Taming errors... pt. 10: What residuals to geodetic control points ARE NOT telling you…

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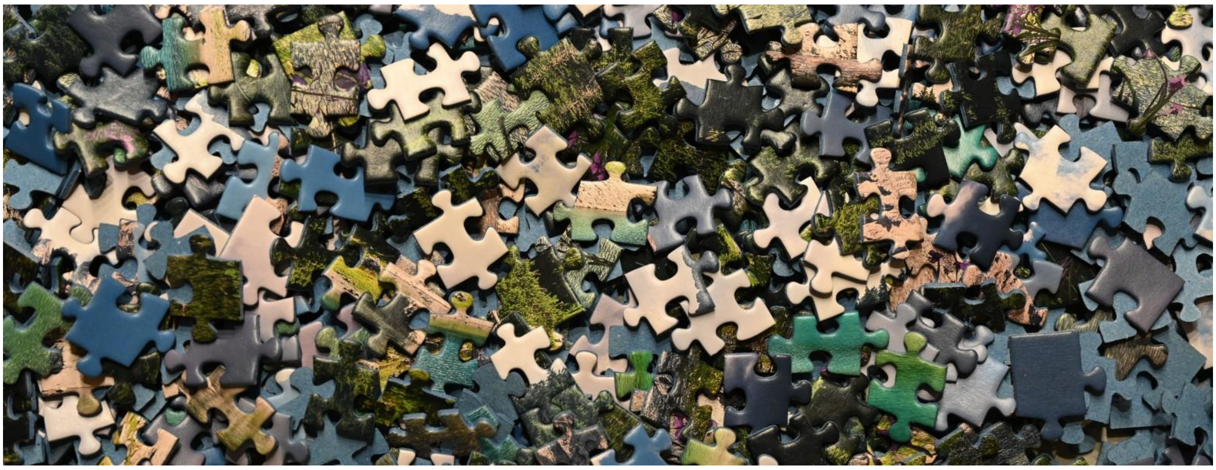
17th May 2022



Control points observed by conventional geodetic instruments are rightfully regarded as the "*gold standard*" of quality assurance in laser scanning. BUT, as always, there are interpretational pitfalls and ways to turn dodgy projects into seemingly shiny ones. Before the word *blasphemy* rolls off your tongue and you're about to write a stiff letter of complaint to the internet, please relax and read until the very end.

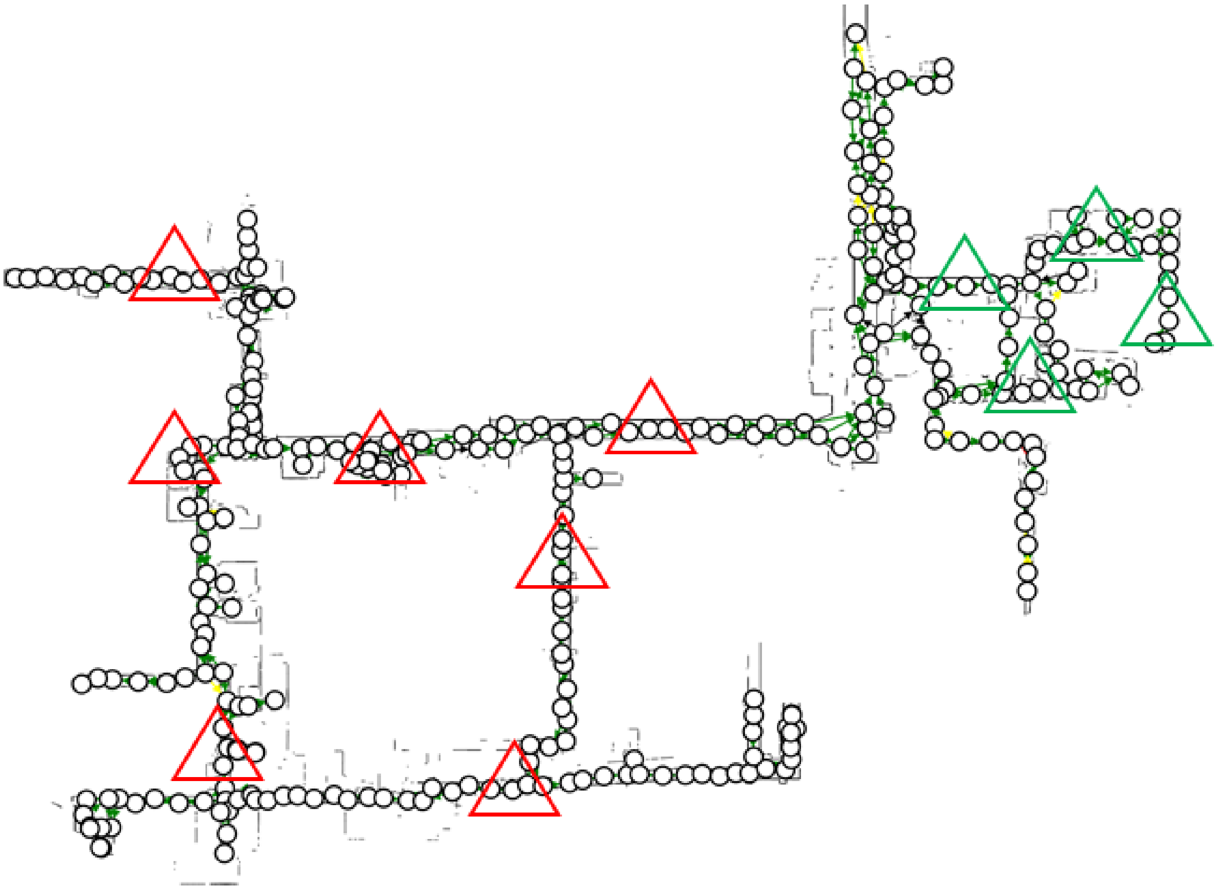
For the sake of explanation, a survey carried out with a static laser scanner as part of a tolerance check on an industrial construction site will be used in the following. The site covers an area of approx. 150 x 210 m which was documented by 370 scans. Individual scans were tied by 528 pairwise registrations. In addition, 63 geodetic control points were surveyed with a tacheometer / total station, which were connected 327 times from different scanning positions. The global accuracy requirement, specified by a construction standard, was 10 mm. After performing a block adjustment, the following contradictions between observations resulted:

