ON A NEW USE OF AUTOMATIC MORPHING TECHNIQUES: TO CORRECT DISTORTION OF ENDOSCOPIC SYSTEMS

Tiago Bonini Borchartt
Marcos Cordeiro d'Ornellas
tiagobonini@gmail.com
ornellas@inf.ufsm.br
Federal University of Santa Maria, Av. Roraima, n° 1000, 97105-900, Santa Maria-RS, Brazil

Aura Conci
aconci@ic.uff.br
Fluminense Federal University, R. Passo da Pátria, n° 156, 24210-240, Niterói-RJ, Brazil

Alicia Del Carmen Becerra Romero
Paulo Henrique Pires de Aguiar
alicia21221@hotmail.com
phpaneurocir@gmail.com
University of São Paulo, Av. Dr Arnaldo, n° 455, 01246-000, São Paulo-SP, Brazil

Abstract. *Morphing is a well know Computer Graphic (CG) tool useful in movies and animations that changes (or morphs) one image into another through a smooth transitions. In this work we present an automatic morphing system, based on triangular mesh, to correct distortions in endoscopic medical images. A chess pattern is used to verify the distortion of the endoscopic system and to create the mesh to generate the equations for apply the affine transformations on the morphing step. After having computed the equations for all parts of the mesh, the same transformations are used to correct real endoscopic images.*

Keywords: *Morphing, Endoscopic Images, Affine Transformations, Texture Mapping*

1. INTRODUCTION

Endoscopy is a method of investigating diseases in the gastrointestinal tract, respiratory system, ear and in the female reproductive system, among others. The examination is done using an endoscope, that is made of a flexible tube with a camera and a light source attached in the end. The endoscope turns possible to assess the interior surfaces of an organ, as well as collecting material or even to perform minor surgery.

Images obtained through endoscopes have some distortion due to lens system used. This distortion affects the diagnostician when they have to determine the exact dimension of a lesion or tumor. This work proposes a method to correct these distortions by applying techniques of morphing and warping in the images captured by an endoscope.

This paper is organized as follows: next section makes a literature review of related works, section III presents the developed application, section IV shows some results, the comparisons of results are done in section V and section VI closes the paper with the conclusion and future work.

2. RELATED WORKS

The literature presents some approaches to correcting distortions in images. Kannala and Brandt (2006) propose a generic camera model, which is suitable for fish-eye lens as well as for conventional and wide-angle lens and a calibration method for estimating the parameters of the model.

In Stehle et al. (2007) a geometric correction based on the model by Kannala and Brandt (2006) and subsequent 3D reconstruction for endoscopy images is used.

Helferty et al. (2001) presents a videoendoscopic distortion-correction technique that can automatically calculate correction parameters. This technique is based on a least-squares estimation and use a dot-pattern image for calibration of the system.

The technique propose by Hartley and Kang (2007) relies on the use of a planar calibration grid which is captured in several images. Such method also computes the center of radial distortion.

This paper presents an automatic method to correct distortion of endoscopy images, where the parameters are automatically calculated. To correct the acquired images a chess-pattern grid is used and adapted to the border shape of the endoscopy system. The great differential this method is the use of affine transformations to correct distortion in the acquisition system, this represent a very fast and simple technique compared to others similar methodology Helferty et al. (2001) Hartley and Kang (2007).

3. AUTOMATIC MORPHING TECHNIQUES

Morphing Techniques are used until now to produce special effects in animations, games and movies. Morphing is often used to depict one person turning into another or as part of a fantasy or surreal sequence. Warping is an application of the Morphing techniques presenting a topological filter responsible for modifying the shape of objects in the image, and an amplitude filter responsible for transform the color information of each pixel.

The Automatic Warping technique uses a triangular grid and affine transformations to modify an original triangle in another triangle in a target position. When all triangular of the grid are modified a new different image arrive with used intervention as the other CG Warping techniques (Conci et al. (2008)).

This work presents how this automatically warping technique can be used to correct distortion in endoscopic image. We propose the uses of a chess-pattern to serve as base for warping mesh. This pattern when acquired by the system to be correct will present distortion, the same distortion caused when any endoscopic examination is performed. But now, as we know what is the correct pattern, we can correct this pattern and use the same process, (i.e. grid and equation system) to correct any other image acquired by this. Moreover, the same processes can be use in the all movie related with an patient on examination by the endoscopic system.

3.1 Chess-pattern

Initially a chess-pattern limited for a circle image was created, as can been see in Fig. 1, to be acquired by the endoscope system. This image is used to create a grid and to verify how the lens modify the image to be acquired. The chess-pattern acquired by endoscope can been see in Fig. 2.

