LASER RANGE DATA REGISTRATION USING SPIN IMAGES

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Abstract: Registration of laser range data becoming from different scanner positions is still a current topic in literature. In this paper we introduce the possibility of solving it by using spin images, which create a 2D image for every 3D coordinate vertex in the scans. Matching between spin images allows the estimation of an initial rigid transformation between the scans, which later can be refined with ICP process in order to achieve a more accurate registration.

1 INTRODUCTION

Laser range scanning has become a quite popular system for the capture of 3D environments. The possibility of combining both the 3D representation obtained from the laser and a visible/infrared camera to apply a texture to the three-dimensional model achieves a precise representation of huge scenes with a minimum effort.

One of the most encouraging challenges in this kind of images is the possibility of register different scans becoming from different unknown points of view, achieving in this way a more wide representation and the filling of laser range shadows produced by the reflection in the objects.

The usual way to achieve this pairwise registration is the so-called Iterative Closest Point (ICP) (Besl and McKay, 1992), which performs an iterative process in order to minimize the mean square distance between two sets of 3D points. Nowadays, this algorithm and its different derivatives (Rusinkiewicz and Levoy, 2001) are still the most usual and effective ways to achieve our objective. The main problem for this algorithm is the necessity of a good initialization if we desire that the iterative process converges to a global minimum and not to a local minimum.

The obtaining of this initialization becomes the main problem in most of the existing literature. Some approaches use a simple combination of a GPS and a Inertial Measurement Unit (IMU) (Madhavan and Messina, 2003; Hsu et al., 2003) in order to obtain both the position and orientation of the laser scanner in every scanning process. This method provide on one side the simplicity thanks to the non-existence of complicated algorithms, but on the other side becomes ineffective in indoor applications or places where the GPS signal cannot be reachable.

More recent approaches make use of the information obtained from the visible camera attached to the laser scanner, extracting information from the more well-known and deeply studied 2D images processing. The basic idea is to obtain characteristic keypoints from the visible images, and later achieve the matching between the keypoints using the SIFT descriptor (Lowe, 2004). Once this matching has been finished, and assuming that the visible camera and the laser range scanner are perfectly calibrated, we can convert this 2D-pixel-matching in 3D-coordinates-matching, and achieving the desired pairwise registration. Main problem of this approach is that the matching of SIFT descriptors is capable to cope with small differences is the viewpoint, but not with high differences in position as could be our case of study. Some solutions arise to this problem making use of the 3D information from the laser scanner (Seo et al., 2005; Smith et al., 2008), estimating the normal of the 3D coordinate in the real world and performing an homography of the visible image as it would be seen from the front side of the keypoint.

Our model is based also in the use of a descriptor,

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but this time in the 3D descriptor called spin image. The descriptor is able to compute a 2D image for every 3D coordinate taking into account the projection of the other 3D coordinates in its proximity. The main benefit from this approach is the computation of the process only using the 3D information from the laser scanner and therefore the non-necessity of a calibration of the visible camera with the range scanner.

The structure of the document is as follows: in Section 2 we see a review of spin images, which allows a good compression of our model in Section 3. Experimental results are explained in Section 4 and finally conclusions and future work can be found in Section 5.

2 SPIN IMAGES

Spin images were initially developed during the PhD thesis of Andrew Edie Johson under the supervision of Martial Hebert (Johnson, 1997). Later they apply the algorithm to different cases of 3D recognition and matching (Johnson and Hebert, 1998; Johnson and Hebert, 1999). Nowadays they are quite used in facial recognition (Li et al., 2006) and 3D object recognition (Assfalg et al., 2007; Matzka et al., 2007).

Basic idea of the spin images is to represent the proximity structure for every 3D point in a surface or object. First step for its computation is the estimation of the surface normal for every point we want to create the spin image. Combination of the 3D point with its normal vector is called oriented point. The oriented point defines a plane and also a cylindrical coordinate system. Two coordinates can then be defined: a radial coordinate α and an elevation coordinate β. α defines the distance of every point in the proximity to the line defined by the oriented point, and β defines the distance of every point to the tangent plane defined by the oriented point. Their graphical representation is shown in Figure 1, where p represents the 3D point that we want to create the spin image, n its normal vector and x represents one of its proximity neighbors.

