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DISTANCE MAPPING FOR IMAGE FILTERING

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ABSTRACT

This paper deals with particle disconnection on a grey-level image. The first approach is to compute a good threshold allowing to obtain two classes of points, one for particles and the other for background. As the particle density is very high on studied images (particles can even cover each other), thresholding does not give good results. The second approach is to compute the gradient image associated with the initial image. All the information about particle boundaries is represented on such an image, but the gradient image is very noisy. Filtering a gradient image in order to determine the particle boundaries is a difficult problem to solve. Classical methods such as thresholding and elimination of small objects have been used but they do not give good results. The proposed method in this paper is based on a combination of two distance maps, one being computed from the thresholded initial image and the other from a particle map. This particle map is obtained by selecting points with high gradient values as points of background on the thresholded image. The particle map and the thresholded image are binary images and a distance map can be computed on each of them. Then, for each point belonging to the background of the particle map (but belonging to a particle on the thresholded image), the corresponding values on the distance maps are checked, in order to decide if the point is noisy or not. This method allows to disconnect most of the particles. This algorithm has been implemented for an application in civil engineering. The aim was to determine the granulometry of a riprap (set of big stones covering an embankment) by image processing. Stone diameters are then computed on the particle map after noise elimination.

Keywords : distance map, gradient filtering, granulometry, particle disconnection

INTRODUCTION

The aim of this paper is to explain how to disconnect particles of any shape on a grey-level image. The disconnection of the particles is obtained by computing a particle map (binary image on which white points have a high probability to belong to particles and black points to the voids between them). This map is a combination of data, like results of thresholding or gradient computation. But using these classical methods gives either less information than we need (thresholding) or a noisy map (thresholding and gradient computation). A process which takes into account only points of the gradient image representing the particle boundaries has to be set up. This process, based on distance mapping has been implemented for an application in civil engineering. The purpose is to obtain the granulometry of a riprap (set of big stones covering an embankment) in order to determine the stability of the structure.

A NEW METHOD FOR FILTERING

The thresholding process yields a particle map which has no noisy point but most particles remain connected. This first particle map becomes a good basis for the process. Nevertheless, such an information is also included in the gradient image because it describes every particle boundary but some points represent edges or asperities of particles and they must not be taken into account.

Figure 1 shows the two particle maps (b and d) extracted from the initial image (a). The gradient image (c) is filtered by a high-pass filter and the remaining points (where the contrast on the initial image is the highest) are taken as points of voids. Edges and boundaries detected by gradient computation are associated with the thresholded image. The superposition of the two images allows to get a particle map : the mixed image (d). This is a binary image, white points representing the inner of particles and black points voids between them.

Then, distance maps are computed from the binary images and their combination gives the final particle map (e).

HOW TO FILTER

A lot of noise is taken into account while computing contrast gradient. So, it is difficult to differentiate between real contrast variation (due to a boundary between two particles or an edge separating two sides of an object) and noise (due to asperities on particle surfaces). A method for noise elimination consisting in thresholding the gradient image using windows of decreasing sizes is described by Robert & Lefebvre (1994). This method presents two drawbacks : first, some noise may remain, and second, some parts of real boundaries may disappear. However, it was efficient enough to partially disconnect the particles. The solution we consider, using distance mapping is based on two different binary images. The first is the thresholded image on that black points have a probability to belong to the voids near 1, whereas the probability for white points to belong to the voids is lower. Actually, we assume that boundary points belong to the particles in order to get disconnected particles on the final map (see fig. 1e). The second one is the mixed image on that white points have a probability to belong to the particles near 1, whereas the probability for black points to belong to the voids is lower. Let BP be the set of black points of the mixed image where the probability to belong to voids is lowest and let WP be the set of white points of the thresholded image where the probability to belong to particles is lowest. Let BD be the point set of particle boundaries on the thresholded image. If GP is the set of points remaining on the gradient image after high-pass filtering, then:

$$GP = BP \cup WP \cup BD$$

BP is the point set where gradient values correspond to asperities or edges on the particle surfaces and WP is the point set where gradient values correspond to particle boundaries.

