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Real - Time Image Rectification of Stereo Images

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Abstract

"Seeing" machines and "intelligent" robots have been the focus of research on Automated Processing Industries and in Autonomous Ground Vehicle. A goal is to gain a basic understanding of vision, as a powerful means of perception, autonomy and intelligence of technical systems, and to construct seeing intelligent robots. These should be able to operate robustly and at an acceptable speed in the real world, to survive in a dynamically changing natural environment, and to perform autonomously a wide variety of tasks. This paper reports about a essential preprocessing step of Imaging system as image rectification, a widely used technique in 3D-reconstruction and stereo vision, that have been developed during recent research projects for automating. Image rectification is a transformation process used to project multiple images onto a common image surface. It is used to correct a distorted image into a standard coordinate system. The important advantage of rectification is that computing stereo correspondences is reduced to a 1-D search problem along the horizontal raster lines of the rectified images. This Paper describes about a linear rectification algorithm through a non-linear transformation technique for general, unconstrained stereo rigs. The algorithm requires the two perspective projection matrices of the original cameras, and enforces explicitly all constraints necessary and sufficient to achieve a unique pair of rectifying projection matrices.

Key words: Stereo image, Epipolar geometry, Image rectification, Epipolar Constraint

I. INTRODUCTION

Increasing demands of Autonomous Ground vehicle as well as automated manufacturing processes and services with greater flexibility, intelligent robots with the ability to adapt new environments and various circumstances are key factors for success. To develop such robots manifold competencies are required with an intelligent vision system, during occlusion also. The Stereovision is the solution for the real time process.

Stereovision [1], is a technique used to find points in different cameras and in different frames corresponding to a same physical point. Once the correspondence problem is established, the shape and the three-dimensional motion of the scene can be recovered by triangulation [2]. Unfortunately, the correspondence problem is a very difficult task in AGV vision [3], because a scene generally has different shapes and appearances when seen from different points of view and at different times [4]. To overcome this difficulty, most existing stereovision algorithms rely on unrealistic simplifying assumptions that disregard either/both shape/appearance changes. The major significance of this paper is the novel method to rectify the grabbed images.

Images acquired at different times usually have different amounts of haze and dust in the atmosphere. These differences can mask real changes or make similar land cover appears to have changed [5]. Before finding the solution for correspondence problem between images, have to make sure that they properly align to each other. This is referred to as image rectification. If they actually align to real world coordinates, these images will also be geo referenced.

Given a pair of stereo images, rectification determines a transformation of each image plane such that pairs of conjugate epipolar lines become collinear and parallel to one of the image axes. The rectified images can be thought of as acquired by a new stereo rig, obtained by rotating the original cameras. It is used in computer stereo vision to simplify the problem of finding matching points between images [6]. It is used in geographic information systems to merge images taken from multiple perspectives into a common map coordinate system.

This paper is organized as follows. Section 2 and 3 describes the technique to establish the vision system. Section 4 gives epipolar model. Section 5 and 6 deals with image rectification in stereo vision. Section 7 discusses the results obtained on two types of image constraints and Section 8 concludes the paper.

II. COMPUTER STEREO VISION

Stereo vision uses triangulation based on epipolar geometry to determine distance of an object from vision system. In Stereo image processing, between two cameras there is a problem of finding a point viewed by one camera in the image of the other camera, the correspondence problem. In most camera configurations, this would require a search in two dimensions. However, if the two cameras are aligned to have a common image plane, the search is simplified to one dimension with a baseline, that is parallel to the line between the cameras. Image rectification is an equivalent alternative to this precise camera alignment. It will transform the images to make the epipolar lines (epipolar geometry) be aligned horizontally.

The image rectifiication without geometric distortion, can easily be made with a linear transformation. X & Y rotation puts the images on the same plane, scaling makes the image frames be the same size and Z rotation & skew adjustments make the image pixel rows directly line up. The rigid alignment of the cameras needs to be known (by calibration) and the calibration coefficients are used by the transform.

To do the transform, if the cameras themselves are calibrated for internal parameters, an essential matrix will relate the relationship between the cameras. The more general case (without camera calibration) is represented by the fundamental matrix [7]. It should be noted that if the fundamental matrix is not known, it is necessary to find preliminary point correspondences between stereo images to facilitate its extraction.

Stereo images can also be taken with a single camera in motion. In this case the relationship of the images can have significant forward-motion components, and a linear transformation may produce severely warped images or very large images. A non-linear transformation technique can be used to manage this difficulty.

