection?
  - What's the impact of multi-path?
- How can the accuracy be improved of a point cloud?
  - Can the combination of different source material improve the quality?
  - What's the impact of combining several deliveries of the same object/area on the quality?

3. Conclusion

Point clouds are a quite new source material type which has a lot of potential to:

- Keep some features and attributes in a geographical database in line with reality. Hereby features/attributes come to mind related to road geometry, road attribution, road furniture and 3D information.
- Improve the positional accuracy of the geographical database.

Due to the fact the source material is new it brings along a number of challenges.

- Handling huge amount of cloud points.
- Extracting features/attributes from cloud points in an automated manner.
- Determining the positional accuracy of extracted feature/attributes from cloud point data.

As one can see point clouds can be helping us in modelling reality but brings along some new challenges for which we have to find answers. Nevertheless point clouds will help us in reaching our goals.

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