A NOVEL QUALITY CONTROL PROCEDURE FOR THE EVALUATION OF LASER SCANNING DATA SEGMENTATION OUTCOME

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ABSTRACT:

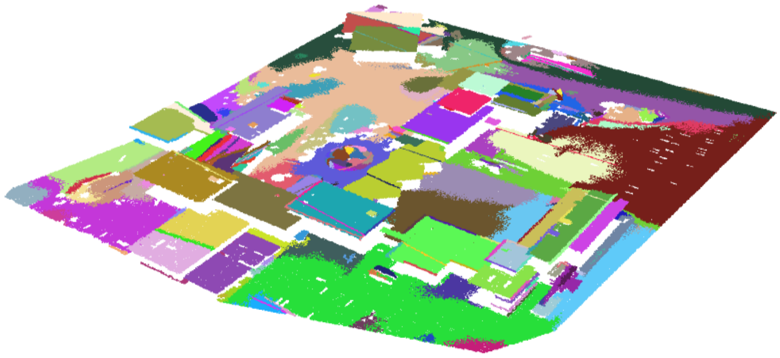
Laser scanning systems have been popularly employed in a wide variety of applications such as digital building model generation, industrial site modelling, cultural heritage documentation, and other civilian and military needs. Usually, the laser scans are acquired over complex scenes that might contain buildings, roads, trees, light poles, and many human-made and natural objects. The raw point cloud does not provide any semantic information about the type of the scanned features (i.e., planar, linear, or cylindrical features). Therefore, it should undergo a segmentation process to extract the required information for the aforementioned applications. The segmentation procedure aims at extracting features of interest from the laser scanning data and reducing the scene complexity by disassembling it into meaningful categories. To date, various segmentation methods with different target functions and processing procedures have been introduced and utilized. In general, any segmentation process is expected to have some artifacts such as non-segmented points, over-segmented and under-segmented features. The non-segmented points are defined as those belonging to features of interest and could not be segmented. This problem might happen when these points are erroneously missed due to deficiency in the segmentation process. The over-segmentation problem happens when a single feature appears as several clusters in the segmentation results. This problem might happen due to strict segmentation thresholds. The under-segmentation problem occurs when having different features segmented into one cluster. This problem might happen due to relaxed segmentation thresholds.

In order to identify the instances of these problems in the laser scanning data segmentation outcome, a new quality control (QC) procedure is introduced in this paper. This QC procedure makes hypotheses about different scenarios/problems in segmentation results, develops procedures for detecting instances of these problems, and suggests possible actions to fix these problems without the need for ground truth data. For each of the identified problems (i.e., non-segmented points, over-segmented, and under-segmented features), a quantitative measure is then established that gives an indication about the frequency of such a problem.

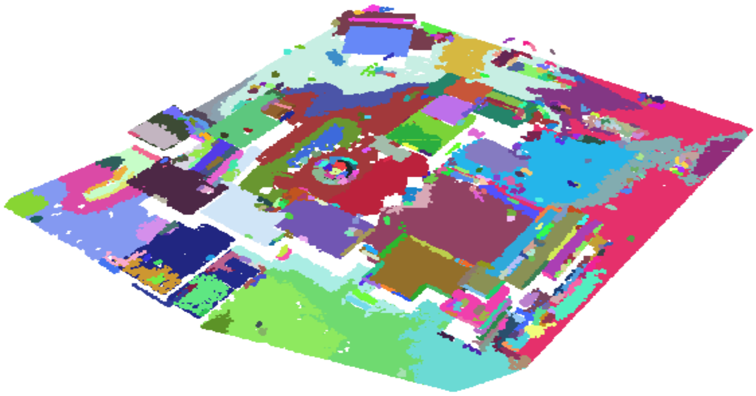
As the first step of this quality control procedure, the surface roughness factor for each segmented planar or linear/cylindrical feature is estimated and utilized throughout the QC procedure process. For each of the segmented planar, linear, or cylindrical features, the surface roughness factor is computed by estimating the Root Mean Square Error *(RMSE)* of the normal distances between the clustered points in that segment and their best-fitted plane, line, or cylinder surface.

