ROAD DATA INFORMATION SYSTEM; BUDAPEST CASE STUDY

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ABSTRACT

Budapest Közút is developing ROad Data Information System based on mobile laser scanning since 2013. All public roads (cca. 5000 km) are surveyed by MLS (Riegl VMX450) in survey grade accuracy and all visible road assets has been digitized and loaded to a complex 3D GIS environment. Since the first full coverage had been done in 2014 the whole city has also been updated - being one of the few large infrastructure in the World that has not one but multiple high accuracy 3D data for the whole network. The high level accuracy, the full coverage and the already available data updates allows Budapest to use the 3D data for multiple operational applications - from traffic- and road design to planning, from assets management to traffic safety analyst and municipality activities.

One of the most cutting-edge applications is the road surface analyst over time that allows the road management company to analyze and optimize different construction methods and is changes over the years.

One example for road quality analyst is the application of data support for PMS (Pavement Management System) how keeps this new component the road surface quality well?

1. INTRODUCTION

In the past decade, automatic 3D scene analysis using LiDAR point clouds has been a challenging task in research fields of photogrammetry [1], remote sensing [2], computer vision [3], and robotics [4]. As a generally utilized data type, LiDAR point clouds can be acquired through different acquisition techniques such as terrestrial laser scanning (TLS),

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mobile laser scanning (MLS), and airborne laser scanning (ALS). However, for dense and accurate 3D scene analysis and interpretation, especially in the context of urban areas, TLS and MLS, which have higher scanning density and more stable carrier platform (e.g., static scanning stations of TLS), are considerably more reliable. [5].

Road Management Company of Municipality of Budapest (Budapest Közút Zrt.) decided to implement a complete 3D data acquisition, 3D data production- and GIS publication/analysis system (RODIS) on 2013. The goal was to provide full GIS data- and application solution for any department of the municipality, such as road- and traffic management, asset management, road planning and construction fields, building management, municipality architect and many more. And the company succeeds.

After one year of research, system and production design then system development RODIS started to cover the full city with survey grade MLS (Mobile Laser Scanner) point clouds and produce 3D geodatabase of all public roads (5000 km network) in 2013. First full coverage took, 1,5 years. The first update took less than a year. Fig. 1. is shown the different components of RODIS: VMX 450 scanner, point cloud data, 3D geodatabase and 3D GIS portal.

Figure 1. Main components of RODIS: VMX 450 scanner (top left), point cloud data (top right) 3D geodatabase (bottom left) 3D GIS portal (bottom right)

Today (2019) the city has already been multiple times covered by MLS point clouds, and the 3D vector geodatabase has been updating. Such large scale 3D data production and update requires careful acquisition planning, well defined reference data that is used at each processes and centralized data production system to track the production progress.

The applied LIDAR system is driving along Budapest's roads every day, some dozens of operators processing the acquired data and produce and now update the dB schema-based

3D geodatabase for various applications.

This way the Company can use network level applications at various domains and can make complex analysis using accurate, detailed and - in the same time - historical data with same quality.

One of the most cost saving and very important analyst is Pavement Management System support that provides network level strategic decisions and later high performance road planning and design.

2. FULL INFRASTRUCTURE NETWORK SURVEY AND MULTIPLE UPDATE

The more up-to-date the data the more useable is. Reacquisition of the road network started right after the first full survey. Updates applies carefully designed geometric reference database that contains survey base points, reference TLS scans and also reference plains generated from already post-processed and survey grade accuracy aligned MLS and TLS point clouds. Reference post-processing project files are also stored in the production metadata dB and are used for further processing:

When an update survey path had been measured all available overlapped reference data is used during post-processing solution. The method allows to produce full aligned data over time, where only changes are the difference between acquisition. 3D geometric changes are used for quality measurements, assets update, pavement quality analyst and many more applications is shown in Fig. 2.
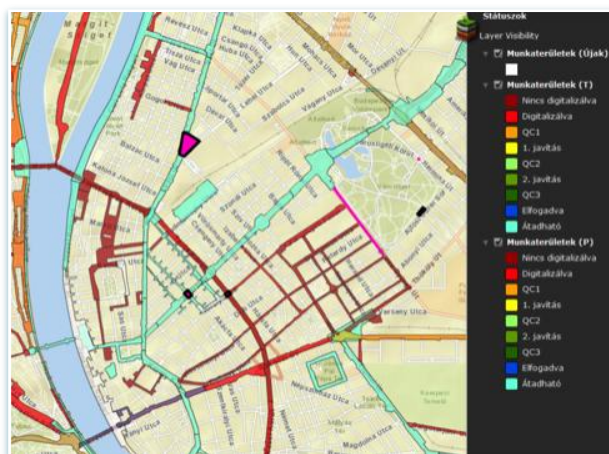

Figure 2. Part of 3D data production management WEB GIS portal that supports fully aligned survey grade accuracy data processing.

