Leeds the Automation Degree in the Processing of Laser Scan Data to Better Final Products?

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SUMMARY

More than 7 Years ago the laser scan technology takes place also as a surveying data acquisition method. But how is the current level in the production requirements, regarding automation degree, process technology and performance. The hardware becomes smaller, faster and compact.

The software development is still nearly on the same level. Some steps in the recognizing process of the targets for the registration are done. But the software stills the key for the success. This paper offers a number of conceptual possibilities with regard to quality, automation and capability. Some examples will be presented.

The proposed approach to realizing the complete automatic technology have been described in this paper based on the experience gained by the Technet Rail 2010 crew during the last 5 years. The main achievements and disadvantages have been discussed, especially concerning the maximum achievable accuracy of the method.

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1. INTRODUCTION

Automated approaches for the conversion of multiple overlapped three-dimensional (3D) point clouds into an integrated surface shape measurement in the form of a complete polygon surface are important in the general field of engineering surveying. Traditionally, the conversion process is achieved in a semi-automated manner that requires extensive user interaction. In this work, automated methods for point set registration are developed and experimentally validated using polygon surface reconstruction to represent raw, 3D point clouds obtained from non-contacting measurement systems in this case laser scanners. Using local differential properties extracted from the polygon surface representation for a measurement data set, a robust sculpture surface (feature-matching method is described for automatically obtaining the initial orientation and mismatch estimates for each overlapped data set. Using both simulated and measured experimental data to quantify the performance of the method, it is shown that differential local surface features are appropriate metrics for identifying common features and initializing the relative positions of individual point clouds, thereby providing the basis for automating the registration and integration processes while improving the speed of the surface distance minimization method developed for the initial registration process. This and other registration techniques are the basis for processing time optimization in the first time intensive step.

2. LASER DATA PROCESSING

The applied concepts has its base in optics, machine, electro technology and computer techniques for processing and modeling. The measurement and processing includes: scanning of the object outline point by point; gaining spatial coordinates and color information of points on the surface; joining the data to generate the shape in the computer and finally constructing the target model accurately.

2.1 Registration process

There are som inhomogeneity based reasons for loosing processing time and qualities.

– First inhomogeneity reason influencing the registration process

Which is the point of the measurement? In the case of point clouds it is not defined. Using a single point for the measurement its position is random inside the measuring standard deviation of the scanner. This is depended of the distance to the measured object. The points for the registration are typically not distributed in the maximal measuring distance of the scanner because otherwise there should be too big. This leads to a extrapolation problem outside the targets an to decrease of the accuracy.

– Second inhomogeneity reason based on the distribution of the measured points.

The distribution and the number of measured points is quiet different in the static ore stop and go measuring mode.
Based on the angular increment of the scanner and the measuring program (as example by Z&F High, super high and ultra high) normally the first 10 000 000 Points are in circle of 5 m around the station (Fig. 1). The contribution of these points for achieving the measuring results is very low. These points can be filtered out with a distance filter. An intelligent densification filter is also possible. In this case the densification can be controlled as a function of the distance to the scanner station.
All this considerations are dispensable by using the kinematic measuring mode (Fig.2) .