Instances of non-segmented laser scanning points are identified as those whose normal distance to the best-fitted plane, line, or cylinder's surface through the points of the neighboring segment is not more than a pre-specified threshold. This threshold is determined based on the surface roughness factor of the neighboring segmented planar or linear/cylindrical feature. To identify instances of over-segmentation problem, the similarity between surface normals to neighboring planar segments and directional parameters of neighboring linear/cylindrical features are investigated. If the surface normals to neighboring planar features or directional parameters of neighboring linear/cylindrical features are deemed to be similar, the neighboring features are merged together as a single planar or liner/cylindrical feature. The surface roughness factor of the merged feature is then estimated and compared to the surface roughness factors of individual features. If the surface roughness factor of the merged surface significantly varies from the surface roughness factor of the original segments, the merged feature is rejected and the original features will be restored. In order to detect instances of the under-segmentation problem, the average surface roughness factors for all segmented planar or linear/cylindrical features are firstly estimated. For each segmented planar or linear/cylindrical feature, if its surface roughness factor is more than a pre-defined threshold (e.g., 2-3 times of the average roughness factor of all derived segments in the same category), that segment is suspected to be under-segmented. For the suspected under-segmented planar regions, the segmentation process is repeated while changing the processing thresholds to check if they can be segmented into multiple clusters.

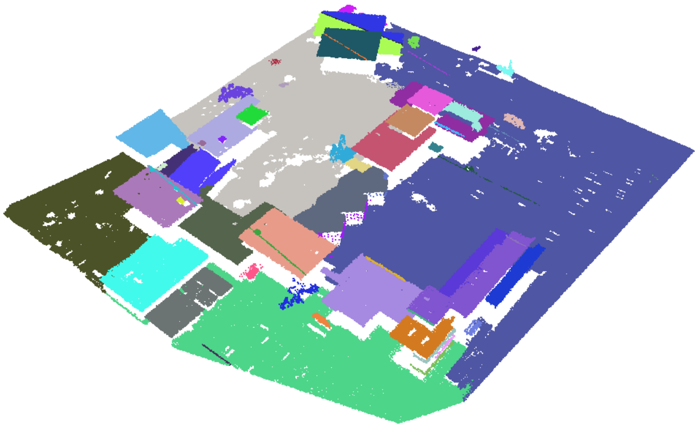
The performance of the proposed QC procedure will be evaluated using the segmentation outcome from two recently-developed parameter-domain and spatial-domain segmentation approaches. These segmentation procedures select the proper parameterization model for planar and linear/cylindrical features based on the PCA procedure. These approaches also consider the noise level as well as the point density variations within the laser scanning data. In order to verify the feasibility of the proposed quality control procedure for the segmented planar features – just as an example, spatial-domain and parameter-domain segmentation approaches are performed for airborne laser scanning dataset. The outcome from these segmentation procedures is then assessed using the proposed QC procedure to resolve the possible segmentation problems. Figures 1.a and 1.b show the planar feature segmentation results using spatial-domain and parameter-domain approaches before the QC procedure, respectively. Figure 1.c shows the planar feature segmentation results using the spatial-domain approach after the QC procedure. In these figures, different colors indicate different planar segments. One should note that the outcome of the parameter-domain segmentation approach after performing the QC procedure is identical to figure 1.c. As can be seen in Figure 1.c, the quality control procedure succeeds in merging the over-segmented planar features.



(a)



(b)



(c)

Figure 1. Planar features segmentation outcome for an airborne laser scanning data using (a) spatial-domain approach before QC procedure, (b) parameter-domain approach before QC procedure, and (c) spatial-domain approach after QC procedure