Data production optimization was one of the core elements when the system was designed. Various engineering and operator task need to be done in parallel on dozens of workspaces, that required efficient resource management and smart tasking actions. On-line data production management solutions were designed, where all involved engineers, surveyors, data processors and vector produced experts were managed in one single system.

3. MLS AND TLS

Taking consideration that very large ground scanning capacity is needed to cover the project, the company has chosen one of the best, high-end scanners available on the market. The *RIEGL* VMX-450 MLS (Mobile Laser Scanner) with integrated platform for VZ-400 TLS (Terrestrial Laser Scanner) has been delivered on September, 2013 and intended for the sole purpose of 3D urban road-mapping of capital of Hungary, Budapest.

The complete scanning platform is either used on a van/tramp-car/boat to scan the road network of the entire city (approx. 5000 km long road network) or VZ-400 terrestrial scanner is used separately from VMX-450 to provide support for mobile scanning system acquiring high precision reference point cloud network places, as well as covering not-scanned areas by VMX-450 (such as undergrounds, important buildings and missing areas not visible for VMX-450 mobile scanner). For the purpose of absolute accuracy assessment, a 3D point cloud was collected from a stationary scanner from three different positions [6] The reference TLS scanner data provides homogeny accuracy all along the road network. Reference plains are stored to reference geodatabase generated from TLS aligned point clouds.

Both scanners are running every possible day, many times in two shifts to provide the necessary amount of 3D survey grade accuracy point clouds for data extraction and data analysis.

Update tasking is focused on hot spot areas based on the requests from the core departments such as traffic management, road maintenance or road planning. The target area is tasked including desired data acquisition (for example after finish of road construction).

MLS scanning and post-processing produces significant amount of data that is handled in the Company's CEPH internal cloud. CEPH is a free-software storage platform, implements object storage on a single distributed computer cluster, and provides interfaces for object-, block- and file-level storage. Ceph aims primarily for completely distributed operation without a single point of failure, scalable to the exabyte level, and freely available (WikiPedia). The cloud has about 1 PB storage capacity. The processed MLS projects has about 200TB size, the on-line available pointclouds (LAS and LAZ formats) reserves 60TB from the file server. The mentioned data is also backed used and some historical data is available in archive structure.

The captured images during MLS acquisitions are 18 035 277 images (20/02/2017 status that daily exceeds with some tens of thousands images). Faces and licence plates of cars are blurred using machine learning algorithm. The image data reserves net 120 TB that does not contained the backup and the raw image size.

TLS scans (over 5500 scan positions at present) also managed on the cloud.

Mobile Laser Scanning (MLS) technology acquires a huge volume of data in a very short time. In many cases, it is reasonable to reduce the size of the dataset with eliminating points in such a way that the datasets, after reduction, meet specific optimization criteria. Various methods exist to decrease the size of point cloud, such as raw data reduction, Digital Terrain Model (DTM) generalization or generation of regular grid. [7] RODIS team developed one of the most efficient file storage system available today that allows the 3D vector feature extraction and modeling team (as well as any other users) to request any 3D point cloud and related panorama images on-line, on-the-fly, applying data compression for more efficient data storage. RODIS uses the LAZ format that keeps all original information from the LAS point clouds when the size is reduced to 5th of the original LAS.

The MLS and TLS post-processing work is supported by RODIS's automated Web GIS based production management system to have the fastest and most accurate point cloud production solution for city scanning can be found today. The point cloud data has 0,01-0,1 cm absolute accuracy (RMSE CE90).

4. RODIS - VECTOR

Although scanning is not an easy task in an entire city size, generating vector data (3D geodatabase and models) is an even bigger challenge nowadays - to keep it topologically clean and aligned even after updates.

Since Budapest using RODIS data for various domains from traffic management and design to road planning/design, from asset management to greenery activities and safety planning the data production team had to built the most productive solutions to provide high quality GIS data in a very short term for the departments.