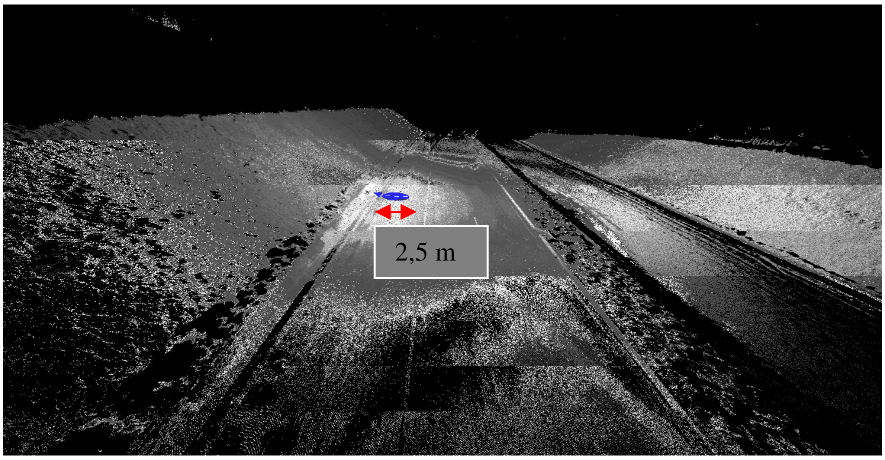

Figure 1. Static scanning result

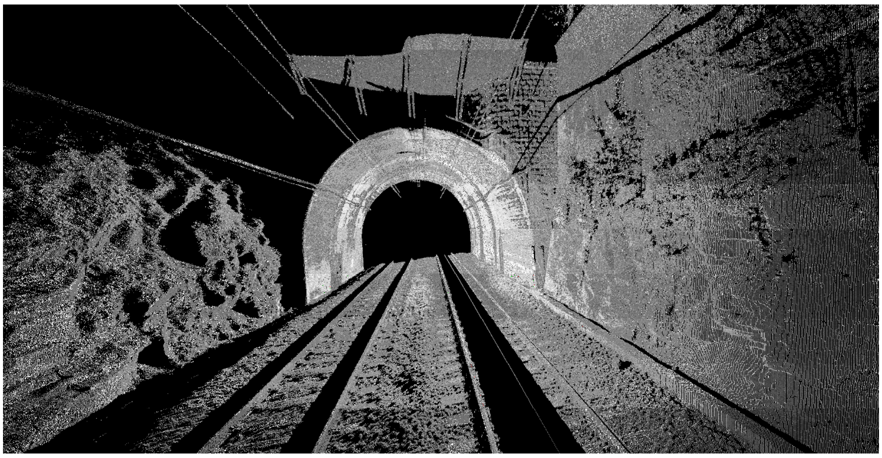

Figure 2. Homogeneous distributed kinematic scanning result

2.1.1 Automated plane detection based Registration

The detection of planes is done separately for each scan in the corresponding image matrix. Rows and columns of the image matrix represent the discrete vertical respectively horizontal angles of the points in the coordinate system of the scanner. Within an iterative process the image matrix is split into sub matrices. After each iteration step an adjusted plane is calculated approximating the points contained in the resulting sub matrices. The iteration process continues as long as a sub matrix stays planar or the stop criterion is reached (Gielsdorf et all. 2008). The identical planes in each scan pair are used for an automated registration process (Fig. 3 and 4).
There are two criteria which have to be fulfilled for accepting a group of points to be planar, both resulting of the plane adjustment. The first criterion is the estimated standard deviation of a single point and decides if the point group is planar. The second criterion is the estimated standard deviation of the top of the normal vector. This value is used as decision criterion if the adjusted plane can be seen as significant or not.

2.1.2 Matching

The objective of the matching process is to find identical planes in different scans. Result is pure topological information containing pairs of identical planes. The algorithm works on a pair of two scans on a time.

2.1.3 Interconnected Transformation

Due to the interconnected transformation an arbitrary number of scans can be transformed into a common datum with an adjustment calculation of one piece. The process is subdivided into the three steps interconnected rotation, interconnected translation and strict adjustment. All steps use the Gauss-Helmert-Model as adjustment approach and the same adjustment kernel for the calculation. To be able to differentiate the partly very complex equations automatic differentiation algorithms were used.

2.1.4 Adjustment Results and Interpretation

Results of the adjustment calculation are the transformation parameters for each scanner station and their covariance matrix. The empirical standard deviations of the translation parameters are easy to interpret. The empirical standard deviation of the orientation angle σ_φ can be calculated from the variance of q_0.

$$q_0 = \cos\frac{\varphi}{2} \qquad \Rightarrow \qquad \sigma_\varphi = \frac{2}{\sqrt{1-q_0^2}} \cdot \sigma_{q_0} \quad \text{for} \quad q \neq 1$$

