XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

AVOIDING MATCH MARKS ON OBJETS FOR QUALITY CONTROL BY IMAGES

J. Sanchez, B. Valera and G. Ruiz
Laboratory of Images, Department of Metrology, Instruments Center
Universidad Nacional de México, AP 70-186, México D.F., México

Abstract: When facilities of images are used to control geometric quality of objets, these have to own match marks, which are reconstructed in 3D, if couples of 2D points of such marks on images are matched by a human or artificial recognition process. Particular applications may avoid match marking and human recognition, but it is necessary to locate objets with particular orientation in precise known places. On the other hand, precise location of objets into virtual reference systems, when those were located freely, is one characteristic of interest in many industrial applications. Some applications are: quick verification of quality by attributes, or navigation of robots, where marks would increase the work which is intended to avoid. This manuscript deal with mathematical possibilities, imaging techniques and computer graphics, to define position of objets and deviations of shape. Our techniques are based on the knowledge of design of objets, made with simple CAD primitives. An original methodology is used to overcome problems of occlusions or sudden discontinuities, ordinary presented in matching couples of images for stereo reconstruction.
Keywords: Pattern recognition, image processing, stereo measures

1 INTRODUCTION

1.1 Evolution of imaging into metrology

Euclid (600 B.C.) discovered principles of binocular parallax, for objets located near observer; many centuries after, Velazquez (1599 1660) painted "Las Meninas" with very high accuracy, in renaissance, Jan Baptista de la Porta drew couples of scenes that produced depth sensation when observed those coupled to eyes [1]. At middle past century, couples of photographs were used to measure hills or rivers on land by using stereoscopes and fine mechanisms. Last decade, digital images arrived to aid human tasks, where metrological applications meet its own problems, mainly about accuracy. Not all problems into metrological applications of images, are related with accuracy, but with new applications like: a) interpretation of graphical information, b) fast calibration of cameras for continuous movement, c) edition of continuous 3D bodies, d) filtering of useful information, d) artificial analysis by processing, and so on.

1.2 Brief revision of principles

When an objet is captured in a photograph, each detail on image has its equivalent in the 3D real world; if distortion is absent, each point on the image is related with its equivalent in 3D system by an homogeneous 3x4 matrix.

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} & m_{14} \\ m_{21} & & & m_{24} \\ m_{31} & & m_{33} & 1 \end{bmatrix} \begin{bmatrix} x_w \\ y_w \\ z_w \\ 1 \end{bmatrix} \quad \text{or} \quad [SU]=[M][Xw] \tag{1}$$

[M] in named as calibration matrix of camera, and may be got by solving the system (1) with six non coplanar points of a master. After calibration, each new x_W, y_W, z_W point in real world (named as objet space), will have its equivalent in u,v system (image space).

For a couple of cameras located forming an angle in between, each one has different calibration matrix, and therefore different distribution of projected points. In an inverse sense however, it is not possible to obtain a x_W, y_W, z_W point from each *u,v* point, but an infinite family forming a 3D wire. If cameras keep its position in between, the 3D wires that depart from matched points, will cross in between, in an equivalent x_W, y_W, z_W point, in the "objet space".

Characteristic of differences on aspect are named as binocular parallax, and 3D reconstruction is named as stereo vision. See figures 1 a, and 1 b.

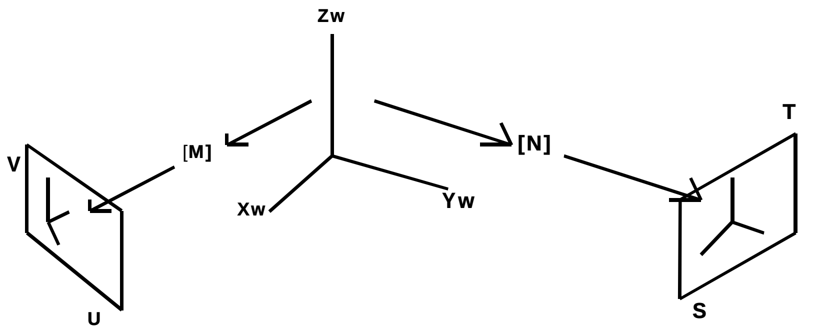

Figure 1a. Binocular parallax means that objet is captured different for each point of view, through [M] or [N] or ...