- Pairwise registrations (based on redundant registration parameters): Mean: 0.2 mm, Median: 0.4 mm, Max: 3.7 mm.
- Tie points and control points: Mean: 3.3 mm, Median: 2.7 mm, Max: 7.7 mm.

Looking solely at the residuals to the geodetic control points, one would be tempted to assume that the accuracy requirement of 10 mm has been clearly fulfilled. However, this assumption ignores two essential aspects. Firstly, it should be noted that, for economic reasons, not all laser scans were checked against geodetic control points. Thus, it is initially not clear whether all scans were correctly registered. Furthermore, it is not clear where the tacheometric control points are located in the scanning network and how they affect its stability. Both aspects will be discussed at a later stage in detail.

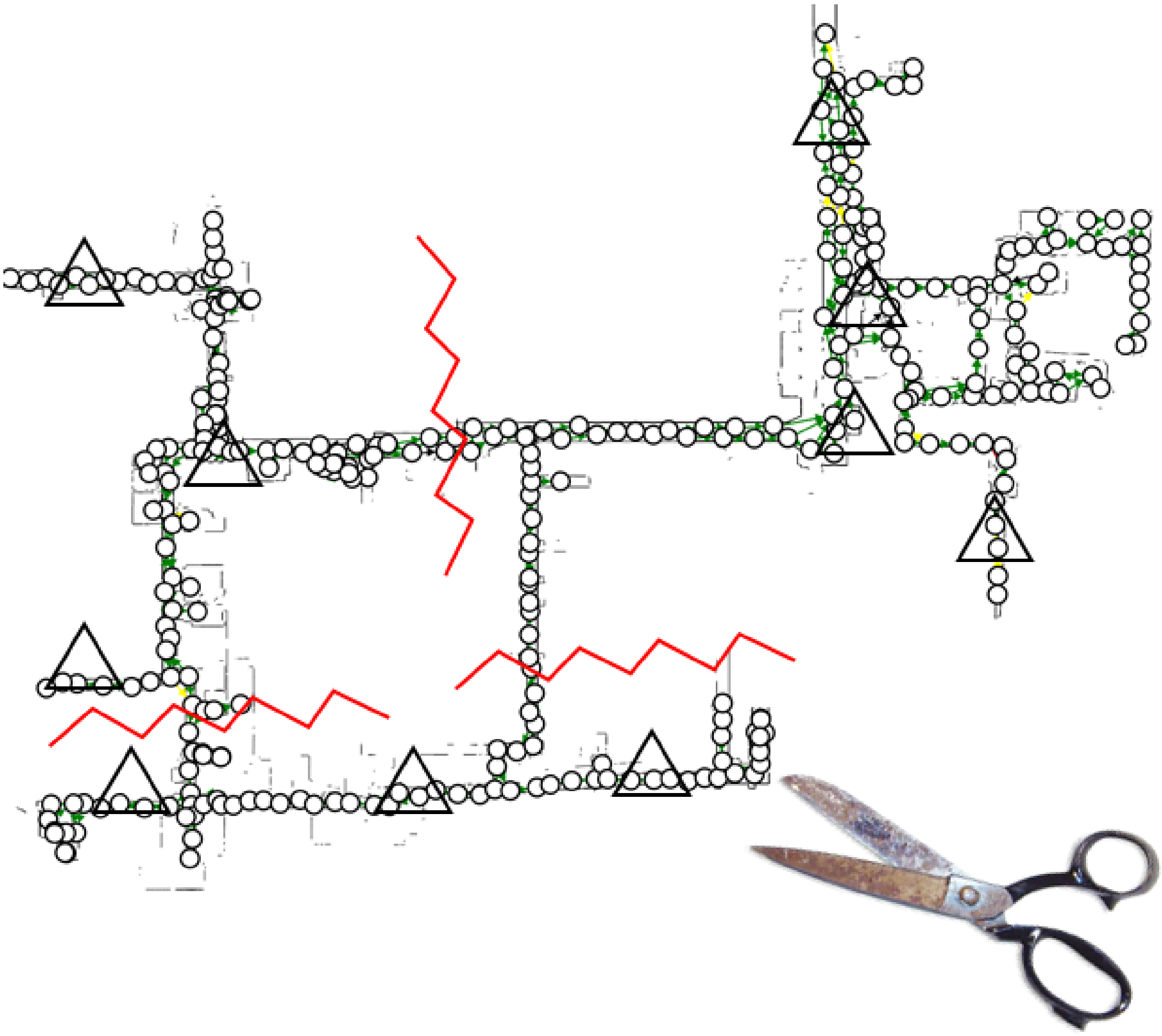
In this issue three simple ways are described how quality verifications against geodetic control points can be tweaked. Note that all options can be applied to static and / or kinematic laser scans. Let us assume for the present example in the following that contradictions to the tacheometric network above 10 mm would be present before fudging.

