# Image analysis techniques used to determine the grain size distribution of a sand-gravel bed surface and substrate

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Sedimentary processes in a river dominated by mixed sediment lead to sorting of sediment in all directions, over various temporal and spatial scales. Sorting is the spatial variation in the grain size distribution of the bed surface and/or substrate. Improvement of measurement techniques to define such spatial variation helps to provide new insight on grain size-selective processes. In the last years image analyses techniques have emerged in this field as they are reliable, rapid and repeatable. In this project two image analysis techniques were evaluated for use in later flume experiments that are aimed at studying the response of the river bed to sediment nourishment and dredging.
The two image analysis techniques were developed to track changes in the grain size distribution of the bed surface and substrate: (1) particle coloring in combination with photogrammetric analysis providing information on the grain size distribution of the bed surface, and (2) core sampling combined with three-dimensional imaging providing information on the grain size distribution of both the bed surface and substrate. Experiments were conducted to test the techniques, partially reproducing the conditions of the later flume experiments. The techniques were applied using sediment within the range of coarse sand to fine gravel, using three well sorted sediments with only slight overlap in grain size.
For our first image analysis technique (Method 1) the three different grain size fractions were painted in different colors. We installed patches composed of various mixtures of the three grain size fractions and various color combinations. An image analysis algorithm was developed to process the images of the bed surface segmenting the three grain size fractions. The color segmentation provides values of the areal fraction of the bed surface covered by a certain color, resulting in the relative presence of the different size fractions. The procedure comprises the following steps (see Fig.1): color saturation, color segmentation, conversion to a binary image based on a threshold, determination of the sum of pixels for each color, and percentage covered by each color. The pictures were taken without water and for three water depths to study the influence of water depth on the results.

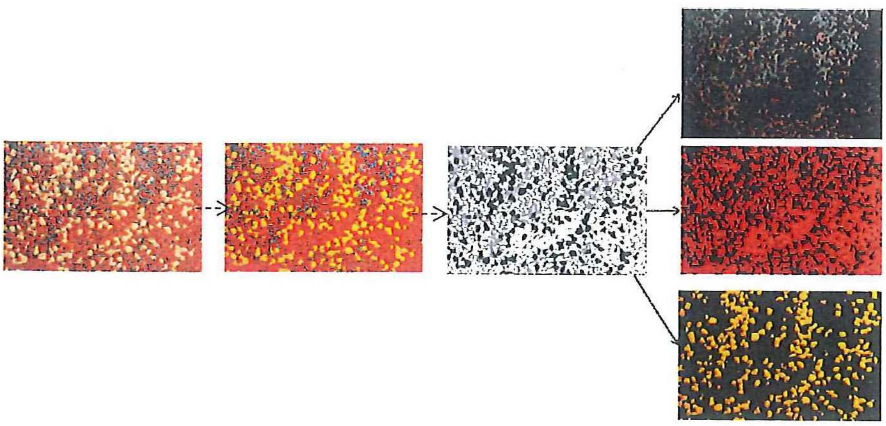

***Figure1*** *Method 1: Initials steps of the image analysis procedure: color saturation and color segmentation. From the left: original image, image with saturated colors, image with labeled pixels, segmented images for the three colors.*

Our second image analysis technique (Method 2) provides information on the grain size distribution of the bed surface and substrate. To this end samples were taken using tube cores (Fig. 2) and analyzed using a micro computed tomography scanner (micro CT scanner). Before analyzing the sample with the CT scanner, the sampled sediment was fixed using glue. The glue is transparent for the CT scanner's x-rays and provides a proper distinction in the scans between grains and the fixing substance. The glue could deal with wet sediment and the chosen viscosity of the glue allowed for sufficient infiltration into the pores of the sample.

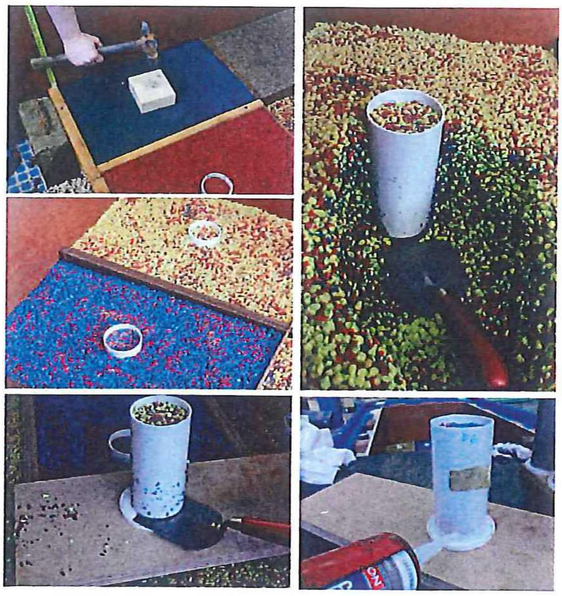

***Figure 8*** *Method 2: Steps of the bed sampling technique. Top: insertion and removal of the samples. Bottom: placement of the samples on the lid and sealing with silicon.*

The samples were then scanned using the CT scanner and processed creating a three-dimensional reconstruction of the sample in which the grains were first segmented (Fig. 3). Then volumes and positions of the grains were determined from which the variation of the grain size distribution over the vertical was derived.
The results illustrate that both techniques can be efficiently used in laboratory flume experiments to track spatial and temporal changes in the grain size distribution.

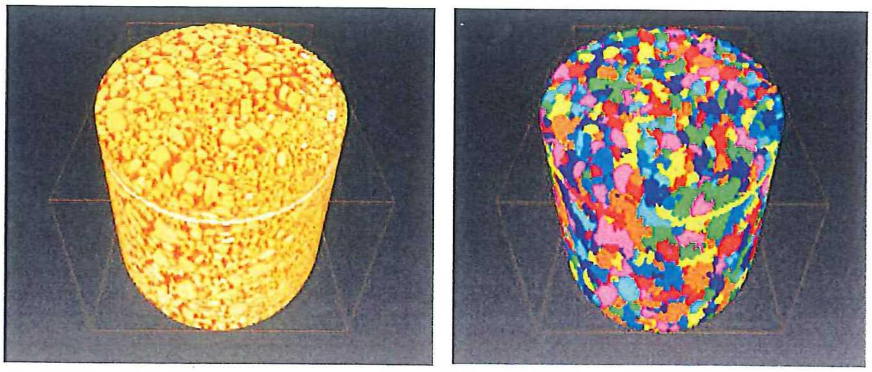

***Figure 9*** *Method 2: Micro CT scanner rendering images: three-dimensional reconstruction on the left, segmentation of the grains on the right.*