

Range image segmentation classification

Khaldi Amine¹, Merouani Hayet Farida²

¹ Department of computer sciences, Laboratory of LRI, Badji Mokhtar University
BP12.Sidi Amar, 23000 Annaba, ALGERIA

² Department of computer sciences, Laboratory of LRI, Badji Mokhtar University
BP12.Sidi Amar, 23000 Annaba, ALGERIA

Abstract

In this paper a new classification of range image segmentation method is proposed according to the criterion of homogeneity which obeys the segmentation.

Keywords: *Image segmentation, Classification, Criterion of homogeneity, Range image.*

1. Introduction

Many researchers have studied the range image segmentation in the 80's mainly, then, this area has been neglected at the expense of intensity images due to their easy acquisition (acquiring a range image requiring a laser) and they are much more prevalent than the range images. During the past decade, with the influx of 3D geometric representations and their complex geometric representations a different interest was focused on range images, 3D image segmentation can go through a projection of the 2D image for segment it as a range image. So much work on the range images were presented and improvements have been made but not using the deformable model. Range image segmentation algorithms can be broadly classified into two categories: edge-based and region-based segmentation. Region-based approaches group pixels into connected regions based on homogeneity measures, while boundaries between regions are located by edge detection methods. Both techniques have their strengths and drawbacks. Edge detection is mostly criticized for its tendency to produce disconnected boundaries. Our work was fully motivated by the fact that a classification according to the criterion of homogeneity was never been proposed before. In this work, the

first section will be dedicated to the definition of the range image and its capture mode, finally, an extensive survey on the range image segmentation methods will be made to establish a classification that will have an overview of the field and will facilitate a possible proposal of an algorithm for range image segmentation.

2. The range image

2.1 Definition

A range image (RI) is a two-dimensional array of 3D positions [1] satisfying the property of spatial coherence, each component of this matrix represents the distance between a reference point and a point in the field of vision sensor. It is the equivalent of a video image [2] in which the gray level of each pixel (x, y) is replaced by an altitude z (2.5D is an intermediate case between the 2D and 3D, it is not fractal dimensions). The peculiarity of this type of data lies in the grid structure (x, y) and the possibility of describing the scene as a graph of function $z = f(x, y)$ the term of Rangel (range image element) denotes an element of the range image. The range images can be seen as clouds of 3D points [3] and have a regular representation [4] and are considered as organized in the sense that neighboring points in the range image are also neighbors in space. In some works [5] an image of accumulation of point clouds is associated to a range image, using a virtual camera positioned on the XY plane, the range image records the maximum distance of 3D points projected onto the plane of the camera and the image of accumulation counts the number of points (3D) that are projected onto the same pixel camera. The range images offer a precise correspondence with the latest laser scanning techniques [6], we found range images in areas such as image recognition, image retrieval, image transmission, modeling object, location and simultaneous construction of a map.

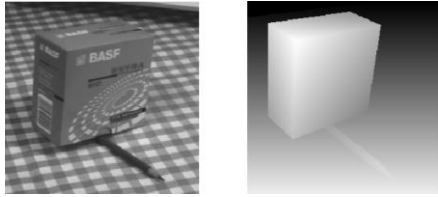


Fig.1 .At right the range image, left him the image intensity corresponding

2.2 Depth of an image

The depth is the distance between the visible surface of objects in a scene and the sensor of the camera, it is a useful indication for the calculation of the coordinates of points on the surface in three-dimensional space of reference, many methods have been developed [7] to obtain the 3D coordinates of objects using images, all exploit changes in acquisition parameters of the system of shooting, the acquisition parameters of the system or the light environment provides essential information to establish a relationship between the image and the real scene.

2.3 Range image acquisition systems

There are a wide variety of acquisition systems for range images, they are distinguished by the method of measurement, geometry of the device, the accuracy and speed, here, only two examples are presented for illustrative purposes. The first is an [8] experimental laboratory system “Fig.2” made with non-specialized equipment where a laser beam shaped plan illuminates the scene, the beam draws a visible trace on the surface of objects and the trace is marked in the image of a camera and thinned to a width of one pixel. For each pixel of the trace in the image, the 3D point defined by the intersection of the plane of light and line of sight corresponding to the pixel is calculated and this is used as RangeI.