Each plane identity can be tested if the discrepancies in the global plane parameters of the belonging planes are significant. Test value is the quadratic form

$$\chi^2 = \mathbf{d}^T \mathbf{C}_{dd} \mathbf{d} \quad \text{with} \quad \mathbf{d} = \begin{pmatrix} n_{xi} - n_{xj} \\ n_{yi} - n_{yj} \\ n_{zi} - n_{zj} \\ d_i - d_j \end{pmatrix} \quad \text{and} \quad \mathbf{C}_{dd} = \mathbf{C}_{ii} + \mathbf{C}_{jj}$$

This test value is used for a stepwise detection and elimination of incorrect identities during the adjustment process.
This method raises the productivity and decrease the time for the registration approximately 3 times and works proper in ~70% of the tested overlapped scans. The degree of success is based on the overlapping factor. Including free form surfaces in the registration model the success quota is rising to 90 %. A free form surface modeling is a precondition for this. Using the combination planes, surfaces, lines and points the automated registration quota is 100%.

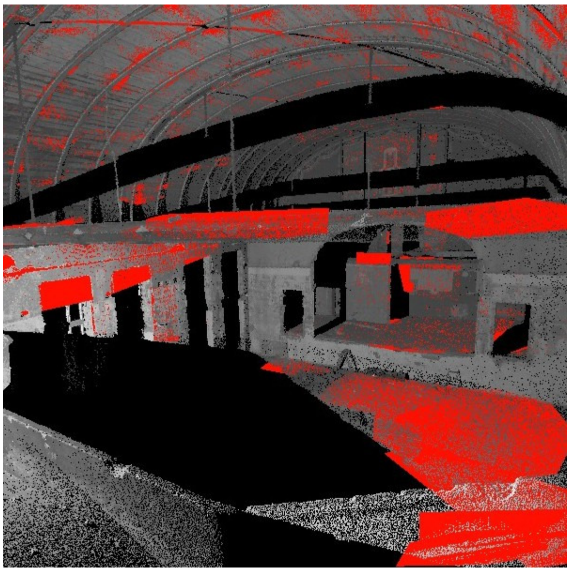

Figure 3. Planes in the first scan

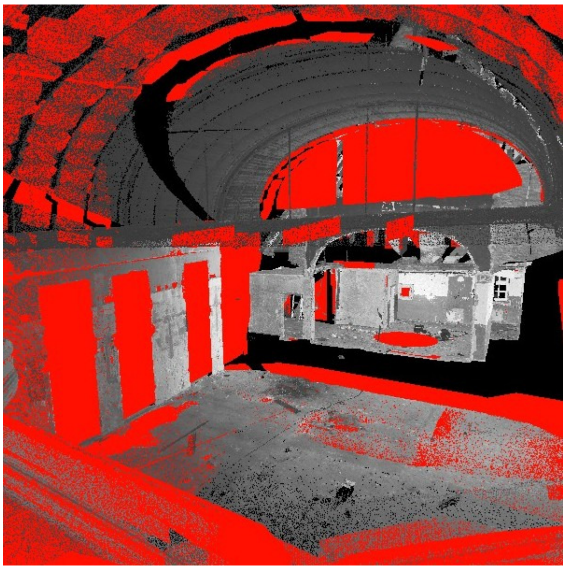

Figure 4. Planes in the second scan

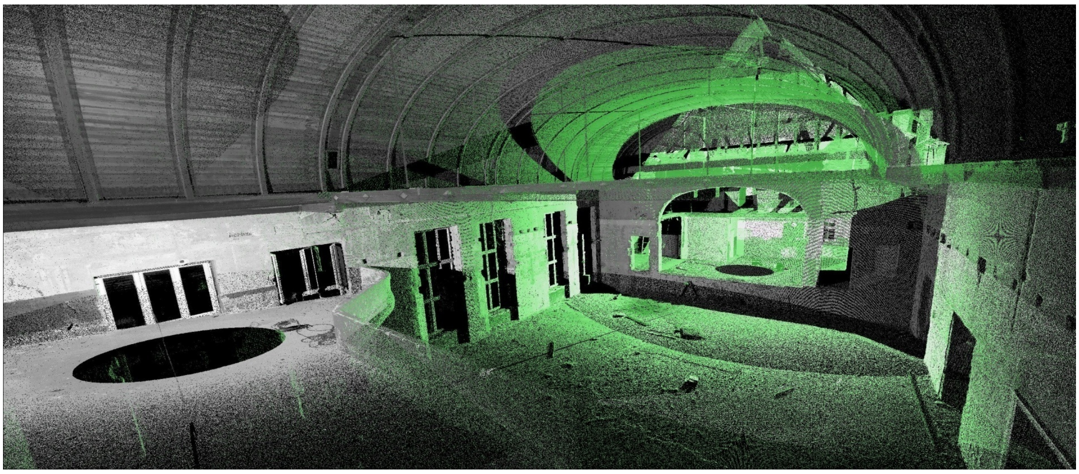

Figure 5. Union view of two registered scans through the point cloud

2.2 Surface Modeling