III. GEOGRAPHIC INFORMATION SYSTEM

Image rectification in GIS converts images to a standard map coordinate system. This is done by matching ground control points (GCP) in the mapping system to points in the image. These GCPs calculate necessary image transforms. Primary difficulties in the process occurs, when the accuracy of the map points are not well known. when the images lack clearly identifiable points to correspond to the maps. The maps that are used with rectified images are non-topographical. However, the images to be used may contain distortion from terrain. Image orthorectification additionally removes these effects.

In computer stereo vision, rectifying images is used to facilitate matching of features. However in GIS, matching of features is used to rectify images. The stereo matching problem can be solved much more efficiently if images are rectified. This step consists of transforming the images, so that the epipolar lines are aligned

The different methods for rectification mainly differ in how the remaining degrees of freedom are chosen. In the calibrated case one can choose the distance from the plane to the baseline so that no pixels are compressed during the warping from the images to the rectified images and the normal on the plane can be chosen in the middle of the two epipolar planes containing the optical axes. In the un-calibrated case the choice is less obvious. Several approaches were proposed [9].

VI. PARALLEL STEREO RECTIFICATION

Parallel stereo configurations greatly simplify the matching process of two images, if a pair of images is taken with a general stereo configuration, an operation known as Rectification can be applied to bring the two retinal planes to be coplanar to a common plane R in space. This plane R can be chosen as follows Figure.2

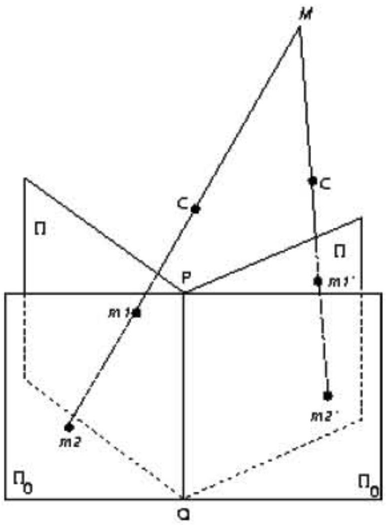


Fig. 2 : Parallel stereo rectification

Step1 : Compute a line PQ, the line of intersection between the original retinal planes and .

Step 2 : Compute the baseline vector CC'.

Step 3 : Compute the equation of the Π ane Π' at contains a line PQ and parallel to CC'.

Step 4 : Assign this computed plane to **R**.

An alternative way of choosing R is, instead of step 3 above, look for a plane that contains CC' and that minimizes the projective distortion.

VII. EXPERIMENTAL SETUP AND RESULTS

A test bench is established with two CCD Zebronic Night Vision Web Camera with adjustable baseline. Image acquisition is performed on two video sequences 540 frames acquired in 52 seconds, of size 640 X 480 X 24 BPP, which are grabbed as indoor image sequences, one with single Object and other with Occluded environment. Image rectification algorithm is performed on a Pentium IV, 2.4 GHz computer using Matlab 7.0. The images are calibrated under camera Calibration technique to define a intrinsic and extrinsic parameter and the results are given Table 1, shows intrinsic parameters of Left Stereo camera, Table 2: shows Extrinsic parameters of Left Stereo Camera, Table 3: Intrinsic parameters of Stereo camera, Table 4: Extrinsic parameters of Stereo Camera

A. Calibration results after optimization:

Table 1 : Intrinsic parameters of Left Stereo camera

Parameter	Magnitude
Focal Length (fc_stereo)	[4328.70908 8115.46569]
Principle Point (cc_ stereo)	[159.50000 119.50000]
Skew (Alpha_ stereo)	[0.00000]
Angle of pixel axis	90.00000 degrees
Distortion (kc_ stereo)	[136.07383 -8463 3.79323 - 0.30976 -0.93556 0.00000]

Table 2 : Extrinsic parameters of Left Stereo Camera

Parameter	Magnitude
Rotation Vector (om)	[-1.495283 -1.507962 -0.917157]
Translation Vector(T)	[-2.028973 -1.679637 874.549960]
Rotation matrix (R)	[0.024258 0.998416 -0.050768 0.414132 0.036185 0.909497 0.909893 -0.043088 -0.412598]
Pixel error (err)	[0.66344 0.97310]

B. Stereo calibration parameters :

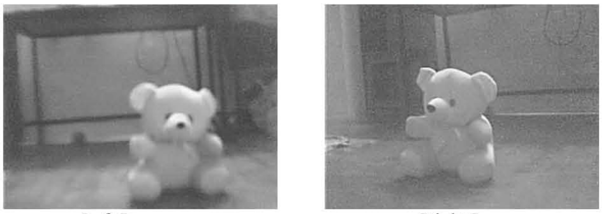
Table3 : Intrinsic parameters of Stereo camera