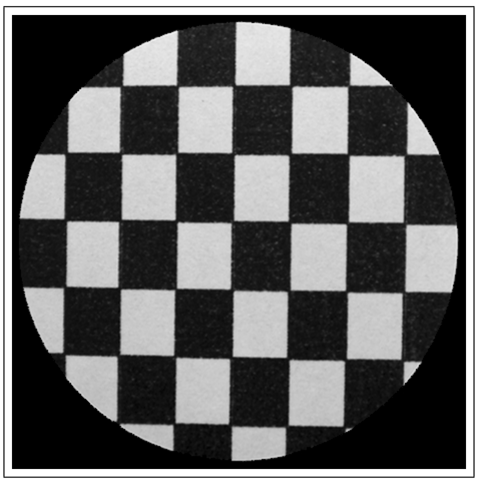

Figure 1: Chess-pattern used to calibration

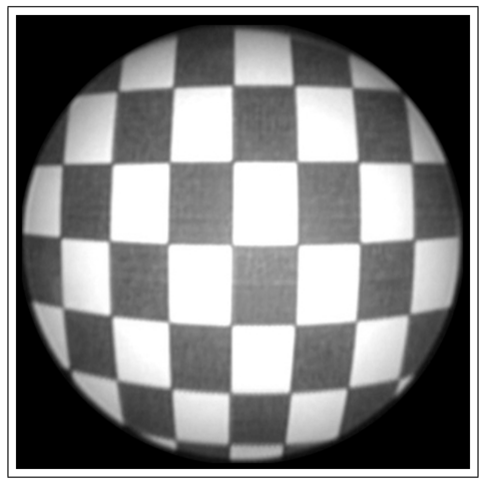

Figure 2: Chess-pattern acquired by endoscope

This design (Fig. 1) is suitable to generate a triangular mesh, because of its chess form, and it is good to identify the radial distortion due to its circular borders. Distortions caused by the endoscopic system can be observed in Fig. 3. This figure represent the image of Fig. 2 subtracted of the image of Fig. 1, after transform both (acquired chess-pattern image and original chess-pattern) to black and white images (pre-processed by applying a threshold) and rescale the result to [0, 255].

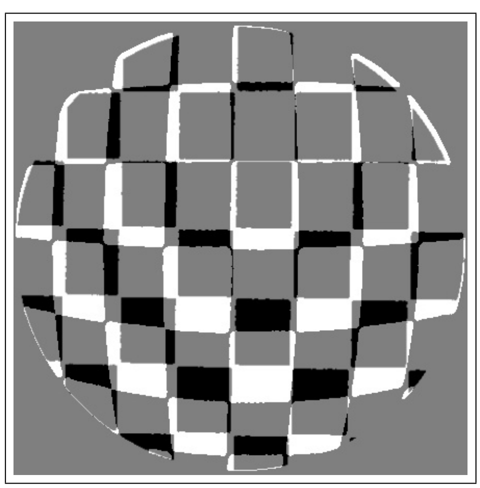

Figure 3: Fig. 2 minus Fig. 1 pre-processed

Figure 3 shows in gray color the locations where pixels presents no distortion. That is, the position where the chess-pattern match in two images. The black and white pixels are positions where there is no correspondence.

3.2 Triangular Mesh

After the chess-pattern capture with the endoscope, next step of the correction system is to generate the triangular mesh in both images (original and acquired). The easy way to generate a triangular mesh is to use the vertices of the squares of chess pattern as vertices of the triangles in the grid. The used grids can be seen in Fig. 4 and Fig. 5.

