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MULTIOcular STEREOVISION

New Constraints for Correspondence by
Using Multiocular Geometry

Jorge Dias, Jorge Batista, Helder Araújo, A. Traça de Almeida

Instituto de Sistemas e Robótica - Departamento de Engenharia Electrotécnica
Universidade de Coimbra, Largo Marquês de Pombal,
3000 COIMBRA, Portugal
e-mail: jorge@mercurio.uc.pt

Abstract

This article describes a computer vision technique that explores the trajectory control of
stereo vision system for 3D reconstruction of geometrical primitives. The experimental work was
based on a vision system with a stereo pair of cameras. The system can be attached to the tool of a
manipulator or used in a mobile robot. Using this setup the position of the vision system can be
controlled and the images acquired at different positions of the scene. The article describes the
geometry of the system and the set of correspondence constraints established by using this multi-
oocular principle.

1. Introduction

The three-dimensional structure can be recovered from images by using stereo images. In human
vision is the difference between the projection of three-dimensional points in the left and right eyes that gives
the perception of the depth. This fact induces the use of artificial vision systems with a similar geometry. These
systems are defined as binocular stereovision systems. The solution to recover the depth and the three-
dimensional structure it is not immediate with stereo images. The solution passes by solving the correspondence
between points and regions of the two images. This problem is defined as the correspondence problem and
different approaches have been suggested to solve it [Marr 76,79], [Pollard 85], [Pollard 89], [Ayache 87]. In
the published literature the correspondence problem is solved by imposing different types of constraints in the
correspondence of points or primitives in the two images. In practice, we verify that the binocular constraints
are not sufficient to impose a unique solution for the correspondence problem.

This article reports a computer vision method to recover the three-dimensional structure by using a
stereovision system and active vision principles [Aloimonos 88] [Ballard 90]. The stereo vision system uses two
cameras with a pre-defined vergence but with the possibility of changing its position in 3D space. Since the
trajectory of the system is always known, we can define new correspondence constraints. These constraints are
based on the geometry of the system for two different positions. Since the trajectory is known, it is possible to simplify the correspondence problem by extending the epipolar geometry. The mobility of the system is also useful to establish other additional constraints for the solution of the correspondence problem. These constraints will be described in point 5.

There are three main stages in any stereovision algorithm (dynamic or not) -- detection and localization of the primitives in the image, the matching or correspondence between primitives in the two images, and three-dimensional structure computation. Once the correspondent primitives are identified, the depths of them can be calculated by triangulation. All these steps are presented in the points described below. The point 3 describes the type of pre-processing and primitives used on the experiences. The point 4 describes the geometry of the system. The point 5 describes the constrains used during the correspondence process. Some experimental results are presented in point 6 and include a the comparison between a binocular method and a the multicocular method.

2. Image Formation Model

To analyze the stereovision process we need a model that relates the object in the 3D space and its projection in the 2D image. It is essential that the model gives a geometric relationship between the three-dimensional object and its correspondent image in the 2D image plane. The model used in this work is the pinhole model described in the figure 2.1. The model assumes that a coordinate system is defined with origin in the pinhole, the xy-plane is parallel to the image plane and the z-axis lies along the optical axis of the lens. The projection of a point in space follows the perspective projection with origin centered in C and equivalent to the lens center. The image plane is situated at a distance f (the focal length) from C and the image of three-dimensional point P in the scene is the intersection p of the line-of-sight ray with the image plane.

The pinhole model is then defined by its extrinsic parameters and intrinsic parameters. The extrinsic parameters give the position and orientation of the referential (CAM) with respected to (W). The intrinsic parameters are defined by the focal length f and the coordinates c = (u0, v0). The coordinates c = (u0, v0) are the intersection of the optical axis of the lens with the image plane. The relation of the two coordinate systems (CAM) and (W) can be described by using a rotation matrix R and a translation T. If P = (X, Y, Z) is a point represented in the coordinate system (W) then its representation in the coordinates (CAM) will be given by

\[
\begin{bmatrix}
x \\
y \\
z
\end{bmatrix} = R \begin{bmatrix}
x \\
y \\
z
\end{bmatrix} + T
\]

(2.1)