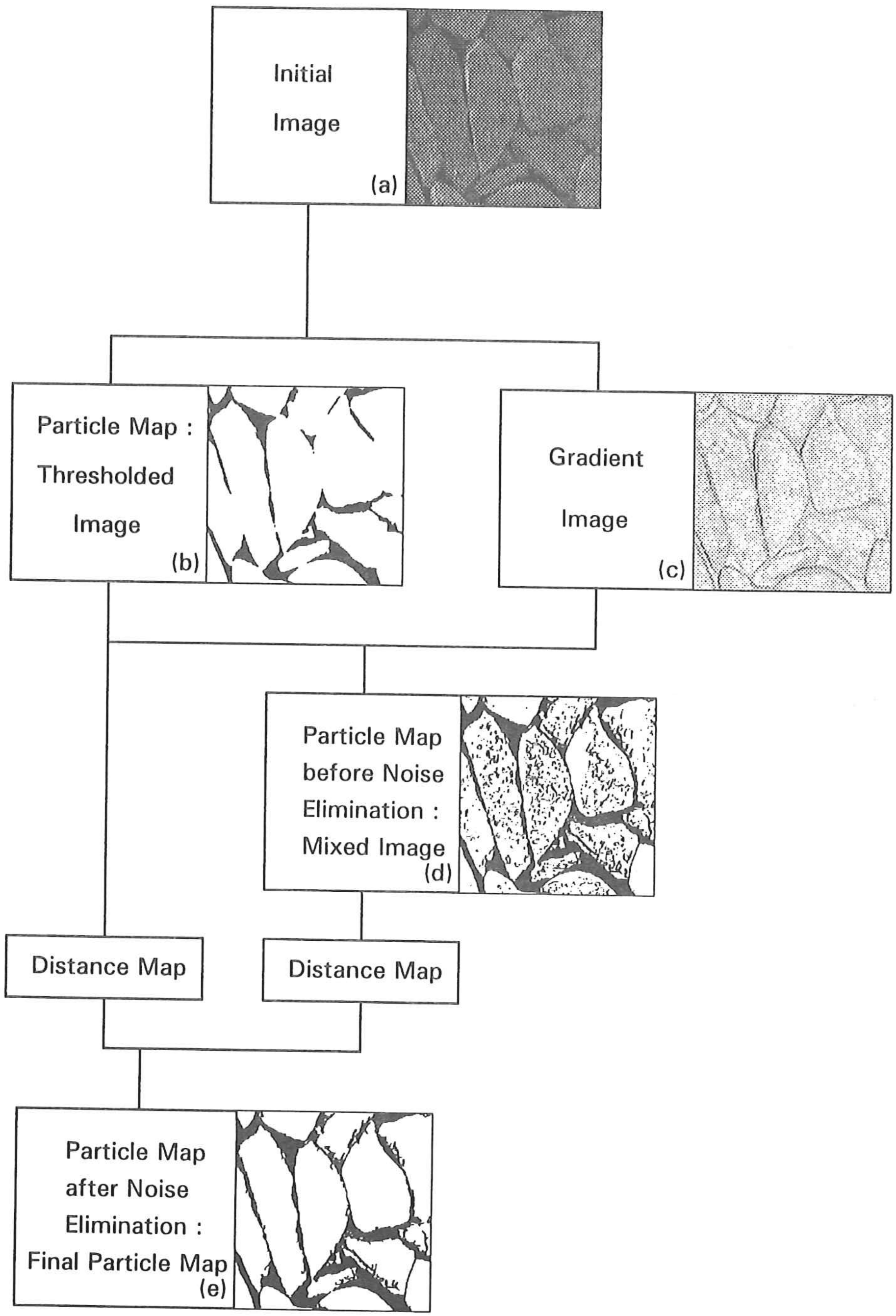

Fig. 1. Computation process of the final particle map.

The distance maps (see figures 2 and 3) are computed, according to the algorithm described by Danielsson (1980). For each point belonging to the particles, its Euclidean distance is evaluated and it represents the radius of the maximum circle, centered at the current point and totally included in the particle set. This distance value is computed by scanning twice the binary image (particle map). Relative coordinates to the voids are determined for each white point. A distance map is elaborated when computing the module of each relative vector (the components of a relative vector are respectively equal to the relative coordinates of the corresponding point).

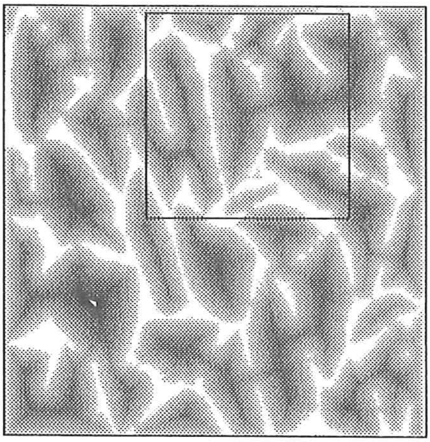

Fig. 2. Initial distance map.