Freeform surface, or **freeform surfacing**, is used in modeling and other computer graphics software to describe the skin of a 3D geometric element. Freeform surfaces do not have rigid radial dimensions, unlike regular surfaces such as planes, cylinders and conic surfaces. They are used to describe forms such as turbine blades, car bodies, boat hulls, textile roofs and complex building forms (Milev 2008). Any object is represented by a single real function of point coordinates. A point is outside the object if the function is negative, inside the object if the function is positive, and on the boundary if the function is zero (isosurface).
All the registration methods shown below are using the proposed modeling methods and are part of the processing software product SiRailScan.
The flexibility combining planes, surfaces, features lines and points allows the high end level of automation in the registration process of scans.

2.3 Automated feature lines extraction

The automated feature line extraction is described in (Milev 2006)

In generally there are different methods for the registration and georeferencing of laser scan data.
After recognizing the targets in a manual, semi automated or full automated way are following the next steps like quaternion based Helmert transformation or bundle block adjustment like in the photogrammetric image processing.
The targets are spheres, rectangle or circle planar targets, three dimensional cubes and boxes ore simple pasted boards or black white printed papers.

2.4 Comparison between kinematic and static scan method

The measuring program (Fig. 5) includes two scanner positions and 6 sphere targeds (Figur 6.) and 30 meters kinematic scan trejaktory including the same cleareance object.