3D Geodatabase schema was designed to contain all necessary information for build and/or cartography the data not only in 2D, but any 3D environment, too. There are 260 feature types in the assets management schema, and 140 different features are being updated based on the MLS/TLS data. The current vector database including historical data (current and updates) has 2,4 GB. It contains all street assets in 3D.

Best available point cloud feature extraction software's have been selected as base solution. Since non of the out-of-the-box products can fulfills all the user's requirements the development team built many tools and add-ons for the original solutions to make the feature extraction faster, smoother and more efficient.

Since CAD and GIS solutions being used for feature extraction the data interoperability was also solved between 3D feature extraction platforms and the Geodatabase. Also data publication engines have been developed to provide the extracted data to different user type in the way they want to use it for their own CAD/GIS/WEB or other platforms.
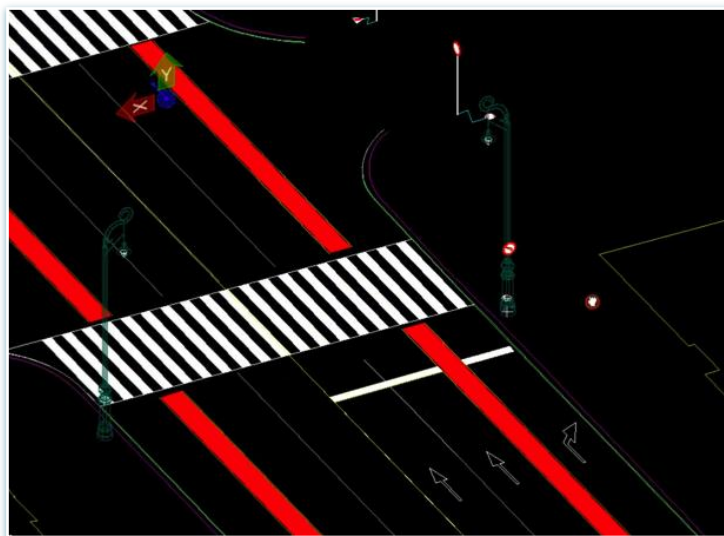

Figure 3. Sample of 3D data in from the GDB

Quality management has big role, too, to deliver high quality and easy-to-analyse data for the users. RODIS produces 11-15 reference maps per year beyond covering the full city. These surveying projects are previously tasked and are delivered to the road designer department.

All necessary features for road design is being extracted by RODIS, clarifying that the solution is faster and even more accurate as basic field survey.

The 3D geodatabase is growing every day, providing 3D traffic management static information (road signs, road paintings, curves and other feature) as well as all features is visible in the road like is shown in Fig. 3.

Having such success RODIS is used for architect and building management purposes, too, once large capacity is needed in with high accuracy and complex usage.

5. RODIS - DATA PUBLICATION

3D data publication is smoothly solved with Web GIS and desktop solutions. Many in-house developments were made to fulfill current and future's user's need of new data formats (panorama images, point clouds, detailed 3D models, 3D vector data).
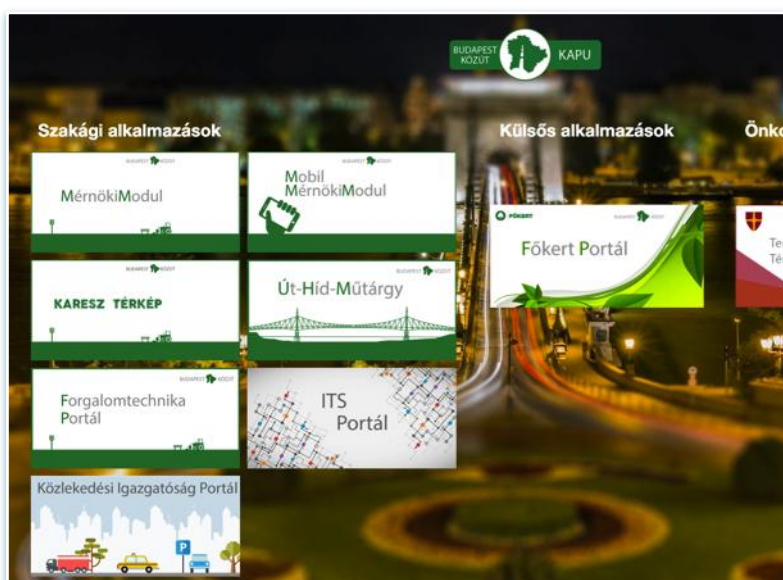

Figure 4. On-line GIS portal opening screen with user-related sub-portals

Thematic GIS subprojects are supporting the different fields from traffic management, assets management, greenery, road maintenance, bridge and underpass management and many municipalities of districts of Budapest. Each GIS sub-site - is shown in Fig. 4 - has different web-services to provide customized data visualization in 2D and 3D, various reporting and data exports (CAD/GIS/alphanumeric formats). Data analyst results and on-the fly data analyst also can be done depend on user authentication level and the GIS sup-sites is currently used.

