Dune monitoring with terrestrial laser scanning at Egmond beach.

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Figure 1: Photograph in the scan direction.

Introduction

On April 14, 2005 we used a Leica HDS 2500 terrestrial laser scanner to measure a beach area and part of a dune front near Pole 39.500 at Egmond beach, see Figure 1. On the dune front some small landslides are visible, while the higher part of the dunes is covered by vegetation (helmgrass). Within the scan area, two beach poles are present.

The scan procedure, performed at a resolution of 3.5 cm at 50m distance, resulted in a point cloud of about $725\ 000$ points. For every returned laser pulse, xyz-coordinates were stored in a coordinate system local to the scanner. Moreover, for every scanned point, an intensity value is stored as well. This intensity value gives an indication for the energy of the returned signal.

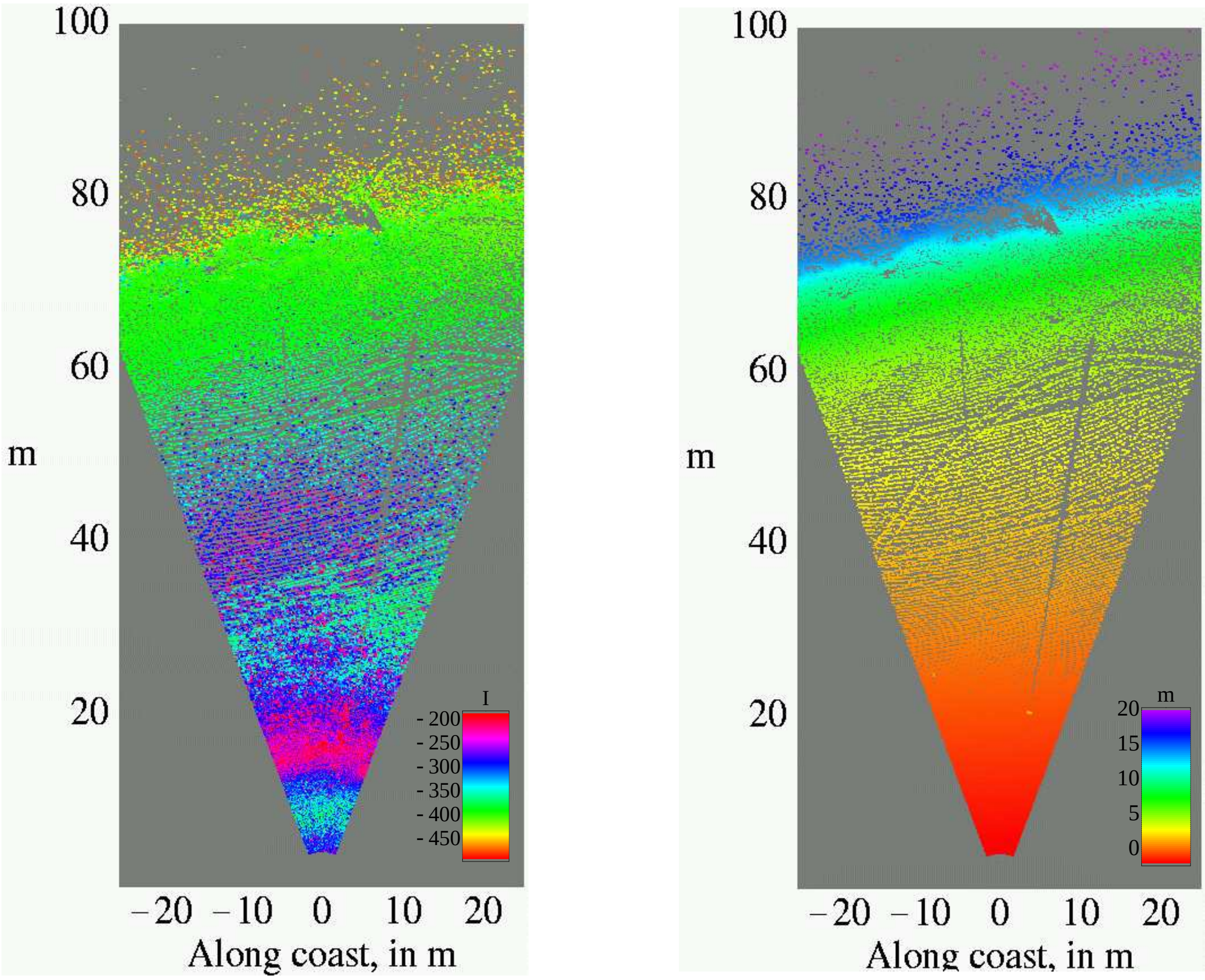

Figure 2: Scanned points in the xy-plane of the scanner. On the left colored by intensity, and on the right colored by the height (the z-coordinate).