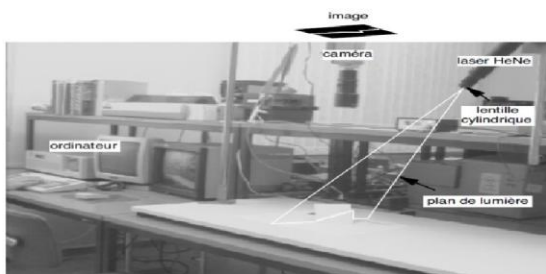


Fig.2. Experimental system for range image acquisition

The second is a system sold, operating on the principle of flight time "Fig.3". An amplitude modulated laser beam is projected in one direction [9] and a light sensor measures the light returning to the source, with amplitude modulation lag between the light signal emitted and received. The time shift is a direct measure of the distance between data acquisition and surface area encountered by the laser beam and a measure of distance in one direction to define a point in the RI, the range image is built by scanning the laser beam.

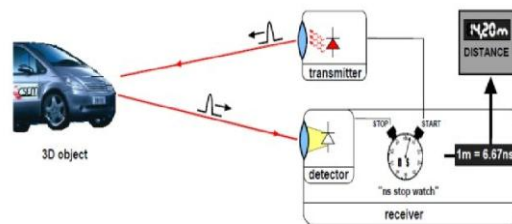


Fig. 3 .Flight time system for range image acquisition

3. Range image segmentation methods

According to documents found in the literature, we can classify the methods of segmentation into four classes according to the criterion of homogeneity which obeys the segmentation, we can find the segmentation depending on the type of curvature, surface, algebraic surface continuity C1 and a fifth category combines other methods.

3.1 Segmentation by type of curvature

The curvature estimation is affected by the presence of noise (measurement error) and the presence of discontinuities. The estimate of curvature is sufficiently good but must be low noise, on the other hand, we must eliminate disturbances due to discontinuities by proper treatment for this type of thresholding segmentation method and labeling of connected components is preferred.

- Besl and Jain [10] use this segmentation only to determine initial seeds and then perform an independent growth region.
- Yokoya and Levine [11] combined with the detection of discontinuities in segmentation type of curvature, discontinuities of the image is used as a mask during the labeling of connected components of the image type of curvature, then a simple region growing is

applied to the image.

- Kasvand [12] performs an erosion of 1 to 2 pixels on the image type of curvature to remove the effect of discontinuities, then place in the labeling of connected components of the image type of curvature and finally growing regions is performed.

3.2 Surface segmentation

Two criteria define segmentation into homogeneous flat surfaces "same orientation" and "same plane equation" methods based on the first criterion must take into account the discontinuities of depth to prevent a merger between two planes parallel but not collinear (example, an upper surface of a cube and a surface on which it is placed). Taking into account the discontinuities of order 0 is often made implicitly, it is estimated through the orientation of discontinuities, it creates a zone of steep acting separation and the major inconvenient is the appearance of regions (segments) parasites.

- Maitre and Hügli [13] have a fusion method based on normal (gradient) to the surface normal are calculated on the facets of minimum size, these facets are used as initial partition. Then, the fusion is performed sequentially by merging each time, among all pairs of neighboring regions, those with the angle between the normal is the smallest.
- Parvin and Medioni [14] use a method of division-fusion based on the normal to the surface or, more precisely, the gradient of the range image, the gradient is estimated by the conventional method using a 3x3 neighborhoods, the method of division-fusion is then applied to the image gradient, the δ measure defines the homogeneity criterion for the division (the standard deviation of the gradient). The angle value between normal vectors associated with the regions define the homogeneity for fusion, this method is subject to the same phenomenon of parasitic regions as Master and Hügli.
- Taylor [15] applies the method of dividing an image fusion of normal (gradient), the estimated gradient is a suitable neighborhood, and the problem areas of

parasites is eliminated at the division and fusion, a depth test must be done when the homogeneity tests are positive on the normal, this prevents parallel planes separated by a discontinuity in depth form a single segment.