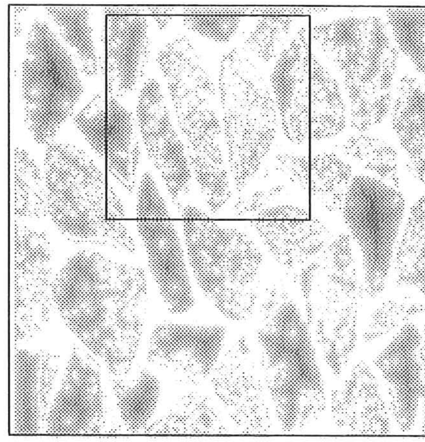

Fig. 3. Gradient distance map.

Let DP be the set of points where the value is equal to 1 on the gradient distance map. Considering the mixed image and B the ball of radius 1, V is the point set representing voids and :

$$DP = (V \oplus B) \setminus V$$

The filtering method consists in sharing DP in three disjoined subsets DP1, DP2 and DP3 (corresponding to BD, BP and WP). For each point of DP1, both values on the initial distance* map and the gradient distance map are equal to 1. DP1 is the set of points neighbouring the boundaries marking off particles on the thresholded image. For each point of DP2 and DP3, the value on the gradient distance map is higher than 1, but points of DP2 can be related to a point of DP1, whereas points of DP3 cannot. A point P2 of DP2 is related to a point P1 of DP1 if P1 itself or another point P'2 of DP2 belongs to the ball centered at DP2. Points of DP2 are neighbouring searched boundaries. Points of DP3 are near asperities or edges. DP2 represents prolongations of the boundaries (see figure 4).

The computation time is about one minute and a half on a PC 486- 66 MHz.

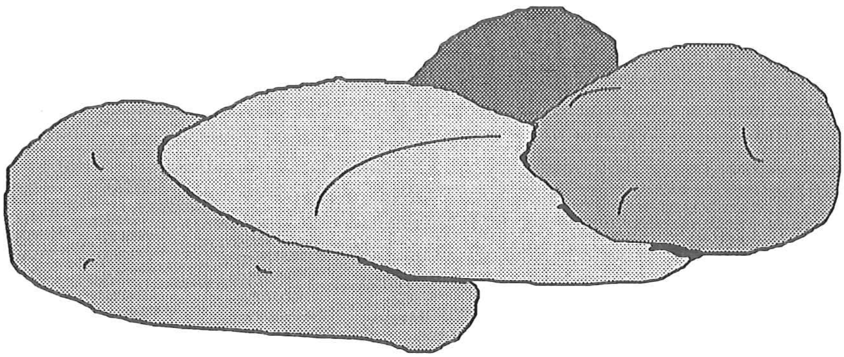

Fig. 4. Prolongation of boundaries : points connected to the boundaries from thresholding have to be retained as points of boundaries.

AN APPLICATION IN CIVIL ENGINEERING

A project of image processing has been initiated at the University of Sherbrooke, supported by Hydro Quebec Company (Robert, 1994). The aim was to establish a granulometry of the riprap of existing embankment dams, just by acquiring a video band. This video band is then cut up in a set of images, representative of the riprap. Each image is then processed in order to obtain a good particle map, where rock diameter can now be measured. A distance map is computed, giving for each white point (belonging to the rocks) its distance to the voids, by using the previous algorithm. Sieving diameters correspond to local maxima on this map assuming that rocks have almost no convex irregularities, and that the inner diameter (measured from the distance map) is approximatively equal to the outer diameter (experimentally measured by sieving).

As particles are not totally disconnected, we cannot search local maxima as unique points for each connected set, because such a set can include two or more particles and a diameter should be measured for each one. But, as we made the assumption that particles have almost no convex irregularities, we can check if this property is verified. In order to do that, segments with the origin at the new local maximum and and the extremity at each of the previously detected ones are considered. The origin is a center of a particle (point giving the sieving diameter), if and only if, all the segments pass through at least one point belonging to the voids.

CONCLUSION

The existing methods to disconnect particles are not efficient enough on images where particles have a non homogeneous surface and where they are not in the same plane (that induces shadows and variations of grey-levels). That is why a new process based on distance mapping has been implemented. This process is shorter in time and gives better results than previous ones. It is sufficient to assume that we can get a good approximation of the particle boundaries by thresholding. And then, a detection of prolongations of these boundaries from the gradient image is computed in order to complete the disconnection. Such a method can be applied to every set of particles, provided that there is sufficient contrast between them. That implies that particles must not perfectly fit into each others. But they can cover each others partially. An application has been presented in civil engineering. The considered images represent a set of stones covering an embankment. The stone surface is not homogeneous and has asperities and colour differences. This method for disconnection is well-adapted for such images and gives good results. The rock particles are enough disconnected to let sieving diameters be computed. This process has the advantage that it does not depend on the particle shape. It is not restricted to spherical or ellipsoidal particles. And it can be used for any kind of shape provided that particles have almost no convex irregularities.

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