The coordinates for the image of the point are given by
\[ u' = \frac{f}{z} X \quad v' = \frac{f}{z} Y \]

\[ u = s_x u' + u_0 \quad v = s_y v' + v_0 \]

with \( s_x \) and \( s_y \) the scale factors. The two equations (2.1) and (2.2) give the relation between the 3D coordinates of a point and its 2D image coordinates. That relation can be written with the linear expression

\[
\begin{bmatrix}
U \\
V \\
S
\end{bmatrix} = \text{CALIB} \begin{bmatrix}
X \\
Y \\
Z \\
1
\end{bmatrix} \quad \text{with} \quad \begin{cases}
u = \frac{U}{S} \\
v = \frac{V}{S}
\end{cases}
\]

Figure 2.1 - The pinhole camera model and the perspective projection

3. Preprocessing and Primitives

Points and lines are primitives that can be easily found in the images. These primitives are extensively used in this work. The straight lines are obtained by fitting lines with contour defined by the edges of the objects. The contours are obtained from images and by previously filtering the images. The filter used is a recursive optimal edge detector proposed by [Derich 88]. The filtering operation describes the gradient magnitude and direction for each pixel of the image. Edge points are detected by threshold and by using hysteresis for non maximal suppression. A pixel is marked as an edge, if the gradient magnitude at the pixel is larger than the gradient of its neighbors. Marked edge points are then linked into contours and traced until find out an abrupt change in the local edge orientation. The line segments corresponding to these contours are then calculated by using least-squares.

The line segments acquired are after represented by the parametric representation

\[ x \cos \phi + y \sin \phi = \rho \]

with \( \rho \geq 0 \) and \( \phi \in [0..2\pi] \) and illustrated below.
4. System Geometry

4.1 Basic Stereo Geometry

We assume that the stereo images are acquired by two pinhole cameras, and the system uses a geometric relation as shown in the figure 4.1. The two cameras are represented by two coordinate frames with origins in $C_1$ and $C_2$ respectively. A point $P$ in the 3D space has projections $p'$ and $p''$ in the two stereo images. Observing the figure 2.2 we note that the line $C_1C_2$ intersects the image planes $I'$ and $I''$ at two points $E_1$ and $E_2$. These two points can be at finite or infinite distances from the referentials and are called epipoles. Notice that $E_1$ (or $E_2$) can be considered as the "image" of $C_2$ (or $C_1$) in the image $I'$. The line-of-sight ray $C_iP$ has a projection in the image $I''$ which is also a line that passes by the epipole $E_2$. That line is defined as epipolar line.

Figure 4.1 - Configuration of the stereo system. The cameras have two orthogonal referentials in the centers of de perspective -- $C_1$ and $C_2$.

The epipolar lines pass by the two epipolar points and contain the correspondent points.

*Epipolar lines and epipolar points*

As shown in the configuration illustrated in figure 3.1, a point $P$ in the scene will project on the points $p'$ and $p''$ in the left and right images. Taken the point $p'$ in the image $I'$ the correspondent point on the image...
\( I' \) belongs to a straight line in image \( I' \), and designed epipolar line associated to \( p' \). Note that the point \( p' \) is the projection of all three-dimensional points \( P \) belongs to the straight line \( C_i \bar{P} \). The image of this straight line in the image \( I'' \), is the epipolar line associated with the projection \( p' \). The problem is perfectly symmetrical for the projection \( p'' \). To compute analytically the epipolar line equation, it is necessary to compute first the optical center of the cameras. The optical centers \( C_1 \) and \( C_2 \) are obtained by solving the two system

\[
\text{CALIB}_1 C_1 = 0 \quad \text{and} \quad \text{CALIB}_2 C_2 = 0
\]  

(4.1)

where \( \text{CALIB}_1 \) and \( \text{CALIB}_2 \) are the calibration matrices.

Given the coordinates of each center \( C_i = (x_i, y_i, z_i) \), with \( i = 1, 2 \), it is possible to compute the projection of \( C_1 \) in the image \( I' \) and \( C_2 \) in the image \( I \). These two projections are designed epipolar points \( E_2 \) (in the image \( I' \)) and \( E_1 \) (in the image \( I \)) and are given by

\[
\text{CALIB}_1 C_2 = E_1 \quad \text{and} \quad \text{CALIB}_2 C_1 = E_2
\]

(4.2).