3.3 Segmentation in algebraic surfaces

The segmentation of algebraic surfaces (not strictly planar) is divided into two categories depending on the nature of 2.5D and 3D surfaces, surfaces 2.5D all correspond to polynomial functions of two variables and obviously apply only images of scalar type. The 3D surfaces are the quadrics and super quadrics where the treatment is more complex than 2.5D surfaces.

- Leonardi [16] presents a method (independent growth areas) division-fusion linked to a 2.5D surface model type polynomial (the degree of the polynomial can vary from 0 to 3), the test for homogeneity division and the merger is based on the approximation error of image values by the polynomial of best approximation and in the merger, approximation error and the polynomial coefficients are updated from those regions merged (It is not necessary to calculate an approximation of the new region), for this method, it is necessary to extract first the depth discontinuities.
- Gupta and Bajcsy [17] present a segmentation method that result in the description of the range image by superquadrics (specifically super-ellipsoid). To achieve the result, the approach taken by Gupta performs geometric reasoning on the basis of two other segments, the 2.5D surfaces preliminary segmentation and a current segment of super-ellipsoid approximation residues, this process goes beyond the treatment of low-level image depth.
- Jiang and Bunke [18] conduct a region growing constrained approximation by a plane (2.5D), the method of growth is special because it is based on straight line segments, regions are lists segments and the growth is done segment by segment, line segments are obtained by dividing a profile (row or column) of the range image.

Regional growth is sequentially (one region after another). The seed which is initialized with the growth consists of three line segments neighboring profiles from three consecutive growth starts with the seed that best satisfies a test of parallelism between segments.

3.4 Segmentation of continuity of order 1

Several methods lead to segmentation with the criterion of homogeneity of surface can be defined as C1 continuity, two principles are applied.

- Detection of discontinuities and labeling of connected components: This is the principle of boundary detection described above, the border points are the points of discontinuity (C^0) and (C^1). In the Davignon's approach [19], growth in the field of border points detected is performed so as to form still closed borders, the growth is done by choosing at each step the neighboring pixel which is the measure of discontinuity nearest (below) the threshold, once the closed borders, regions are approximated by a related algebraic surface (polynomial type) of increasing complexity, until the approximation error is sufficiently small, the position of the discontinuities is then adjusted based on this surface representation.
- Fusion of segments from a segmentation constraint: The method of Besl [20] begins with a segmentation by type of curvature, the derived regions are eroded from seed obtained, the method proceeds by growth, as described above, finally takes place a merger of the regions on the basis of the presence or absence of discontinuity between regions. This process has the effect of systematic closure of borders associated with discontinuities.

3.5 Other segmentation methods

The methods described below apply the same principle of merging segments more constrained as the method of Besl, however, the merger is based on more restrictive conditions than the absence of discontinuities between segments, the final segmentation therefore obeys a homogeneity criterion more stringent than C1 continuity.

- The method used by Ade and Ylä-Jääski [21] has three steps. The first step is a "clustering" of normal vectors and labeling of connected components, the small regions (narrow) are eliminated at the end of this first stage, the second stage performs a growth of conserved regions, finally, held a melting step in which two adjacent regions are merged if their normal and principal curvatures have similar values and if they have a sufficiently long common border.
- Wand and Suter developed the MDPE (Maximum Density Power Estimator) which is a nonparametric estimator of density and including the gradient estimation techniques [22] similar to many random sampling estimators. The algorithm consists of choosing a search window and a p-random subset, then the Mean Shift algorithm is applied on every point of the window, then the density is calculated on all data points of the window chosen to determine the power density. The essence of the method lies in the application of several procedures for finding the maximum local density of these residues (data points with less residue should be as many as possible, and residues should be as low as possible).
- Paulo Fabiano proposes an algorithm [23] for range image segmentation combining depth and region technical. First, a 3×3 median filter and an analysis of main components is applied to estimate the vectors of surfaces, then for each pixel, the angular variation in the normal direction is calculated from the pixel P in a Q pixel neighborhood, after the use of a low and high threshold, each point is then marked as belonging to a flat, curved, or indeterminate (if not), this pre-treatment allows the classification of pixels to be used to identify flat and curved regions.