The first strategy is based on a deliberate reduction of redundancy with a focus on the geodetic control points. For this purpose, all point identities between tacheometry and laser scans that exceed the "required accuracy" are simply eliminated. In the figure below red triangles indicate deactivated point identities to control points, while green triangles highlight used control points. It is obvious that it is easy to achieve "accuracies" of a few millimetres, as long as one only thins out further and further. The consequence of this action is a general destabilisation of the network, which is usually accompanied by extrapolative effects. Both negative influences are NOT reflected by the resulting quality measures. These still suggest a highly accurate result.



In the second strategy, the redundancy within the network is also deliberately decreased, but now by breaking up pairwise registrations or splitting kinematic scans. If tensions occur in the network that have a negative effect on the contradictions at the control points, they can be separated either between two control points or alternatively within an existing loop. The result of this method are individual blocks of connected static and / or kinematic point clouds, which are connected to the geodetic datum (aka the tacheometric coordinate system in our case) by at least three control points per block. Again, the resulting residuals after "successful" application of this method suggest a sufficiently accurate result.

The consequence of this fudging strategy are typically unclean transitions between individual blocks. It should be mentioned that this effect occurs unconsciously in many commercially available software solutions for the registration of static scans. Specifically, this occurs when the software is not able to adjust larger scan projects. In this case, the projects are either divided into sub-projects that can still be processed or are separeted into groups or so-called clusters. The following figure visualises the aforementioned method. Triangles again indicate geodetic control points, while the red zigzag lines represent the separation points of individual blocks.



A third method of improper influence onto the outcome is inadequate weighting. It is worth mentioning here that in many software solutions this manipulation is not consciously induced by the user, but by the manufacturer in the form of fixed weights of individual observations. To illustrate this method, we assume a kinematic scanning project. Control points were measured outdoors using GPS.

Short magical interlude: *Every visitor of a magic show knows that the white tiger, white rabbit or white pigeon has to be hidden by the magician at some point during his performance, so that the audience beliefs that it magically disappeared. However, the audience actually knows that the magician will distract their attention in order to pretend that magic happened.*

And now back to adjustment of networks where the very same trick is applied. The accuracy of GPS points is known to be significantly lower than that of tachymetric observations. For dual frequency differential GPS one would expect positional point accuracies of 0.015 m and vertical ones around 0.025 m. In order to obtain small residuals at the control points, one chooses, for example, overly optimistic *a priori* weights of the GPS points in the low millimetre range. By this, the contradictions between the two data sources are squeezed into the tacheometric network…and the white tiger magically disappeared.

Why is this a very bad idea? The more optimistic / unrealistic the accuracy is assumed, the greater the constraint imposed on the network. As a result of this, the point cloud is distorted while the residuals at the control points again suggest an accurate outcome. This is sometimes seen in projects with GNSS control points whose elevation accuracy is noticeably worse than the positional one, in the form of wavy grounds.

Again, it is not my intention to discredit the use of geodetic control points (long lives redundancy!) but the geodesist in me is irritated that there appears to be only one quality metric in laser scanning to rule them all. Hence, we'll have a look at additional metrics that are used in geodesy and surveying beyond residuals in the next issue .