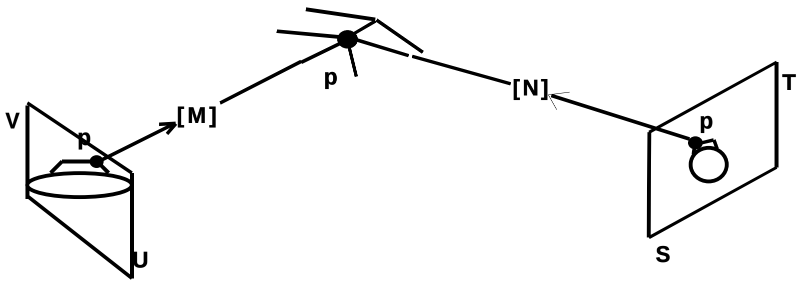

Figure 1b. In inverse sense, two lines are used to reconstruct a perfectly matched ***p*** point.

1.3 Matching tasks

In tasks of measure by stereo principles, it is necessary to match each couple of points: *p* in left image with *p* in right image, in order to define a *p* in 3D world system (x_W, y_W, z_W). Frequently, tasks of identification are made by seeding marks on objets, which have characteristics easy to identify by simple image processing. If marks represent reference positions, those have to be located with accuracy on the objets. On the other hand, natural characteristics of objets like its corners or edges, may be used to do higher processing. Memorization of images for master objets, may be used to discover faults in objets of production, if these are located equal to master. For both cases, the work of seeding of marks, or precise location of objets, is similar to measure in coordinate machines. The goal of this resource however, is the avoidance of additional work.

2 PROBLEMS IN AUTOMATIC MATCHING

2.1 Discontinuities and occlusion

Some techniques of matching images are used to edit mosaics, and they are based on mapping the previous image on the next, through planar projections [2]. That techniques maps a whole image on the next, but strictly, most points of second image will not coincide with the previous, because real objet is not planar. See figure 2 a.

Moreover, will be new regions in subsequent images, absent in the previous. For concave or convex bodies, and for wide rotations, will not be functions that maps images in between. See figure 2b .

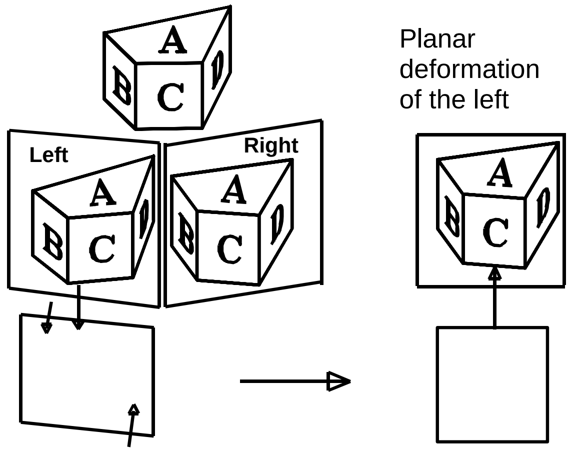

Figure 2 a. For small rotations, projections looks like planar transformations.

Moreover, will be new regions in subsequent images, absent in the previous. For concave or convex bodies, and for wide rotations, will not be functions that maps images in between. See figure 2b .