The calibration matrices \( \text{CALIB}_i \) establish the relation between the very three-dimensional coordinates of a point and the two-dimensional coordinates at the projection in image. This relation is given by

\[
\begin{bmatrix}
U \\
V \\
S
\end{bmatrix} =
\begin{bmatrix}
c_{i1} & c_{i2} & c_{i3} & c_{i4} \\
c_{i2} & c_{i3} & c_{i4} & c_{i5} \\
c_{i3} & c_{i4} & c_{i5} & c_{i6}
\end{bmatrix}
\begin{bmatrix}
x \\
y \\
z \\
1
\end{bmatrix} =
\begin{bmatrix}
c_{i1}P + c_{i4} \\
c_{i2}P + c_{i5} \\
c_{i3}P + c_{i6}
\end{bmatrix}
\]

(4.3)

with \( e_i \) the vector (3x1) obtained from the first 3 elements of the row \( i \) of \( \text{CALIB} \). The coordinates of the projection \( p' \) are given by

\[
U = \frac{U}{S} \quad \text{and} \quad V = \frac{V}{S}
\]

(4.4)

Using the relations (4.4) it is possible to rewrite the relations (4.3) as a system

\[
\begin{align*}
(c_1 - u c_2)^T P + c_{14} - u c_{34} &= 0 \\
(c_2 - v c_3)^T P + c_{25} - v c_{35} &= 0
\end{align*}
\]

(4.5)

The system (4.5) represents the equations of two planes whose intersection defines the straight line that projects the point \( P \) in the image \( I \). A vector collinear to this projection line \( C_i \bar{P} \) is given by the cross-product between the normal of each plane

\[
n = (c_1 - uc_2) \Lambda (c_2 - vc_3)
\]

(4.6)
The line $\overline{C_1P}$ is therefore given by

$$P = c_i + \lambda n$$  \hspace{1cm} (4.7)

with $\lambda$ a real number. If the projection line $C_1P$ is given by $P = C_1 + \lambda n$ the epipolar line of $P'$ is given by

$$\begin{bmatrix} U_2 \\ V_2 \\ S_2 \end{bmatrix} = \text{CALIB}_2 \begin{bmatrix} C_1 + \lambda n \\ 1 \end{bmatrix} = E_2 + \lambda n = \begin{bmatrix} e_u \\ e_v \\ e_s \end{bmatrix} + \begin{bmatrix} F_u \\ F_v \\ F_s \end{bmatrix}$$

\hspace{1cm} (4.8)

Rewriting this equations the parametric equations are given by

$$\begin{align*}
U_2 &= \frac{E_x + \lambda F_x}{E_x + \lambda F_x} \\
V_2 &= \frac{E_y + \lambda F_y}{E_y + \lambda F_y}
\end{align*}$$

\hspace{1cm} (4.9)

This equation establishes the main geometrical constraint of a binocular stereo system and defined as epipolar restriction.

4.3 Three-dimensional reconstruction

For points

The computation of the three-dimensional coordinates of a point $P$ in the scene can be done by using the equation (4.3) for the left and right images (at time $(t)$ or $(t+\Delta t)$). These equations can be written as a system with 4 equations with 3 unknowns. The system is

$$\begin{align*}
(e_i - \mu e_3)'P^+e_{14}-\mu e_{34} &= 0 \\
(e_i - \nu e_3)'P^+e_{24}-\nu e_{34} &= 0 \\
(e_i - \mu e_3)'P^+e_{14}+\mu e_{34} &= 0 \\
(e_i - \nu e_3)'P^+e_{24}+\nu e_{34} &= 0
\end{align*}$$

\hspace{1cm} (4.10)

where ($) represents the left image and ($) represents the right image. Re-writing this system on matrix form

$$AP = b$$

\hspace{1cm} (4.11)

with $P = (x,y,z)$ and

$$A = \begin{bmatrix} ... & (e_i - \mu e_3)' \\ ... & (e_i - \nu e_3)' \\ ... \end{bmatrix} \quad \quad b = \begin{bmatrix} ... \\ \mu e_{34} - \mu e_{14} \\ \nu e_{34} - \nu e_{24} \\ ... \end{bmatrix}$$

\hspace{1cm} (4.12)
where \( i \) represents one of the images (' or '') at time \( t \) or \( (t+\Delta t) \). The equation (4.12) can be solved by least-squares by using the equation

\[
P = (A^T A)^{-1} A^T b = A^+ b
\]

if \((A^T A)\) has inverse. The matrix \( A^+ \) is known as the "pseudo-inverse matrix".