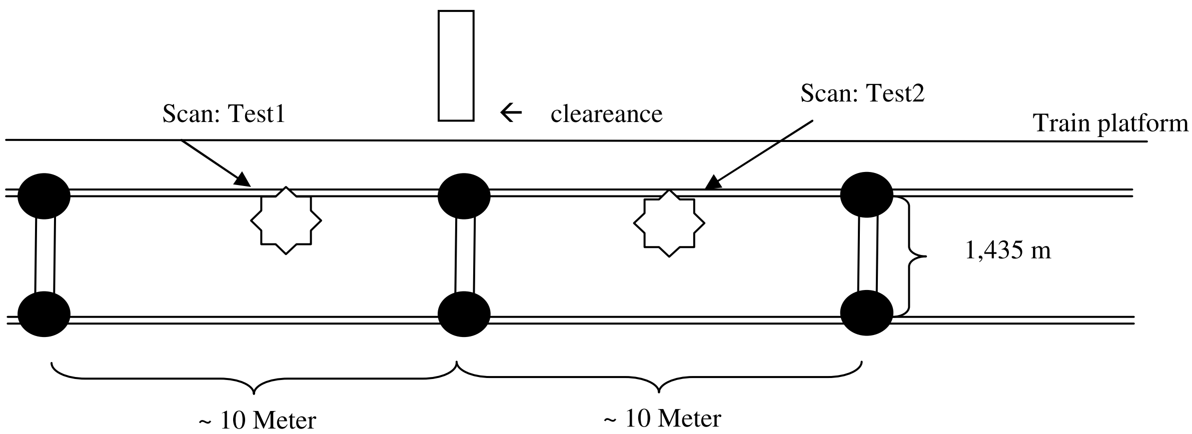

Figure 5. Measuring plan for single scans

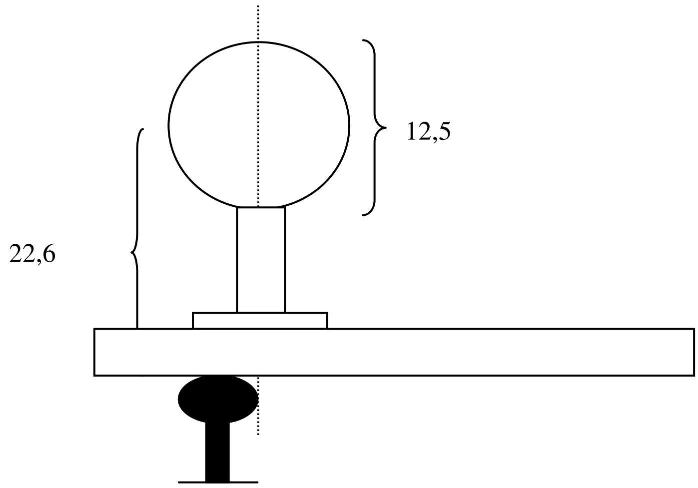

Figure 6. Sphere used for the registration (by Riemenschneider Ltd.)

The Standard deviation by the sphere fitting for all 6 objects was < 1mm.
For the same test object the coordinates coming from a robotic tacheomether will be transformed in real time into the valid reference system. The coordinates refer to the active prism placed on the scanner body. Based on the fixed geometrical relations of the integrated measurement frame of the system the transformation of the coordinates to coordinate system of the laser scanner will be done and thus georeferenced in real time Therefore all profiles of the proximity situation, recorded with 33 Hz, are georeferenced too. For an avarage speed of 1,5 m/s of the kinematic measurement process and the time stamp of 0.25 ms all 3 to 4 cm a georeferenced profile results (Figure 7).

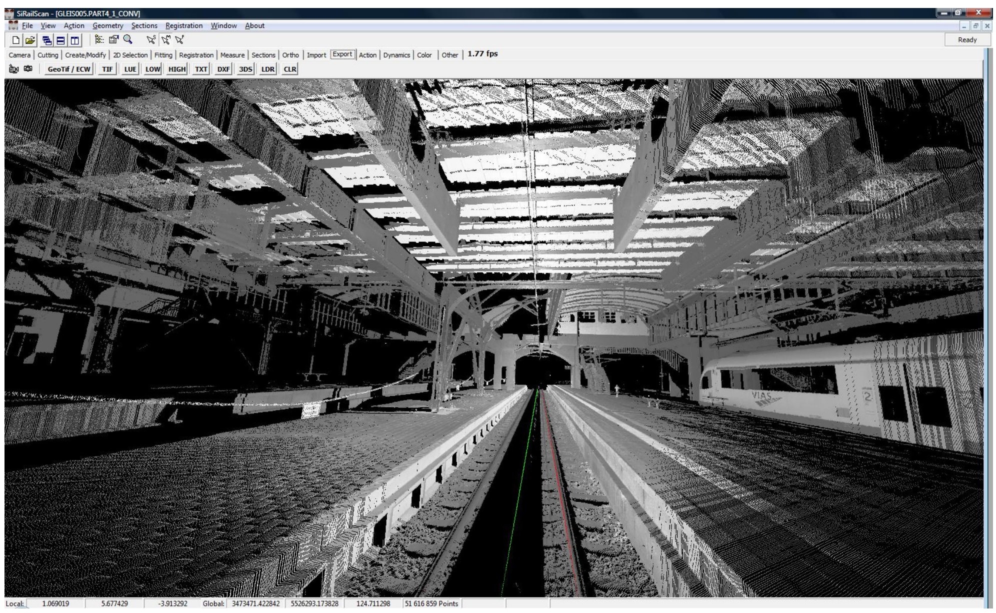

Figure 7. Kinematic mesured profile scans with high end homogenitie

Figure 8 represents the diferences colored in a section between the two scan stations georeferenced on the base of spheres and the kinematic profile scans. The bigest diference is about 6mm. Both metods are achieving the acuracy requierments. The kinematic scan method is combinig ”all in one” registration and georeferencing ans is about 4 times quicker by preparing the end product.