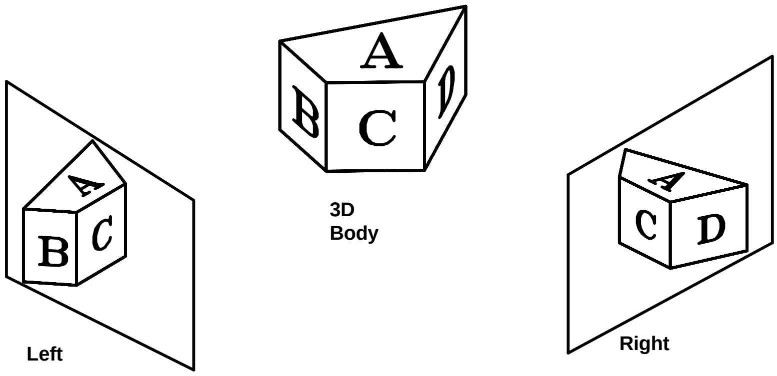

Figure 2 b. For large rotations, there is not functions that maps the left image into the right

2.2 Segmentation

By segmenting areas on images, will always be possible to map some regions of left image into the right, because small areas represent planar segments of objets , and planar faces will always produce planar projection; for instance, the face *"A"* in figures, appears in all images with planar transformations. After matching planar regions, such planar segment will have 3D accuracy as usual in stereo reconstruction techniques.

The problem is to establish a method to find all regions that have equivalent in the other. New again, human assistance is necessary to spend.

3 OVERCOMING DISCONTINUITIES AND OCCLUSION, GEOMETRIC PRINCIPLES

Our techniques are based on dividing the problem into three parts: the design space, the image space, and the matching of both. The first one owns the characteristics of objets like dimension, tolerances, texture, and may be added light sources. The second one owns the calibration matrix, the aspect of images, the filtering of noise, and all techniques necessary to convert real images as such obtained from solid modeling systems. The third one treats about techniques to match design with real preprocessed images. After process, we have located our designed objet into real world, represented by the image. When image and objet are matched, fine details as assembles or fault of pieces, are discovered easily

3.1 Monocular vision in the space design

In forming a solid, it is possible to convert the design of any objet into simple CAD primitives. For instance, 3DFaces (Autocad), produce arrays of three or four 3D points; and using techniques of projection and shading, it is possible to draw it with photographic appearance. Fortunately most of CAD tools produce **.DXF* files to interchange information. Occlusion may be solved by defining the order of corners and direction of its normal [3]. For arrays of two or more faces, forming non convex objets, the painter's algorithm [4], may be used to draw and render the faces, that really are viewed. Taking into account that a) images own planar and depth information as well, b) sudden discontinuities are solved as occlusion in monocular vision, and c) there is not problems of matching in one image, monocular vision principles are used as the main tool for analysis. See figure 3.

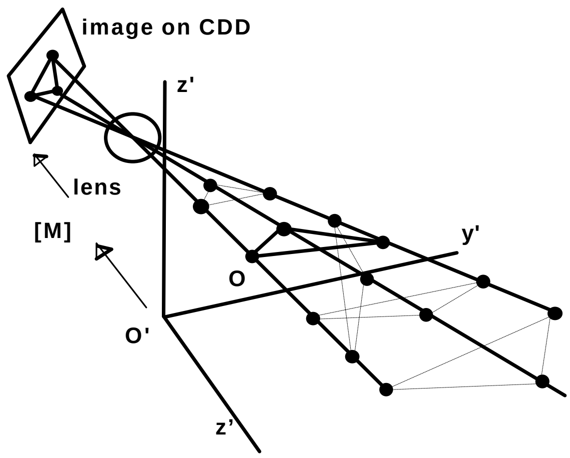

Figure 3. Although one image give us 2D information in monocular vision, depth information is got when lines that depart from CCD, form a triangle that coincide with design.

3.2 Considerations of image space

In this part we consider a) calibration matrix and if necessary, non linear correction, b) characteristics of brightness on each face of objets, that coincide with particular location of lamps. c) all necessary preprocessing, to produce "perfect" images, on dark scenarios.

Although the position of objet is unknown for a particular free location, position of lamps have to be related with the world system through *M*. Real faces of bodies will have particular brightness for particular position of camera. Perfect images on dark scenarios, may be produced by choosing colors of light, filters, positions of lamps, black walls, or by numerical filtering, and preprocessing.