**For lines**

In a multiocular system, the reconstruction of a 3D line from 2D projections is similar to the reconstruction using more than two images. The figure 3.5 shows the case of 3D reconstruction of a line from several images.

![Figure 4.2 - Reconstruction of a line using three images (real case)](image)

As shown in figure 4.2, the reconstruction of the lines by using multiple projections gives multiple possibilities for the solution. We need an optimized method to reconstruct the 3D line but minimizing the error. To establish an optimized form, we assume that the 3D line is not perpendicular to \( Z \) axis. Representing this line by the following parametric equations

\[
\begin{align*}
x &= az + p \\
y &= bz + p
\end{align*}
\]

where the parameters \((a,b,p,q)\) are unknowns. Using (4.13), (4.3) and (4.4) we obtain the expressions for the coordinates \((u,v)\) in the image

\[
\begin{align*}
u &= \frac{(z_1a_1 + b_1z_1)z_2a_2 + b_2z_2z_3a_3 + b_3z_3}{(z_1a_1 + b_1z_1)z_2a_2 + b_2z_2z_3a_3 + b_3z_3} \\
v &= \frac{(z_1a_1 + b_1z_1)z_2b_2 + b_2z_2z_3b_3 + b_3z_3}{(z_1a_1 + b_1z_1)z_2b_2 + b_2z_2z_3b_3 + b_3z_3}
\end{align*}
\]

(4.14)
where \( i \) represents the left and right images (at time \((t)\) or \((t+\Delta)\)). Expressing the 2D line with the equation

\[
\hat{m} u + \hat{l} v = 0
\]

(4.15)

and using the expression (4.14) we can write the system

\[
\begin{align*}
\hat{m}(a t_{11} + b t_{12} + t_{13}) - \hat{l}(a t_{21} + b t_{22} + t_{23}) & = 0 \\
\hat{m}(p t_{11} + q t_{12} + t_{14}) - \hat{l}(p t_{21} + q t_{22} + t_{24}) & = 0
\end{align*}
\]

(4.16)

for the left and right image (at time \((t)\) or \((t+\Delta)\)). Re-writing the system (4.16) we obtain the linear form

\[
\begin{align*}
\hat{m}(\hat{m}_i t_{11} - t_{21}) - \hat{l}(\hat{m}_i t_{12} - t_{22}) & = 0 \\
p(\hat{m}_i t_{11} - t_{21}) - q(\hat{m}_i t_{12} - t_{22}) & = 0
\end{align*}
\]

(4.17)

or using the matrix representation equation

\[
n_i = M_i m
\]

(4.18)

where \( i \) represents the left and right image (at time \((t)\) or \((t+\Delta)\)). The vector \( m^T = [a \ b \ p \ q] \) is the vector of unknowns. Similar to the equation (4.12) the expression can be solved by using least-squares by using the pseudo-inverse method.

5. Constraints for Correspondence

5.1 Conventional Constraints

The fundamental constraint of a stereo vision system is the epipolar constraint discussed above. On this work the epipolar constraint is extended to the multiocular stereo vision. However, there are other constraints that can be explored in stereovision. Some of them are the following:

The epipolar constraint

For the class of stereo imaging geometry that we are concerned i.e., those in which the optical axes of the two imaging devices lie in the same devices lie in the same plane, all matching primitives appear on left/right pairs of (straight) epipolar lines. The points along one member of the epipolar pair can only match
with points situated along the other member, and vice versa. In the special case where the principal axes are parallel, all epipolar pairs will be horizontal and matching points will be found on corresponding raster lines.

**Local constraints**

These constraints are determined between attributes of two homologous straight lines. They are called local because they do not involve any other segments.

**Interval of variation of the angle**

We consider a pair of homologous straight lines, and look for an interval of possible variation of the angle between them. The limits on the interval of variation of the angle $\phi$ are useful, for rapidly rejecting impossible matches. The interval of the angle may be computed for each segment before the matching process. However, they do not supply any information on the nature of the probability distribution of the orientation. Arnold and Binford have shown that, for camera stereo geometry, a uniform distribution of the orientation of the 3D segments in the scene implies a distribution of the difference in angle $\theta$ between homologous image segments which is very narrow and centered around zero [Arnold 80].