Point cloud.

In Figure 2 the stored scan points are visualized. On the left, the points are colored by the intensity of the returned signal, on the right by their height. The shadows of the beach pole most close to the scanner and of a little dune (near position $(3, 78)$) are clearly visible. In the middle a car track can be recognised. On the upper side of the images some points occur that were returned by a fence on top of the dune front.

It can be observed that on the beach the intensity of the returned signal is far from uniform, although some clear patterns can be observed. At the moment it is not clear what causes these differences. Possible explanations include influences by salt spray, pebbles, sand humidity, and angle of incidence of the laser signal.

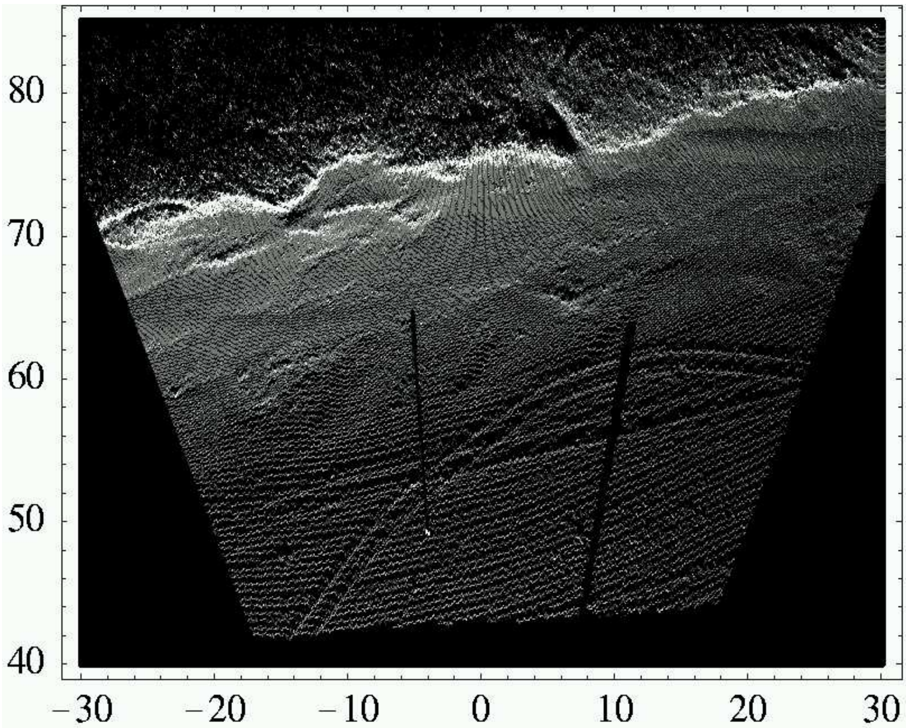

Figure 3: Point densities in the dune front area. Higher local densities, indicated by white pixels, correspond to steeper terrain sections

Point density.