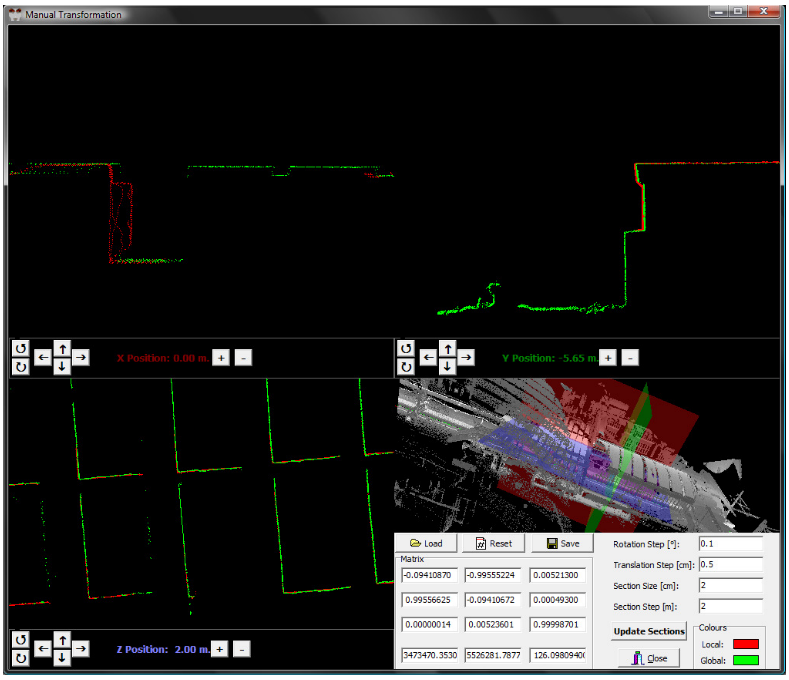

Figure 6. Differences between kinematic and static scanning

2.5 Sections and surface modeling

The software has in a automated way to provide reverse-engineering results whereby a 3D computer model is created from digital measurement of a physical model, finished part, or mold cavity. Laser scanning is useful in instances where manufacturers simply want to produce a new mold for an existing form that was created without the use of CAD. For inspection of finished parts, laser scanning is also used to determine whether parts match the original CAD model, product specifications, and/or regulatory requirements.
Automated spline and NURBS interpolation of the scanned surfaces reduces the noise in the raw point cloud and enhanced the quality of the vectorisation process. The Surface triangulation is an important milestone in 3D mesh generation as it forms the input for the tetrahedralisation of volumes which is a 3D analog of triangulation in 2D. But efficient methods like Delaunay triangulation cannot be applied to surfaces as the Delaunay criterion is not defined for surfaces like it is for planar domains (2D) or volumes (3D).
Triangle editors are not the efficient way for qalitative adequate modeling(Milev 2005).

3. CONCLUSIONS

The scanner provides a standard deviation for a single measured distance of about 6mm. It turned out that a limit of 5mm for the empirical standard deviation for the point plane distance is feasible. This value takes in account the accuracy of the scanner and contains also a part for the abstraction of the surface. For the significance of the normal vector a limit value of 10mm were chosen. This performance can be achieved only in a fully automated registration process. A manual definition of the plane positions is not usable. The quality and reliability of the end product and the effort to guaranty this is economically justifiable by using the maximal possible degree of automation.
For the future good governance and good management key for successful laser scan project management will stil the processing software.

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BIOGRAPHICAL NOTES

Dr. Ivo Milev, born 1963. Graduated in 1988 as Dipl.-Ing. in Surveying and Mining Engineering from Technical University of Sofia. Obtaining doctorate degree in 2000 from Technical University of Berlin. Since 1998 Head of Engineering Surveying Development Group of technet GmbH Berlin

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