**Length**

Given a segment in an image, that is possible to compute an interval $[l_{\text{min}}, l_{\text{max}}]$ of allowable length for its homologue in the other image. We determine $l_{\text{min}}$ ($l_{\text{max}}$) as the minimum distance (maximum) between the points belonging respectively to segments $A_iA_j$ and $B_iB_j$.

**Uniqueness**

The uniqueness constraint assumes that an image point $p'$ of image $I'$ has one homologue in image $I''$ (asymmetric hypothesis applies for an image point $p''$ of the image $I'$). This constraint assumes that there exists no pair of 3D points aligned with the optical center of one of the cameras. In the figure 4.1, the points $P_1$ and $P_2$ have the same image $p_1$ and two distinct images $p_1'$ and $p_2''$ for camera $I'$. 
Similar restriction can be obtained for lines.

**Order constraint**

This constraint assumes the preservation of the order of homologous points along the two epipolar lines. This constraint is violated as soon as there exist, in the same epipolar plane, points of the scene visible from both cameras and which can be joined by a line passing through both optical centers.

**Continuity constraint**

The basic idea of this constraint is that the world is mostly made of objects with smooth surfaces. This means that the reconstruction function that assigns to a pair of matched points a 3D point $P$ is smooth almost everywhere. If we assume that object surfaces are sufficiently regular, and that the geometric primitives are sufficiently dense, then objects will be represented by subsets of neighboring primitives in space which can be traversed continuously. It is possible to define a continuity constraint based in the disparity between the coordinates of the image points, for the left and right images.

Given a point $p'$ of coordinates $(u',v')$ in image $I'$, and its corresponding point $p''$ of coordinates $(u'',v'')$ in image $I''$, disparity is defined as
\[
\delta = (u' - v')
\] (5.1)

This definition implicitly assumes the camera geometry of figure 3.4, where the two retina planes are the same. A disparity of 0 implies that the 3D point \( P \) is at infinity. If we bring the \( P \) to near the cameras and along the line \( C_1 P \), the value of the disparity will increase (absolute value). It is admissible to establish an interval \([\delta_{\text{min}}, \delta_{\text{max}}]\) for the disparity value. This is equivalent to define an interval for the possible distances of the objects in the scene. In practice, disparity values are limited:

- because the points are situated in front of the image planes;
- by the image dimensions;
- by the dimensions of the scene when finite.

This continuity can be measured using a disparity gradient [Pollard 89]. The disparity gradient proposed by Pollard is a simple measure of continuity and establishes a strong constraint of continuity.

5.1 Multiocular Stereo

**Multiocular Epipolar Constraint**

This constraint is an extension of the epipolar constraint for the binocular stereo vision. The stereo images are images acquires at time \((t)\) and \((t+\Delta t)\). Starting from a primitive from the left image at time \((t+\Delta t)\), \( r' \), we establish the epipolar constraint for the right image at time \((t+\Delta t)\), \( E_{p}' \), and right image at time \((t)\), \( E_{p} \).

For each primitive, \( r'' \), intersected by the epipolar \( E_{p}' \), right image at time \((t+\Delta t)\) we establish another epipolar constraint on the left image at time \((t)\), \( E_{p} \). The two epipolar lines, \( E_{p}' \) and \( E_{p} \), in image left at time \((t)\) must intersect at one primitive if the lines \( r' \) and \( r'' \) are correspondent -- see figure 5.3. If this constraint fails, the hypothesis of matching \( r' \) with \( r'' \) also fails. If the constraint does not fail, the hypothesis is a possible match, and another element is inserted to the list of hypothesis. Similar processing is executed with lines from the right image. At the end will be two lists of hypothesis - from left and right images.

![Figure 5.3 - Multiocular process.](image-url)
The multiocular process uses images acquired at different times \((t)\) and \((t+\Delta t)\) and the trajectory between these two points is perfectly know.

![Diagram of epipolar lines generation on the multiocular process. The line \(r'\) generates the epipolar \(E'_{xp}\) for the right image on time \((t+\Delta t)\) and epipolar \(E'_{p}\) on the left image on time \((t)\). The correspondent line \(r''\) of \(r'\), generates the epipolar \(E''_{p}\) on time \((t)\). The two lines \((E'_{p} and E''_{p})\) must intercept, theoretically, on the primitive \(r'\).]