6. RODIS - ANALYSIS

With point cloud never seen before dimensions came to reality for city managers, professionals and any users are working to manage and maintain a metropolis. Since the selected MLS has very dense point resolution very complex analysis can be done.
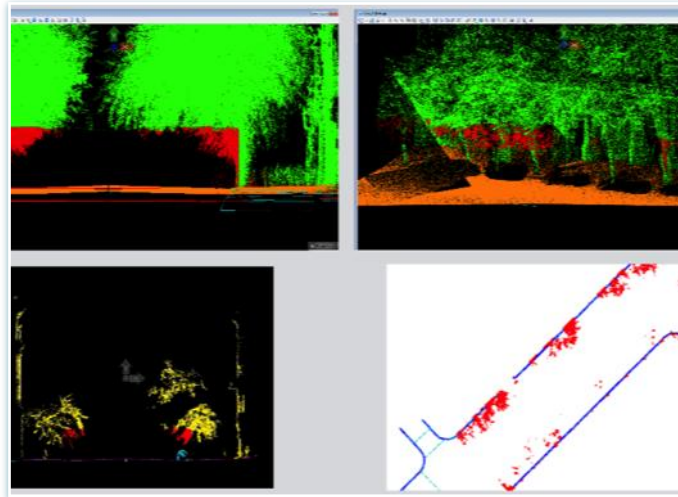

Figure 5. Tree clearings analyst and output scenes

RODIS GIS development team designed fully automatic solution for road surface error detection, even can provide very accurate IRI (International Rough Index) data automatically generated from RODIS point clouds and 3D vector data!

Analysis is widely used for clearings, road surface study as well as for flood analysis. We show in Fig. 5 and Fig. 6 two nice example (tree clearing analysis and flood modeling) how useful is the RODIS in the analyzation method.
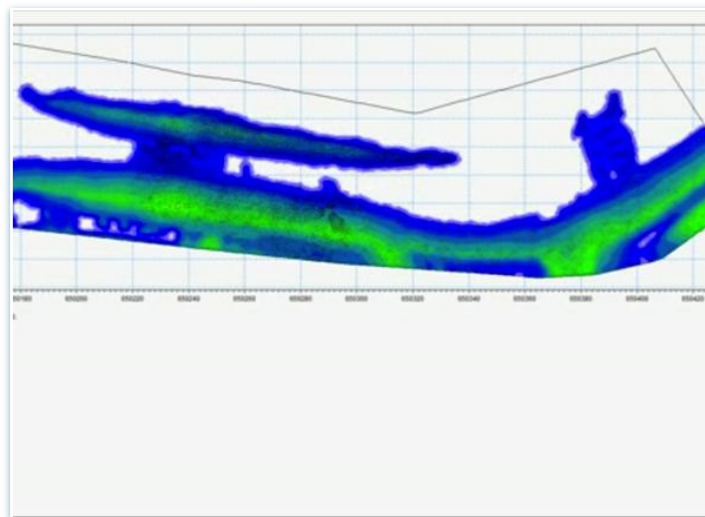

Figure 6. Flood modeling based on DSM of MLS point cloud

7. OPTIMISATION FROM THE RODIS: PAVEMENT MANAGEMENT SYSTEM IN BUDAPEST APPLIED BY RODIS

It is important goal of Budapest Közút, as manager entity of public roads of the capital to provide the services fitting to the requirement of today needs. Considering such the company has been implementing the cutting edge technologies and improves the level of quality of the daily work. Pavement Management System is applied in Budapest as well to improve the long, life-cycle term planning for the road network. PMS is a "set of defined procedures for collecting, analysing, maintaining, and reporting pavement data to assist the decision reporting pavement data, to assist the decision makers in finding optimum strategies for maintaining pavements in serviceable condition over a given period of time for the least cost" [8].