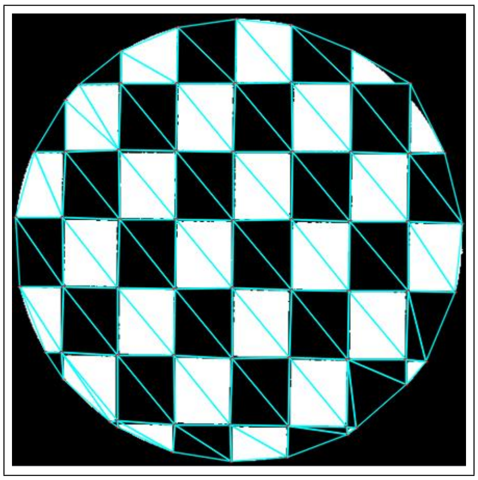

Figure 4: Mesh generated in Chess-pattern

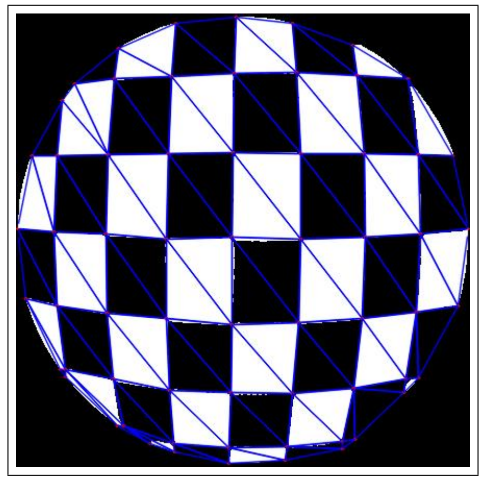

Figure 5: Mesh generated in endoscope image

The next step is to transform the contents of a triangle of the image acquired by endoscope to the corresponding triangle in the chess-pattern mesh. The meshes in the two images show triangles with disproportionate areas, the system can not simply copy the contents of a triangle of origin to a destination; it would cause a discontinuity in the image, because some pixels do not have color information and others would present multiple values.
If a triangle has its area expanded, we face the problem of providing values for pixels that presents not corresponded in the destination. However, if a triangle has its area reduced, the problem is the possibility of multiple pixels being aggregated in the same region. Then, we must use some method to choose the final value of the color pixel. In this work these problems were solved by resample the acquired image. We increase four times the image size with a bilinear filter, before applying the transform. The new color values of each pixel are defined as an arithmetic mean between the all 4 possible values.

3.3 Affine Transformations

The main step is to compute the equations that morph each triangle of the grid on the source image to the correspondent triangle on the target image. The system calculates the affine transformations that changes the position of the vertices of a triangle in the vertices of another triangle using the equation(Conci et al. (2008)):

$$w_i = M.v_i + t$$

This can be re written in two dimensions as:

$$\begin{bmatrix} w_x \\ w_y \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} \\ m_{21} & m_{22} \end{bmatrix} . \begin{bmatrix} v_x \\ v_y \end{bmatrix} + \begin{bmatrix} t_x \\ t_y \end{bmatrix}$$

Where w_i represents the pixels of the pattern image, v_i represent the distorted chess, m_{ij} is responsible for transformation of position of pixels in the original image and t_i represents the translation of the pixels. The values of m_{ij} and t_i are unique and different for each of the triangles of the grid.
Developing the matrix operations for each triangular vertex, we arrive to the following equations:

$$\begin{aligned}
w_{1x} &= m_{11}.v_{1x} + m_{12}.v_{1y} + t_x \\
w_{1y} &= m_{21}.v_{1x} + m_{22}.v_{1y} + t_y \\
w_{2x} &= m_{11}.v_{2x} + m_{12}.v_{2y} + t_x \\
w_{2y} &= m_{21}.v_{2x} + m_{22}.v_{2y} + t_y \\
w_{3x} &= m_{11}.v_{3x} + m_{12}.v_{3y} + t_x \\
w_{3y} &= m_{21}.v_{3x} + m_{22}.v_{3y} + t_y
\end{aligned}$$

The implemented system calculates the values of w_i and v_i in the meshes, and compute M and t solving a linear system with the six equations generated previously, using the method of Gauss.
Having calculated the values of M and t from each triangle pair source/target, the system applies the transformation to all pixels belonging to the respective triangle in the distorted image. This process is repeated for all triangles of the mesh.
As the limit of the area of interest in the image is circular and the sides of the triangles are straight, at the end of the process, an algorithm to maintain the circularity was performed. This removes some pixels in the circular edge.
After computed all equations needed, the morphing of the image chess-pattern captured by endoscope is applied and if it is a successful outcome, the same equations can be used to correct images of real endoscopy.

3.4 Texture Mapping

Another method developed for the application of the morphing techniques was through texture mapping using OpenGL. In this method, the distorted image (Fig. 2) is imported as a texture. The coordinates of the triangular mesh of Fig. 4 is used by system to draw triangles in which the texture is defined by mapping the distorted image using the mesh of Fig. 5 as texture coordinates. Associating each vertex of the mesh generated in the chess-pattern with respective vertex in the image captured by endoscope.
The same coordinates generated through the mesh of the image chess-pattern acquired by endoscope are used to apply the morphing in the real endoscopy screening.
In this work, a trilinear filter is used to render the texture. More about texture mapping can be viewed at Möller and Haines (2002).

