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Hole-ness of point clouds

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Accurate and dense 3D models of soil surfaces can be used in various ways: They can be used as initial shapes for erosion models. They can be used as benchmark shapes for erosion model outputs. They can be used to derive metrics, such as random roughness. . .

One easy and low-cost method to produce these models is structure from motion (SfM). Using this method, two questions arise:

1. Does the soil moisture, which changes the colour, albedo and reflectivity of the soil, influence the model quality?
2. How can the model quality be evaluated?

To answer these questions, a suitable data set has been produced: soil has been placed on a tray and areas with different roughness structures have been formed. For different moisture states – dry, medium, saturated – and two different lighting conditions – direct and indirect – sets of high-resolution images at the same camera positions have been taken. From the six image sets, 3D point clouds have been produced using VisualSfM.

The visual inspection of the 3D models showed that all models have different areas, where holes of different sizes occur. But it is obviously a subjective task to determine the model's quality by visual inspection.

One typical approach to evaluate model quality objectively is to estimate the point density on a regular, two-dimensional grid: the number of 3D points in each grid cell projected on a plane is calculated. This works well for surfaces that do not show vertical structures. Along vertical structures, many points will be projected on the same grid cell and thus the point density rather depends on the shape of the surface but less on the quality of the model.

Another approach has been applied by using the points resulting from Poisson Surface Reconstructions. One of this algorithm's properties is the filling of holes: new points are interpolated inside the holes. Using the original 3D point cloud and the interpolated Poisson point set, two analyses have been performed:

- For all Poisson points, the distance to the closest original point cloud member has been calculated. For the resulting set of distances, histograms have been produced that show the distribution of point distances.
- As the Poisson points also make up a connected mesh, the size and distribution of single holes can also be estimated by labeling Poisson points that belong to the same hole: each hole gets a specific number. Afterwards, the area of the mesh formed by each set of Poisson hole points can be calculated. The result is a set of distinctive holes and their sizes.

The two approaches showed that the hole-ness of the point cloud depends on the soil moisture respectively the reflectivity: the distance distribution of the model of the saturated soil shows the smallest number of large distances. The histogram of the medium state shows more large distances and the dry model shows the largest distances. Models resulting from indirect lighting are better than the models resulting from direct light for all moisture states.