Taming errors... pt. 9: The difference between residuals, residuals and residuals (cont.)

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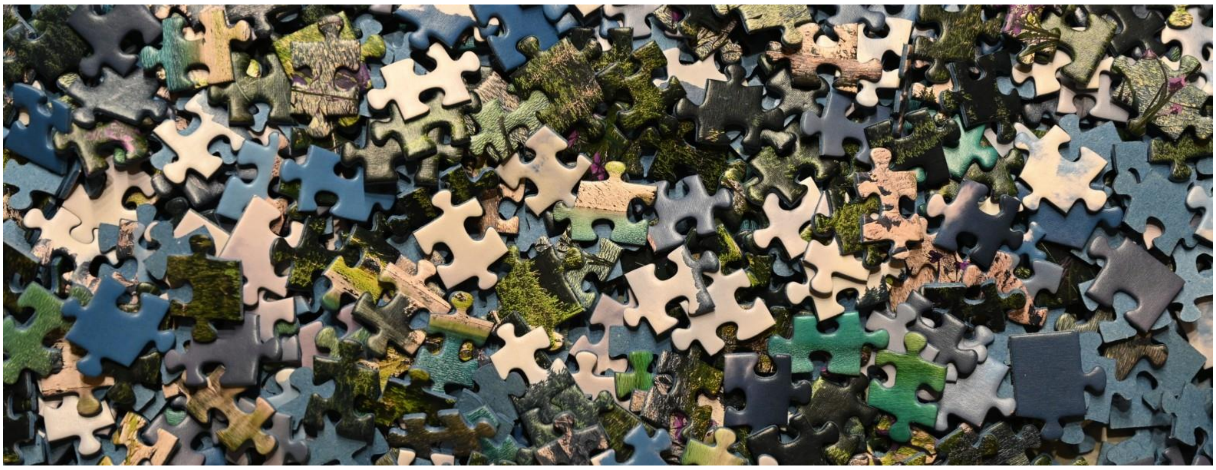
13th Dezember 2021



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Registration algorithms use redundant subsets or extracted information among overlapping point clouds based on which registration parameters can be computed.

The initial sentence may not appear too revolutionary at first glance. Yet, if you watch closer then you will notice that it contains two sources of information that can be used for quality assurance in scanning networks, namely the point clouds themselves (we have seen “how well” that works e.g., in the last issue) - and the registration parameters. In this issue we will explore how the latter information can be used to compute sound quality measures regardless of which registration algorithm was used. The irony of this strategy, which is based on so called constraints, is that it is well known for several hundred years, used in many other surveying approaches and thus not something entirely new.

Now, let us have a look at what constraints are. You may not be aware, but you have encountered constraints some while ago in primary school where you were taught that the sum of inner angles within a planar triangle is exactly 180°. Thus, if you have measured the inner angles of a triangle, chances are quite high that the resulting sum deviates from 180° since all measurements are subject to noise and measurement errors may occurred. While the first circumstance is inevitable, outliers need to be identified and finally resolved. Note that we will clarify the question of what separates ordinary noise from an outlier in one of the next issues.

If one of the next schools you have visited was survey school then chances are quite high that you were shown how to determine height differences, e.g., by levelling. A typical early exercise is a levelling loop where the starting and ending point of the survey are identical. This strategy allows to introduce the following constraint: the sum of height differences within this loop has to be 0 – or in other words – the height of beginning and end of your survey should be identical! The beauty of this approach is, that it is applicable to EVERY measuring technique that allows to determine height differences, such as geometric levelling, water levelling, tacheometry or, for the ones who are on a tighter budget, standardised beer coasters – separately or even in one common block adjustment!

While levelling is a one-dimensional problem, registration of laser scans is a six-dimensional one. Yet, the very same concept can be applied to the latter problem. Let us imagine we have captured three scans, as depicted in Figure 1. Two registrations among the scans would be enough to transform all point clouds into a common coordinate system. However, it would not be possible to tell whether all registrations are correct. In order to establish a self-controlling configuration, we compute a third registration among the scans. The registrations are represented by three magenta tinted lines in the figure below. As a result, we have one more registration than we require, which allows us to clarify if we achieved a consistent result.

The constraint that is used to achieve this is similar to the aforementioned concept deployed in levelling. In order to understand the general concept, we generate a virtual copy of the green station which is coloured in bright green on the right of the figure. Then we compute a so-called closed traverse or loop which originate at the dark green station. This is achieved by applying the computed pairwise registration parameters to their corresponding stations: dark green to blue, blue to red and finally red to the virtual copy in light green. Assuming that the registration parameters are error-free, which is a purely theoretical construct, the reference station (dark green) and its virtual copy (bright green) must be identical regarding their position AND orientation. Consequently, this constraint allows us to inherently control ALL degrees of freedom! As seen on the right of the figure a large error vector can be seen as highlighted by the orange line and the misorientation of the station itself.