3.3 Matching design space with image space

The third one part is based in the establishment of hypothesis about location and orientation of objets, and their evaluation. Although the establishment of hypothesis and their evaluation employs genetic algorithms (GA), other algorithms may be more efficient in closed loops. The basic information of location of objets, into *Xw* system, is defined by the matrix [*N*], so the basic chromosome is formed with n_{11}, to n_{33}; each n_{ij} is a gene. In this case each N_i is a member of population.

3.3.1 Criteria for forming generations

The first Parent generation may be formed with a thousand N'_S, got from randomize generators. The second group of generations is made by interchanging genes between chromosomes. After the fitness of populations reach a good prefixed value, an alternative process of cross and mutation is done, till reach convergence. See tables 1, 2 and 3.

Table 1. Criteria for forming the first generation of N's in genetic algorythm

1st Parent generation

$$N_{11} = (0.0015, -0.8666, -0.1532, \ldots, 0.9658)$$

$$N_{1j} = (n_{1,j}, n_{2,j}, \ldots, \ldots, \ldots, \ldots, \ldots, \ldots, n_{9,j})$$

$$N_{1,1000} = (-0.03237, 0.80266, -0.32, \ldots, 215.48)$$

$$-\sqrt{3} \le n_{1,j}, n_{2,j}, \ldots, n_{6,j}\ (randomize) \le \sqrt{3},$$

$$n_{7,j}, n_{8,j}, n_{9,j} = \pm \max imum\ cube\ on\ measures.$$

Table 2. The seconf generation is formed from the first, through randomize selection of genes

$$\begin{aligned}
&2nd\ generation\\
&N_{2,1} = (n_{1,1\geq j\leq 1000}, n_{2,1\geq j\leq 1000}, n_{3,1\geq j\leq 1000}, \ldots, n_{9,1\geq j\leq 1000})\\
&N_{2,j} = (n_{1,1\geq j\leq 1000}, n_{2,1\geq j\leq 1000}, n_{3,1\geq j\leq 1000}, \ldots, n_{9,1\geq j\leq 1000})\\
&N_{2,60} = (n_{1,1\geq j\leq 1000}, n_{2,1\geq j\leq 1000}, n_{3,1\geq j\leq 1000}, \ldots, n_{9,1\geq j\leq 1000})
\end{aligned}$$

After population is formed, next member is killed if its fitness is lower than mean value. Population win fitness by killing weak members in a recursive process.

Table 3. Genetic Algorithm, used to produce three generations, where the 3 rd ($N_{3,j}$) has probably the best solution.

Third generation

$$N_{3,j} = (n_{1,j} \pm \Delta n_1, n_{2,j} \pm \Delta n_2, n_{3,j} \pm \Delta n_3, \ldots, n_{9,j} \pm \Delta n_9)$$

Mutation in 3rd generation is formed from 2nd
Each new member is killed if its fitness is lower than mean value, and then born other again.

Into third generation, mutation and cross are made until n_i converge to values to be tested. If the process does not converge, a fast drawing of wire frame is showed on screen with the image, permitting to leave the process.

3.3.2 Fitness of members in populations of GA

The core of this GA is the principle in which the fitness is evaluated. The maximum fitness is reached when aspect of synthetic image coincide with real image. Aspect of each N_i objet is calculated by a set of parameters like gravity center, brightness center, contours, by mean of principles of monocular vision described before. Next two figures show likelihoold between samples of populations and their fitness based on vectors of brightness.