Parameter	Magnitude
Focal Length (fc_stereo)	[3425.16853 5016.45676]
Principle Point (cc_ stereo)	[159.50000 119.50000]
Skew (Alpha_ stereo)	[0.00000]
Angle of pixel axis	90.00000 degrees
Distortion (kc_ stereo)	[65.57183 -35382 0.00146 -0.07242 0.57943 0.00000]

Table 4 : Extrinsic parameters of Stereo Camera

Parameter	Magnitude
Rotation Vector (om)	[1.529944 1.676865 -0.971601]
Translation Vector (T)	[-11.367686 -5.164689 30.674855]
Rotation matrix (R)	[-0.098000 0.995120 -0.011524 0.504889 0.039736 -0.862269 -0.857603 -0.090321 -0.506319]
Pixel error (err)	[1.47998 1.09251]

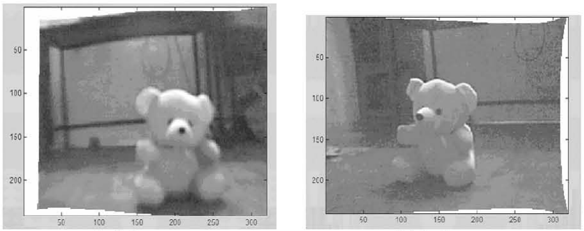
The image rectification Algorithm is performed as proposed in section 6 with two stereo pair examples shown in Figure 3, shows an image before rectification on single object of 0.65 meter Baseline and 0.85meter Optical axis with 90 degrees Viewing angle.



Left Image Right Image

Fig. 3 : Distorted Stereo Image Pair (before image rectification)

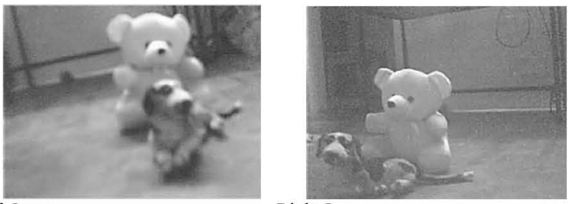
Fig. 4. show an image after applying image rectification on single object.



Left Image Right Image

Fig. 4. Rectified Stereo Image Pair

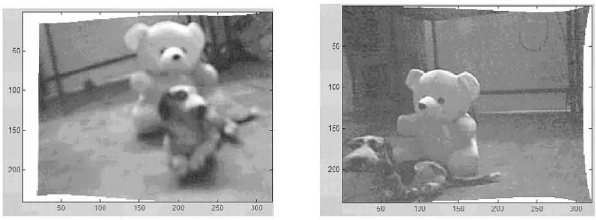
Fig. 5. shows an image before rectification under occluded environment of 0.65 meter Baseline and 0.60meter Optical axis with 90 degrees Viewing angle.



Left Image Right Image

Fig. 5. Distorted Stereo Image Pair Under Occlusion

Fig. 6. shows an image after applying image rectification under occluded environment.



Left Image Right Image

Fig. 6. Rectified Stereo Image Pair Under Occulsion

After rectification, the epipolar lines between images left and right coincide with the horizontal scan lines. It can easily be recognized that corresponding features now lie on the same line. The initial point correspondence needed to orient the epipolar geometry was not obtained through feature matching, but by intersecting the known viewing pyramids of the cameras and choosing the closest point in a decent distance to both camera centers. A sample reprojected image is shown in Figure 7.

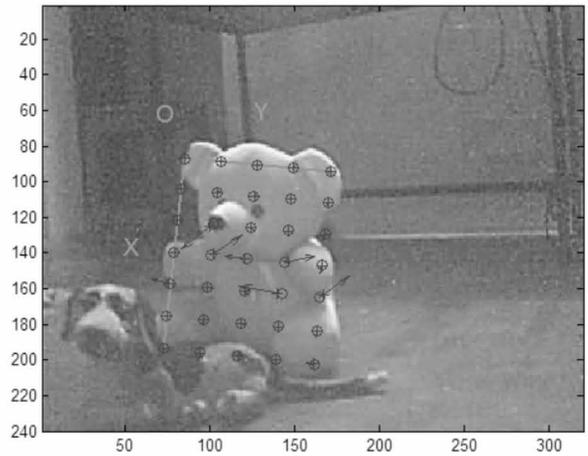


Fig. 7. Reprojected Right Image of Stereo Image Pair Under Occulsion

VIII. CONCLUSION

Given the proposed extension of the rectification process, it is now possible to deal with general camera positions, where former methods failed in special cases. As even extreme camera positions of an acquisition system can be evaluated now, e.g., for 3D reconstruction in an object acquisition system, this opens new possibilities for more flexible autonomous systems, where successive camera positions are unpredictable.

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