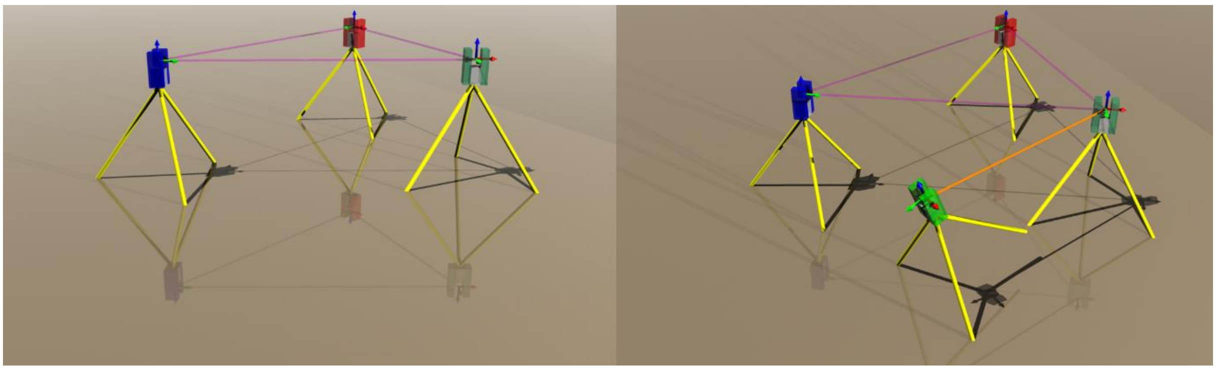

Figure 1: Three scans connected by three perfect registrations (left)
and the same setup with erroneous registrations (right)

In order to exemplify this approach in practice, a small set of nine scans captured in an industrial scene were registered by a) artificial targets as a reference, b) a commercial cloud2cloud-implemenation and c) a plane-based approach. A self-controlling network configuration was realised by connecting the scans by 12 registrations. Note, that this is not intended to be a shoot-out among different solutions but a demonstration that you can derive meaningful quality measures independent of what registration algorithm was used.

Figure 2: Sample scan within an industrial scene

Figure 3 illustrates the three networks after individual block adjustments where larger circles highlight the location of scans. Note that the figure on the left was rotated for illustrative reasons. Black lines represent local point locations of individual targets. The final misclosures based on 40 point correspondences are 1.1 mm on average with a maximum of 2.6 mm and a median of 1.05 mm.

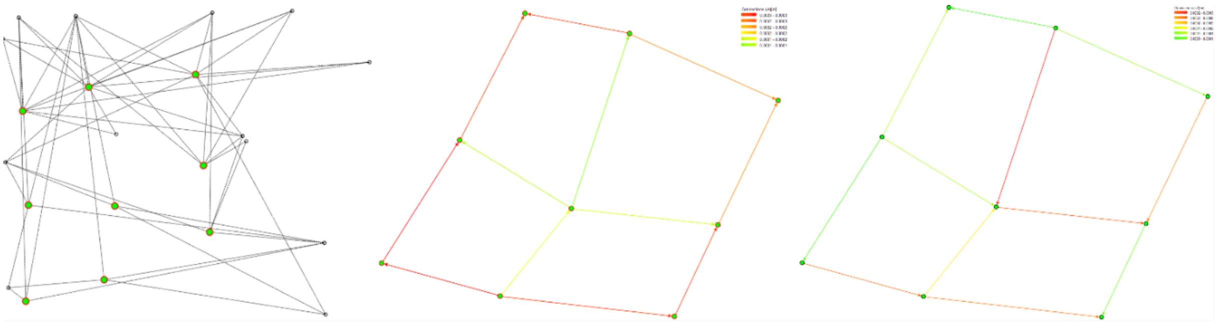

Figure 3: Identical scans registered via artificial targets (left),
Cloud2Cloud (centre) and based on detected planes (right)

The translational misclosures of a block adjustment based on pairwise cloud2cloud-registrations are 0.21 mm on average, with a median of 0.25 mm and 0.3 at max. Tinted arrows in the centre and the right of Figure 3 highlight the corresponding misclosures. The corresponding values for the plane-based approach feature an arithmetic mean of 0.13 mm, a maximum value of 0.3 mm as well as median of 0.1 mm.

Now what do these numbers tell us? They tell us how well redundant registration parameters between scans fit together. Thus, the major advantage of this strategy is that it is unbetrayable. It does not matter which algorithm was used to compute pairwise registrations and which points were chosen from the original point clouds to compute the registration parameters – you will not receive great quality measures if the parameters do not add up.

While deploying constraints among redundant registration parameters within a block adjustment yields in sound quality measures between adjacent scans, we will have a look at scenarios where residuals fail to solely express quality in any network – regardless of if it was captured by e.g., laser scanners or tacheometry.