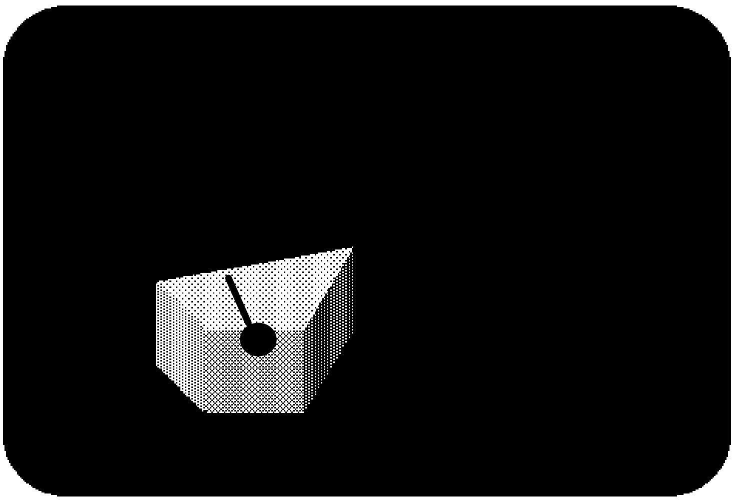

Figure 4. Synthetic body showing gravity center and brightness vector. Vectors are calculated from transformations, not from screen.

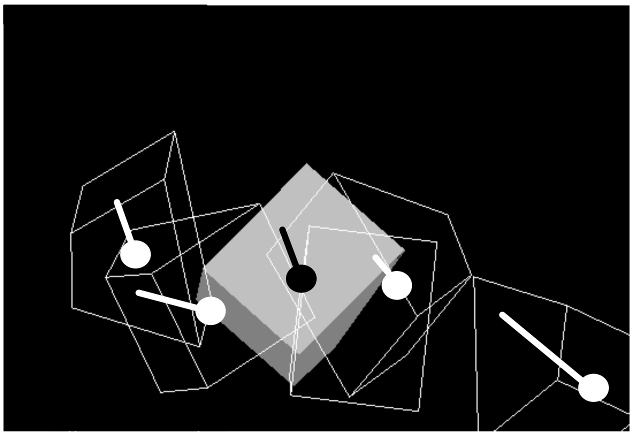

Figure 5. Vectors of synthetic bodies are compared with filtered image at early stages, to obtain fitness.

4 RESULTS

A trapezoidal polyhedron was constructed with polystyrene foam, (200, 150)x150x180 mm, and located into a black box of 800x800x800 mm., and a simple lamp 75 watts was located at -200,-100,300 mm from frame of calibration (origin near the left hand of observer). Using monocular principles, the process converge to good results in 85 % of cases, in two minutes. Relocating the body near previous position, and using the last generation as probable set of solutions, success level is 96% in about 20 seconds. It is considered that success is reached when differences of synthetic and filtered image are near to one pixel. Data Translation cards for digitalization, are been used to apply algorithms in parallel and in real time. We estimate that using monocular vision principles, but more cameras in parallel, results would permit fast holding of objets by robots, navigation, and quality control on line. After first success, perhaps feed backing process will converge faster than using genetic algorithms.

5 CONCLUSIONS

Efficiency of process depends: on the history of verifications written in the third generation, on the variability of their location, and also on the level of accuracy to reach. As in results is reported, success is not reached in short time for a first new location, but industrial practice does not demand randomize location, but small variations. Other applications like holding parts from shipping boxes, will not demand precision.

Principles mentioned as the essence of this paper, are considered by us as original solutions for old problems, and as an alternative for small industries or workshops, and as thesis for discusion in schools.

REFERENCES

[1] Three Dimensional Imaging Techniques, Tekenori Okoshi, Academic Press 1976.
[2] Richard Szeliski, Video mosaics for virtual environments, IEEE Computer Graphics and applications, V 16, N 2, March 96.
[3] Computer Graphics for CAD/CAM Systems, Jack E. Zecker, Indiana University, Marcel Dekker Inc. 1994.
[4] Rogers, D., Procedural Elements For Computer Graphics, McGraw-Hill , N.Y. 1985.

AUTHORS: J. SANCHEZ, B. VALERA and G. RUIZ, Laboratory of Images, Department of Metrology, Instruments Center, Universidad Nacional de México, AP 70-186, México D.F. México
Phone: ++ 525 6228603, Fax: ++ 525 6228620
E-mail: sanchezj@aleph.cinstrum.unam.mx , valerab@aleph.cinstrum.unam.mx