From Figure 2 it can be observed as well that on the beach the point density is clearly decreasing with increasing distance to the scanner. This is as expected: with constant angle increment, the distance between two consecutive points of constant height increases with the distance to the scanner. On the dune front however the landscape steepens, resulting in a higher point density per area unit. As an extreme example, think of a beach pole: all points reflected by the pole have similar (x, y) coordinates, resulting in a high point density. Therefore it is possible to use the point density to visualize the landslides. This is illustrated in Figure 3. Here the number of scan points per area unit of $10\text{cm} \times 10\text{cm}$ is given by using different gray values.

Again the pole shadows are visible as areas with zero point density. The position of the left pole, near $(-4, 49)$, corresponds to some white dots. As the terrain starts to steepen, near $y = 60$, the point density starts to increase as well and more structure becomes visible. The white areas correspond exactly to the dune scarves, compare the photograph in Figure 1. The top of the dunes, above the dune scarves, is covered by helm grass. The signals received back from the grass are rather inhomogeneous, showing different densities and also different intensities (Figure 2). This is due to the bad visibility of the dune tops from the scanner and to the reflective properties of the grass.

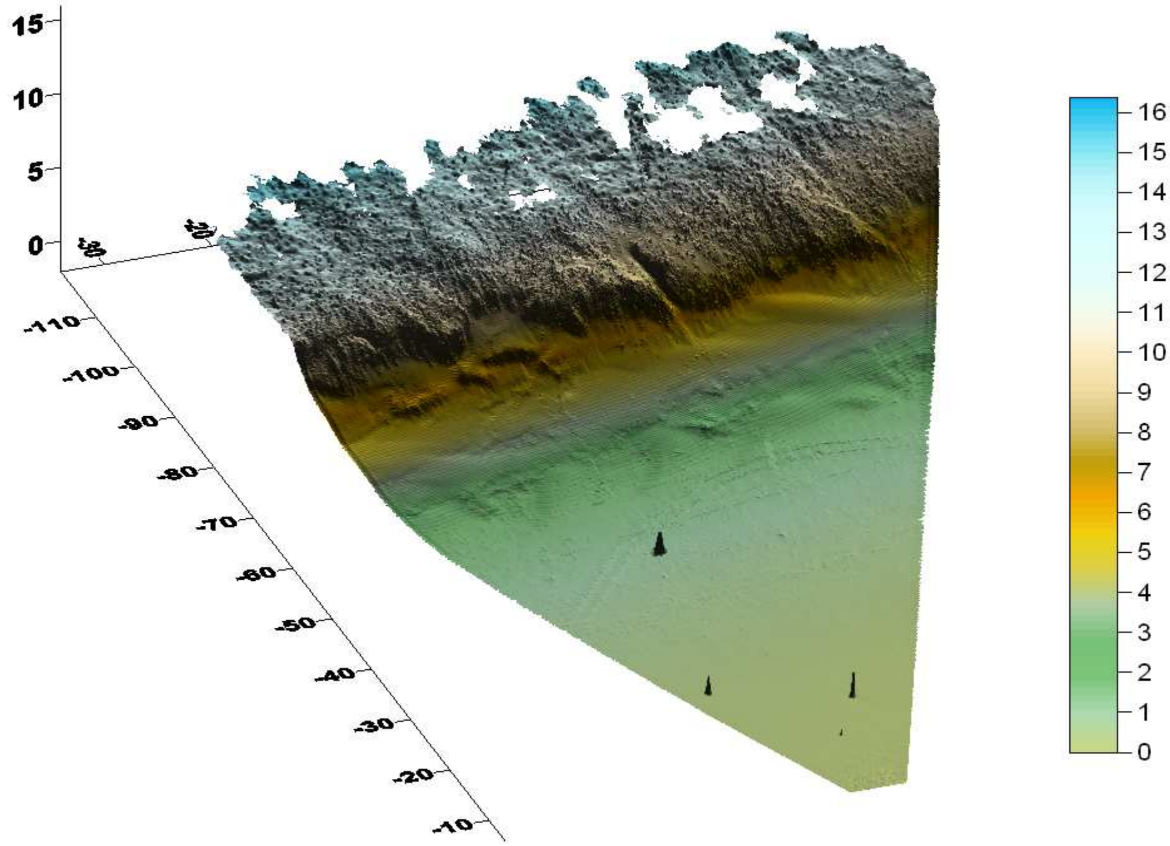

Figure 4: Perspective view of the digital elevation model created from the laser point cloud.