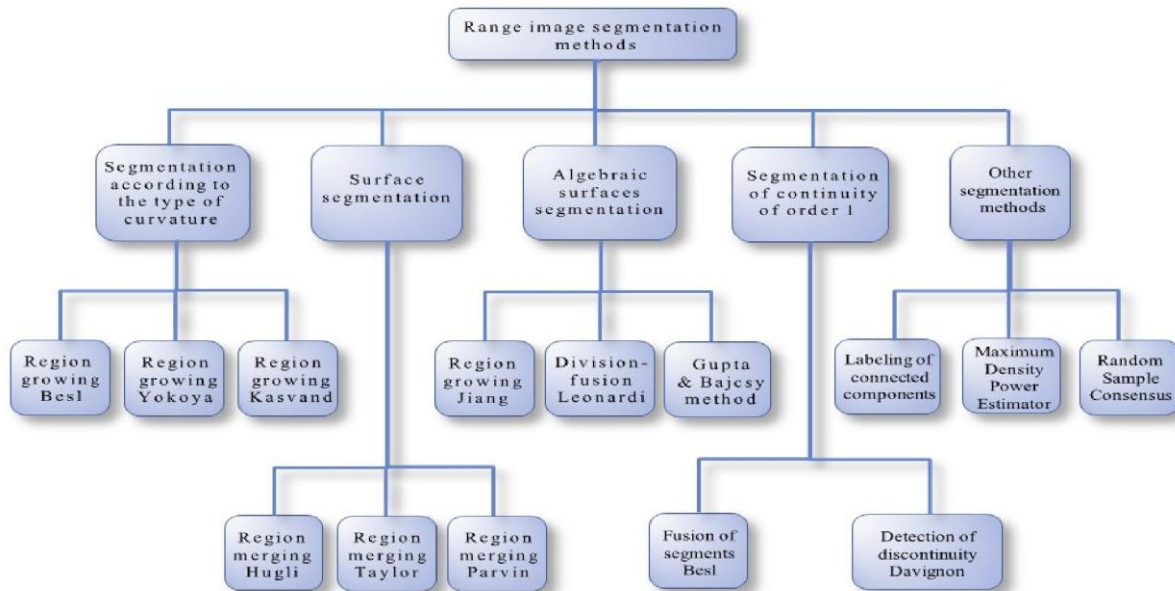


Fig.4. Range image segmentation methods classification

We can still classify virtually all methods following the four criteria "Fig.4" of homogeneity (type of curve, surface, algebraic surface and continuity C1), here is an overview of methods, accompanied by critical comments.

- Type of curvature methods face the problem of estimating the curvature, it is affected by both noise and discontinuities, segmentation is representative of the measured surface as if the noise is low and if the disturbances due to discontinuities are removed by appropriate treatment.
- Algebraic Surface: On algebraic surfaces there are two types of methods, division / fusion and region-independent growth, methods of division / fusion are poorly adapted to the segmentation of range images based on a model surface because of the particular algebraic discontinuities in the methods of independent growth area, there are two approaches that differ in their fundamental principle, the approach initiated by Besl seeks a minimum approximate representation of the image depth and approach Leonardis is an exhaustive search of the best location of one

or more surface models in the picture.

- Flat surface: The methods are numerous, but most use specific properties to a flat surface, the segmentation into planar surfaces should be treated the same way as the more general case of algebraic surfaces.
- Continuity C1: Next to the simple method of segmentation following C1, there are sophisticated methods, all the effort invested by these methods is devoted to forcing the closure of borders defined by the discontinuities, a systematic closure of borders is a change in the criterion of homogeneity, making it more restrictive than the pure C1 continuity, it is noted that it provide, unlike other methods, a simplified representation of the segment.

4. Conclusions

The aim of this work was to provide a new classification of the range image segmentation methods and the literature review has shown how the basic methods were used in practice, sometimes forming methods combined, although the test for homogeneity of the resulting segmentation were not always explicit.

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