Taming errors... pt. 4: Geometric primitives and direct (Geo-) referencing

Daniel Wujanz – daniel.wujanz@technet-gmbh.com

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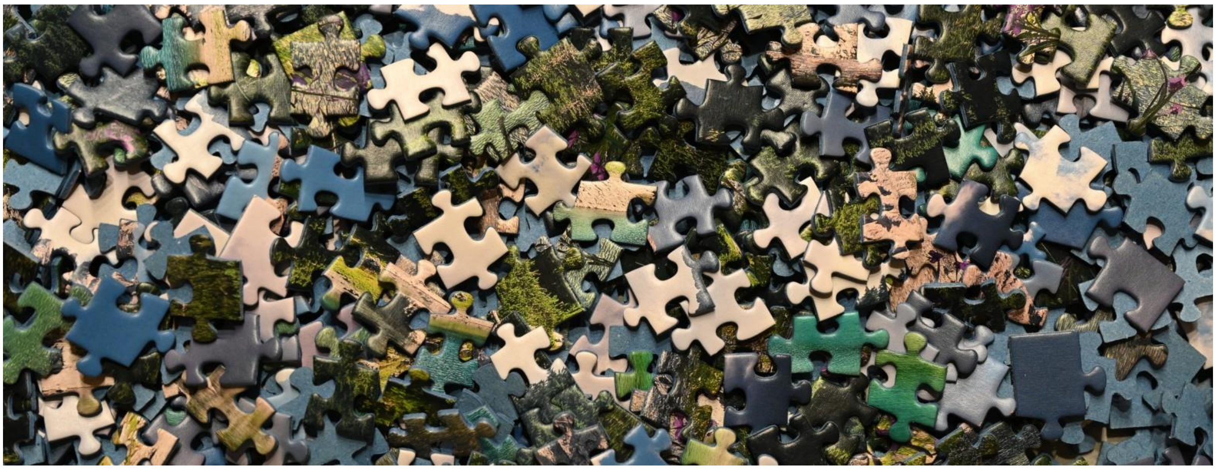

2.2.3 Registration based on natural geometric primitives

After artificial targets were deployed for registration it is time to move on to some more natural information. Natural in this context means that geometric primitives (e.g. spheres, cylinders (Moritani et al. 2019), planes (e.g. Previtali et al. 2014, Wujanz et al. 2018) and the like), which may be inherently given in a scene, are used to compute registration parameters. The first step of this procedure is a segmentation process where individual points are associated to a primitive. Figure 1 illustrates an industrial scene in form of an intensity image after segmentation. In this case planes were detected which are tinted in dependence to the direction of their face normal.

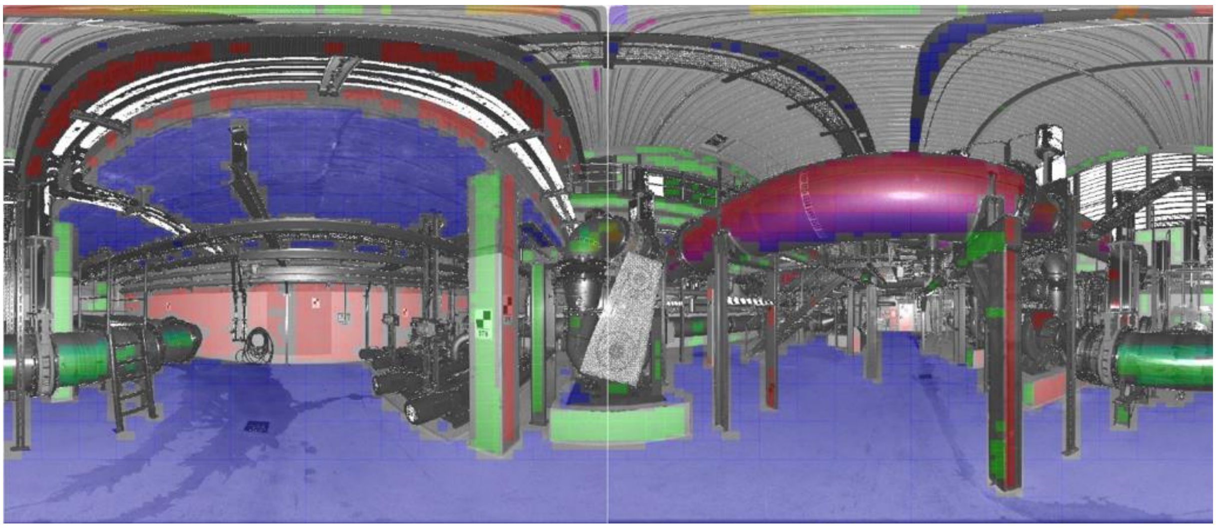

Figure 1: Detected planes tinted in dependence to the direction of their face normal

All segmented points are then used to estimate parameters in dependence to the respective primitive. Subsequently, correspondences must be established between detected geometric objects in order to compute registration parameters among scans. In contrast to the ICP (see section part 2 of taming errors) these procedures are not iterative and hence far less dependent to chosen settings. Since every adjustment additionally yields stochastic measures these values can be used for weighting of individual primitives during registration, so that more precise parts of a scene have a higher influence onto the outcome than less precise ones. There are several advantages of using geometric primitives for registration while the first one is the reduction of complexity. Instead of handling millions of points only hundreds or thousands of primitives are processed even though the original information is considered. The second advantage is a notable increase of accuracy since adjusted parameters are more accurate and more reliable than single points, used e.g. in the ICP. A third aspect that speaks for these approaches is their invariance against differences in the point sampling (see aliasing in part 2) – which is one of the reasons why people like to use artificial targets. However, wherever there is light, there's also darkness: if the scene does not contain a sufficient amount of well-distributed primitives, this strategy will fail. Geometric primitives can typically be found in manmade structures such as buildings, factories, or bridges.