Digital elevation model.

Figure 4 shows a 3D model made from the point cloud. For this purpose the point cloud was interpolated to a regular $5cm$ grid by nearest neighbour interpolation. On the beach this interpolation seems to have some smoothing effect, but the result gives a clear overall representation of the dune front. Again the top of the dunes appears speckled due to the bad visibility and the larger variability of the helmgrass height.

The dune slides appear a bit smoothed as well. This is caused by the coordinate system that was used for the interpolation. Points on a steep slope that are not so close in $3D$ can still be close with respect to the horizontal distance which implies that these points have an averaging effect in an interpolation procedure. This effect can be avoided by first applying a coordinate transformation into a polar coordinate system or by interpolating locally (in the steeper parts) in the xz plane rather then in the xy plane.

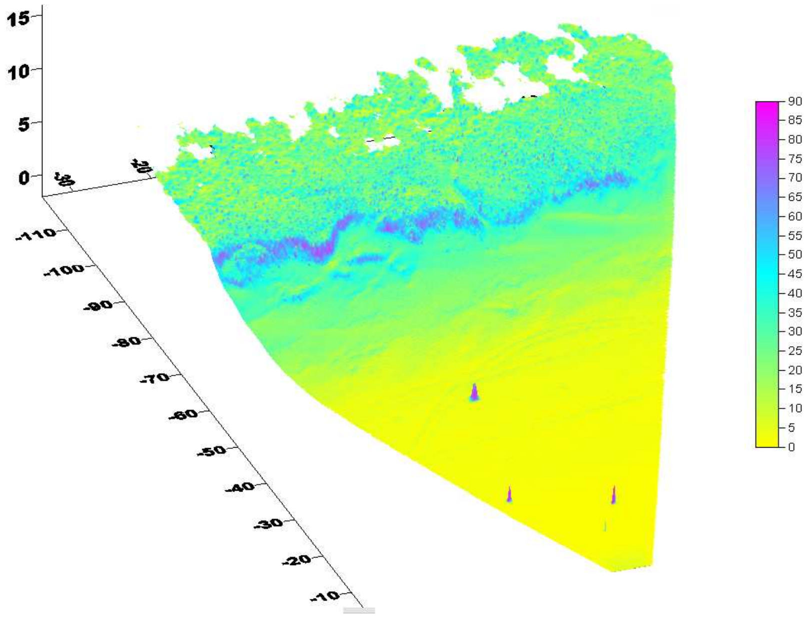

Figure 5: The same DEM as displayed in Figure 4, now colored by slope.

Slope.

Figure 5 displays the same DEM as Figure 4, but now colored by the maximal slope per grid point. Clearly the beach poles pop up, while again the dune slides are more emphasized in this coloring. This Figure can be seen as an equivalent of Figure 3 that showed the steepness by displaying the local point densities.

Conclusion.

A first short analysis of terrestrial laser scan data gives promising results. A scan of a dune front taken from about 70m at the beach resulted in a representation of 50m along coast dune front at a resolution of $5cm$. Features like beach poles, car tracks, dune slides, helm grass and even a little fence are easily recognisable in the scan.

A more in depth study would allow for assessing the obtained point accuracy as a function of the distance to the scanner and the properties of the scanned surface. Without strong efforts the interpolation of the dune slides can be improved as indicated.

It would be interesting to find out more about the meaning of the intensity signal as registered by the scanner. This can be done by analyzing the beach surface while scanning, by taking more details photographs for example, or by taking an intensity map back to the beach.

The next step would be to create a series of scans from the same position which would allow for a deformation analysis of the beach after high tide run overs and of the dune front for dune slide detection after heavy storms.