Fitting to this approach the company applies the up-to-date and approved public road asset management data to its pavement management related and optimized decisions. It is required not only collecting road-related data in a state of the art way but also data analytics development is required. [9]

The company has been collecting data for PMS analytics for years. In recent years pavement management systems have experienced a significant evolution, on the increasing role of modules increased cost analysis and forecasting as well as the evolution of GIS systems have proved their usefulness and PMS. [10]

Thanks to development of GIS and management of data capture allows the complex analytics based on scientific models today.

RODIS provided the survey grade level 3D MLS point cloud for the whole surface of public roads and pedestrian paths. Based on this source data 3D traffic vector base-map were created (that is updated every year). This 3D GIS data provides all necessary information about road width, surface and length of curbs.

Also International Roughness Index which is relevant data for a good PMS provided by the RODIS. Normally an apparatus mounted car measures IRI, but the most different solutions tried to simplified the measuring process like autonomous robot which used to measure the International Roughness Index. [11] Instead of the complex and expensive measuring equipment (laser profilometer, quarter car or autonomous robot) regarding to our RODIS we could calculate the IRI the most cost ant time effective way from the GIS point clouds. [12] [13] Fig 7 shows the calculated IRI data from the RODIS point clouds.
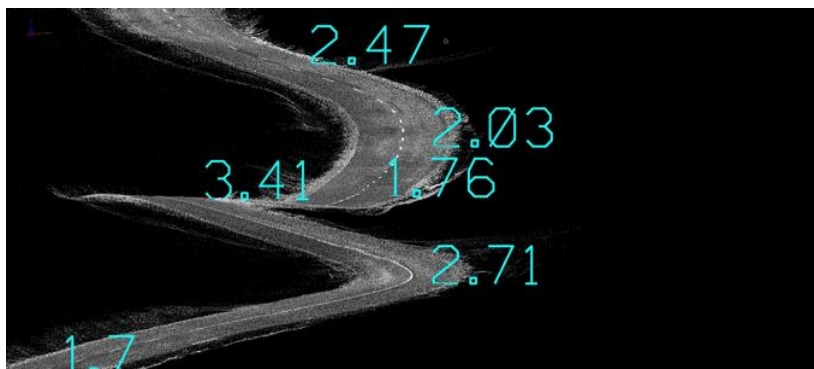

Figure 7. IRI data from the RODIS point cloud [14, Almássy Gábor, 2014]

Next to RODIS provided data for an appropriate PMS need more data like thickness and type of the pavement, the last invention year, traffic volume, etc.

Finally based on our RODIS and other data collections we get a pavement status of the road network are calculated for 5, 10, and 15 years, then above defined method is applied to re-calculate the intervention model and expenses, too. The intervention solutions take into account the optimized repairing methods for each road and also optimize all intervention in network level.

It is definable with long term model if how are the expected status values without intervention, and what are the costs of later executed interventions. Fig. 8 Shows the immediate necessary inventions in Budapest.

Figure 8. The required immediate inventions in Budapest's roads [15, Almássy Kornél, Dávid and Pusztai, 2018]

There were two PMS point cloud processing campaigns, were involved 1369 km road lengths. One is 2015 (first full coverage) and updates were done in 2016 and 2018. The

solution is set up to make the process and the update of the PMS result any time once the new updates will be available.

Based on our data PMS proposes next year reconstruction road sections. The proposal is based only the measured technical parameters, so it does not consider many such opinion, that may define the reconstruction list. Such can be utility reconstruction, or not measured status parameter issues (such as water management) Based on above PMS proposal can be the base for decision making but cannot replace personal decision.

Based on existing data only 5 % (around 1 million sqm, 85 km) missing data was noticed. 69 % of the roads (appr. 12,8 million sqm, 927 km) there is no need to apply serious intervention, but 26 % (4,8 million sqm, 356 km) should need intervention already in the first year. To reach homogeneous quality we would need 328 billion HUF (1 EUR = 315 HUF) based on computing model. This budged is far away from the realistic available financial resource, so the optimisation and prioritization is a must [14].

8. CONCLUSIONS AND RODIS FUTURE

Applications and different data production request comes fluently to RODIS Team. Today the solution is not only serves Budapest's road-related departments, but architectures, strategic decision makers, heritage protection institutes and city landscape designers are requisition different applications and data.

RODIS is improving every day. Automated feature extractions are already in use, road signs recognition is not limited to 2D but RODIS road sign recognition automatically stores the features in its real 3D position directly to the geodatabase.

New sensors (drone scanners, handheld scanners) are being implemented to the production workflow chain in the future, allowing RODIS to keep being the leader of ground 3D data and GIS solution of the World.

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