2.3 Measuring registration parameters

The general concept of the aforementioned strategies was to use redundantly captured areas among two scans to compute registration parameters. This section discusses different approaches where some or all required degrees of freedom are measured by use of additional sensors.

2.3.1 Direct (Geo-) referencing

Geodesy has its own fine selection of Bond-villains: vegetation, ironically topography, physics, combinatorics / permutations and finding initial values during parameter estimation. The latter one is of particular importance for registration since ALL registration algorithms may end up in local minima if inappropriate initial values were chosen. Now what does that mean? You'll end up with a set of registration parameters that misaligns already misaligned scans and that's not really what you're looking for. Probably the biggest revolution in terrestrial laser scanning, despite its own emergence, was to equip scanners with additional sensors in order to measure differences in location and orientation between scans. Figure 2 illustrates two viewpoints with two different local coordinate systems which consequently yields in differences of orientation and location.

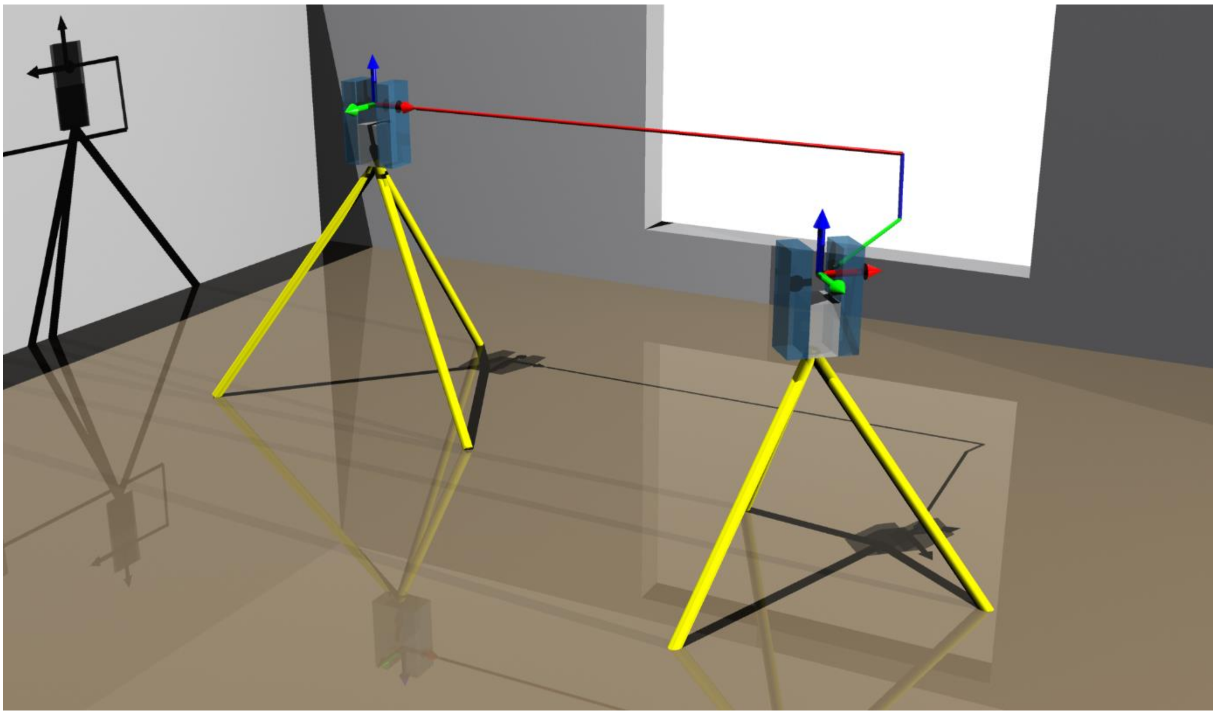

Figure 2: Two viewpoints with different orientations and locations

Early developments of this strategy frequently used GNSS-techniques (Reshetyuk 2010) to determine viewpoint locations in a superior coordinate frame or additionally differences in orientation (Paffenholz et al. 2010). Since satellite navigation relies on direct sight to the sky these strategies were useful for exterior tasks yet not of great help for interior data acquisition. Hence, in 2015 Zoller + Fröhlich moved on and added accelerometers, gyroscopes, barometers and compasses to the mix which allowed to measure locational and orientational differences between viewpoints with their IMAGER 5010X even within buildings. In 2018 Leica presented their RTC-scanner which deploys five cameras as well as an IMU to present a different solution to the very same problem.

At first some bad news: direct (Geo-) referencing is typically far less accurate than results obtained by registration. The reason for this is that sensors have (as always) limitations in terms of accuracy. You could of course purchase only the most accurate sensors on the market yet then the price of the scanner would notably increase. Consequently, the sensors that you'll find in scanners are a compromise between accuracy and price. Now the good news: the applied sensors are good enough to serve as initial values for registration algorithms. That does not sound too revolutionary at first glance yet notably helps to avoid local minima and reduces the amount of iterations which accelerates the registration process.

Another benefit of using additional sensors to compute pre-registrations is related to combinatorics / permutations. Let's consider a standard network with 1000 scans. Checking all possible connections yields in 499500 connections which would be very demanding in computational terms. Hence, the question is, how to reduce the solution space. The first option could be to define a search radius in which another station is considered to be a direct neighbour. However, two scans could be 1 metre apart and still do not have any overlap due to the existence of a wall that happens to be located in between the two viewpoints. Hence, one could sort the pre-aligned scans into a treestructure (Samet 2006) in order to clarify if there are overlapping regions between scans which can be used for registration.

References

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