Consider the midpoint of a line detected in the image \(I'\) at time \((t+\Delta t)\). Based in this point, it is possible to define two epipolar lines in the other images -- see figure 5.4. On in the image \(I''\) at time \((t+\Delta t)\) and another in the image \(I'\) at time \((t)\). Similar principle can be used if we start with a line in the image \(I''\) obtained at time \((t+\Delta t)\). The epipolar line of a primitive \(r'\) in the image \(I''\) intersects different primitives (points of the straight lines) inclusively the homologue primitives \(r''\). For any primitive intercepted in image \(I''\) it is possible to establish a correspondent epipolar line on the image \(I'\) at time \((t)\). The interception of the two epipolar lines on the image \(I'\) must contain the homologous primitive (in practice the must search in a circle around this point). Using a similar process but starting from a primitive on the image \(I''\), we establish a method to obtain homologue primitives in stereo images.

**Cross of hypothesis**

The multiocular process generates two lists of possible matches if we starting from the left or from the right image. Normally these two lists are not equal and they exhibit different hypothesis of matching. If it is expected to match hypothesis that appears in the two lists the two lists must be processed. To obtain these hypotheses the two lists are crossed together and the hypotheses that appear in the two sides are retained.

**Correlation**

The multiocular constraint does not guarantee only one hypothesis of matching for each primitive. To find the correct hypothesis we need another constraint to choose the correct match between different hypothesis. The correlation of light intensity between the left and right windows is a similarity function used to establish correspondence between areas in the left and right images. This also is a powerful technique to find the correct
correspondence between the different hypothesis of matching for one primitive. If this measure is evaluated for the different hypothesis of match we choose the match with the higher similarity. Since we are using a similarity function based in a light intensity difference the best hypothesis will be the one with the lowest value of the difference. To obtain better results the dimensions of correlation window are adapted to the image situation. The window dimensions are variable and they depend of a measure of variance of the light intensity.

6. Results

Several experiences were made by using two types of algorithms - a stereo vision basic algorithm and a stereo vision multiocular algorithm. The algorithms are applied in the two experimental sites: one six degrees of freedom manipulator and a mobile robot. The figure 6.1 exhibits some results with the mobile robot.
(b) Matched Segments

(c) Different 3D maps generated by the multiocular algorithm for the images above.

Each square represents 1x1 meter in the scene

Figure 8 - (a) Example of images acquired by the vision system in the mobile platform. (b) Matched segments. (c) 3D map generated by the multiocular algorithm.

The results obtained by multiocular algorithm exhibit better results when compared with the binocular stereo algorithm. The total of correct matches produced by this algorithm is greater than for binocular stereovision. The experiences were made by using the following constraints for the stereovision basic algorithm: binocular
epipolar constraint; local constraints; uniqueness constraint; gradient disparity constraint. The multocular stereo algorithm exhibits good results with only the following constraints: multocular epipolar constraint; correlation constraint and local constraint.

The table below shows the success/error ratios for the images above and using the two algorithms.

<table>
<thead>
<tr>
<th></th>
<th>Binocular Stereo (image 1)</th>
<th>Multiocular Stereo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative Success</td>
<td>32%</td>
<td>87.5%</td>
</tr>
<tr>
<td>n° correct final matches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n° of correct hypothesis generated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fail ratio</td>
<td>15,1%</td>
<td>7,14%</td>
</tr>
<tr>
<td>n° incorrect final matches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n° of possible matches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Success</td>
<td>3,74%</td>
<td>13,46%</td>
</tr>
<tr>
<td>n° correct final matches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n° total hypothesis generated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real Error</td>
<td>3,74%</td>
<td>7,69%</td>
</tr>
<tr>
<td>n° incorrect final matches</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n° total hypothesis generated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Conclusions

This article presented a multocular stereovision process. The vision system uses stereo images acquired at different positions. The geometric relations between the different positions are always known. Using this capacity, it is possible to establish a new geometric constraint for the stereo correspondence. The experimental results demonstrate that this method is powerful that the classical binocular stereovision and generates better matching results.

8. References