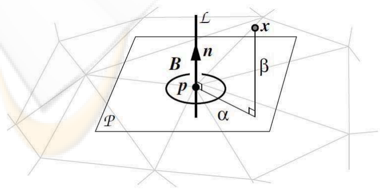

Figure 1: Generation of spin image at oriented point p.

$$\beta = (x-p)\cdot n \tag{1}$$

$$\alpha = \sqrt{(x-p)^2 - \beta^2} \tag{2}$$

Once all the points in the proximity have been projected to the plane we obtain a 2D image with a cluster of dots. At this point the second step of the spin image generation starts: the 2D image can be seen as an accumulator, resulting in darker areas where the accumulation of points is higher and lighter areas where the accumulation is lower. For this accumulation result we must previously define a bin size, defined as the geometric width of the bins in the spin image. The final result of the spin image should be a gray-level image normalized between 0 (white color) and 1 (black color).

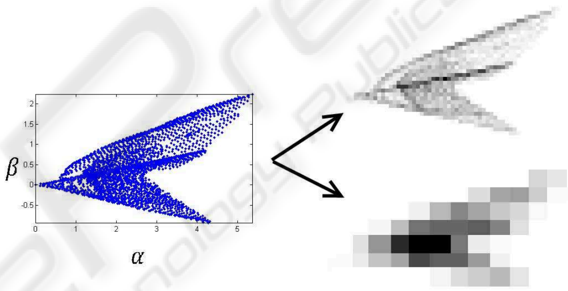

Figure 2: Dependence of bin size in the spin image.

Spin images from two different scans representing the same object will be similar but not exactly, so in order to compute the possible matching between two spin images we can use a simply correlation coefficient. The higher the correlation coefficient, the more probable that both points represent the same vertex in the object or surface.

3 REGISTRATION PROCESS

As mentioned, basis of our system is the generation of spin images. Anyway, due to computational cost is not advisable to generate a spin image for every 3D vertex in the two scans, so some kind of characteristic points selection is needed. Main advantage of our system is that it does not require the information of the visible camera to achieve the registration. For this reason we can simply use the range image or the reflectance image of the range scanner, which are perfectly registered with the 3D scan since they are captured at the same time as the 3D scan. We can use also the visible camera image, but taking into account that probably the calibration would not be so exact.

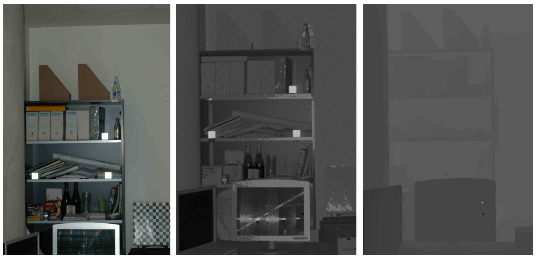

Figure 3: Visible image, reflectance image and range image.

For our study case we use the reflectance image of the two laser range scans, where we apply a keypoint detector in order to find a group of characteristic points. We implemented it with a Harris detector (Harris and Stephens, 1988), but other keypoint detectors can be used (Lowe, 2004; Mikolajczyk and Schmid, 2005).

Once the keypoints from both images are selected, we can compute the spin image of every 3D coordinate associated to the keypoints. As probably both scans will have a huge extension, we limit the generation of the spin image using only 3D coordinates that are at a distance lower than 5 meters. With this restriction we achieve a spin image that represents the local structure of the feature independently to the rest of the laser scan.

Matching between the spin images is carried out with a simple correlation factor. Every spin image of a scan are compared with all the spin images of the other scan, and those that overcome a correlation threshold (0,6 in our experiments) are selected as possible correspondences. With all the possible correspondences between both scans in hand, we should still find the higher group of correspondences that are geometrically consistent. We apply the algorithm explained in (Johnson and Hebert, 1998), where the consistency is evaluated through the Geometric Consistency Distance (W_{gc}). After applying the algorithm the group with more elements will be considered as the most probable one, and the rigid transformation T from scan A to scan B is calculated by minimizing the error considering all the correspondences of the chosen group.

$$\min \sum \|a_i - T(b_i)\|^2 \qquad (3)$$

Finally, in order to accurately register both scans, the ICP process is applied. Since the initialization should be good enough the process converge to a global minimum and the final registration will improve the previous result.

4 EXPERIMENTAL RESULTS

The experiments have been carried out with two scans captured with a laser scanner Riegl LMS-Z420i. Both scans capture a similar portion of a scene, containing walls, vegetation and vehicles. Dates of capture were different, so there is no correlation between the vehicles. The positions of the scans are lightly displaced, and also with a difference in elevation. Both scans can be seen in Figures 4 and 5. Also, for a better scene understanding, the associated visible images are shown.

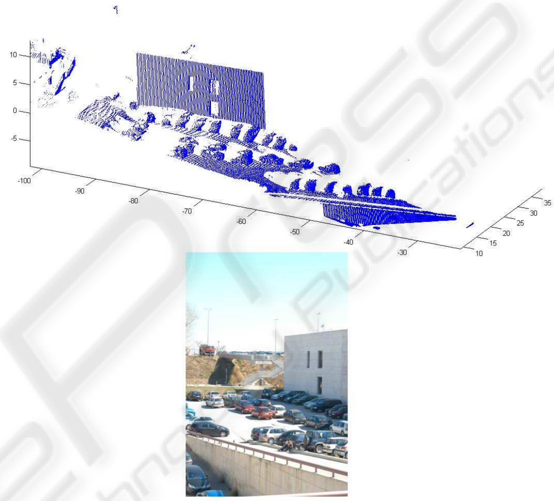

Figure 4: Scan A and its associated visible image.

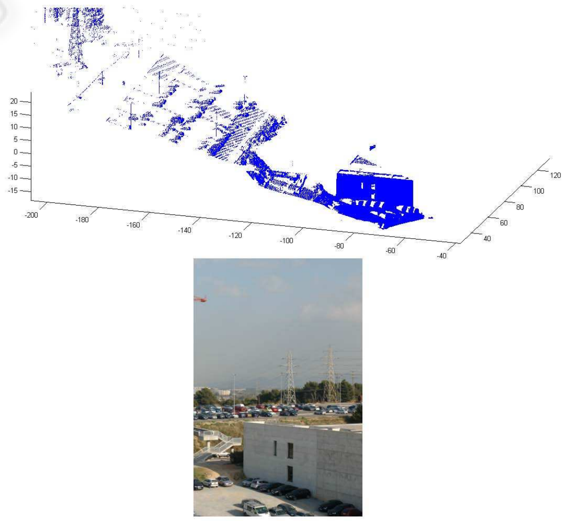

Figure 5: Scan B and its associated visible image.

Execution of the different steps presented in this paper lead us to 542 possible correspondences between the spin images. After the geometric consistency grouping, the group with more correspondences is selected (167 correspondences) and the rigid transformation is calculated. Result can be seen in Figure 6. As expected, result can have some minor errors, so the Iterative Closest Point algorithm is applied in order to refine the registration. Final result with a more accurate registration can be seen in Figure 7.

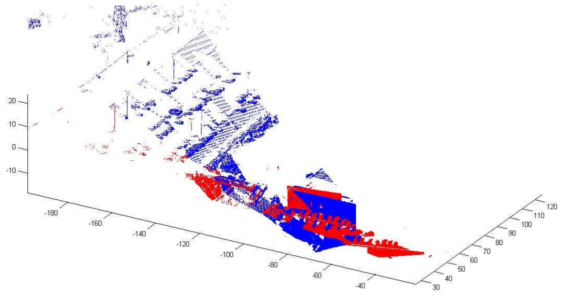

Figure 6: Registration result after the matching grouping.

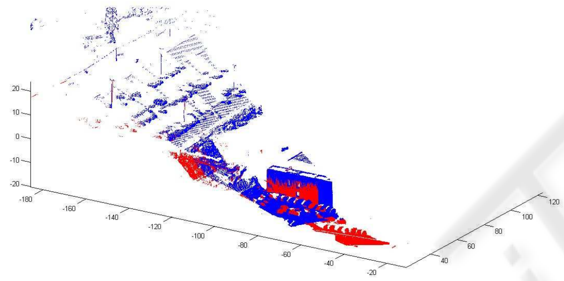

Figure 7: Final registration result after the ICP process.

5 CONCLUSIONS AND FUTURE WORK

This paper explains the initial developments of an algorithm to achieve the pairwise registration between laser range scans taken from different unknown positions. The registration is based in the computation of the spin images for different specific 3D coordinates and the later matching between them using a simple correlation factor.

Use of spin images allows us the possibility of working directly with the 3D data and evaluate, for every 3D coordinate, the relationship with the other 3D coordinates in the proximity. In addition, the processing of the visible image in order to find an initial approximation is not mandatory and all the processing can be done only with the information obtained from the laser scanner.

Following steps in this study will be the detection, directly in the 3D surface, of specific typical forms: planes (useful for buildings and walls), cylinders (for trees, streetlight or traffic lights) or any other forms that could be representative for different objects present in typical scenarios. The detection of these typical forms will allow a filtering of non-static objects (e.g. cars) and thus a better registration between the 3D points sets. Of course spin images could be really helpful for this purpose, as they can represent the local distribution of the 3D coordinate and its neighborhood.

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