4. RESULTS

After the use of the affine transformations determined by the equations calculated in section 3 in Fig. 2, we obtain the result that can be seen in Fig. 6. Figure 7 can be seen the result of subtracting the resulting image (Fig. 6) of the chess-pattern after the same pre-processing described to obtain Fig. 3. The efficiency of the method can be evaluated when observed that the percentage of white and black pixels is reduced from 24.7% in Fig. 3 to 5.4% in Fig. 7. This means an increased of correct pixels being matched between the two images after apply the morphing techniques.
Figure 8 shows a real examination endoscopy image as it is acquired by endoscope. Figure 9 show this image after processed by the automatic correction method here presented using mor-

phing techniques.
More results can be seen in Borchartt (2009). In the same place the executable software can be try.

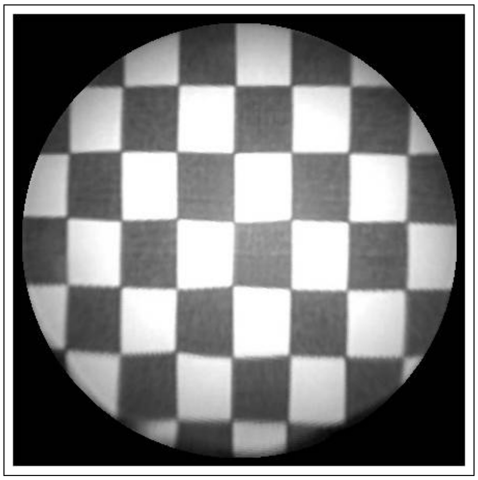

Figure 6: Result of applyng the method in Fig. 2

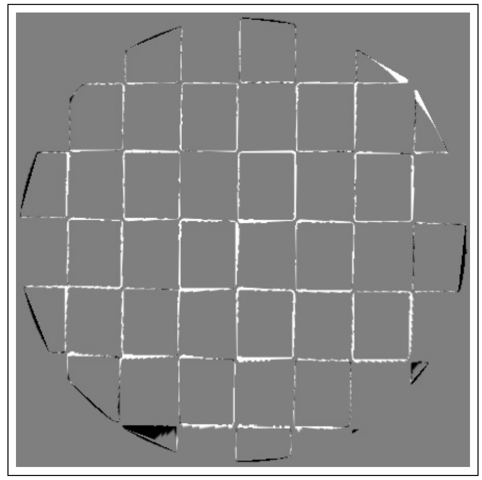

Figure 7: Fig. 6 minus Fig. 1 pre-processed

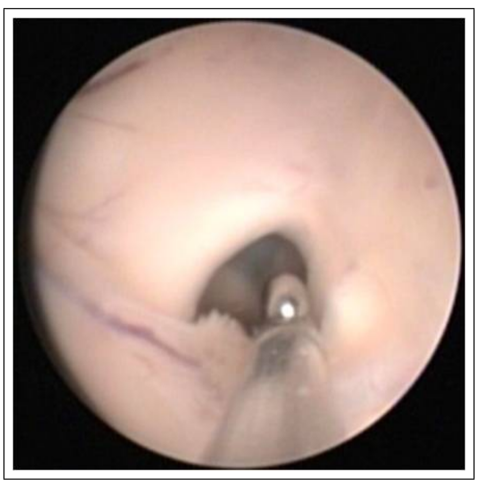

Figure 8: Real examination endoscopy image

Figure 9: Fig. 8 processed by correction method

5. CONCLUSION AND FUTURE WORKS

The main advantage of here presented technique of morphing and warping for image correction is that these methods accept the use of several triangular regions in an image and warp each region in a different way. This provides greater freedom to handle the image.
When the techniques developed are applied to the chess-pattern captured by the endoscope has a result image very close to the chess-pattern created.
Comparing the two techniques implemented (i.e Affine Transformations and Texture Mapping), the texture mapping is more adequate for real time processing. It processes the images very fast while the method of linear equations as is applied pixel to pixel takes around 20 seconds to process each image. This is because the texture mapping is processed directly on the graphics hardware. Moreover, the quality of technique of texture mapping is better: the final images are more visually softened.
To improve the results using morphing techniques is necessary to improve the algorithm that

generates the mesh and also test the system using other patterns for calibration.
As future work we can handle the extra lighting in the image caused by light source coupled to camera and try to optimize the algorithm to be applied directly in videos and in real time during an examination.

REFERENCES

Borchartt, T., 2009. More results and the executable software. *in: http://www.ic.uff.br/~uffufsm/?p=software*.

Conci, A., Azevedo, E., & Leta, F., 2008. *Computação Grafica: volume 2*. Campus/Elsevier.

Hartley, R. & Kang, S., 2007. Parameter-free radial distortion correction with center of distortion estimation. *IEEE Transaction on Pattern Analysis and Machine Intelligence*, vol. 29, n. 8, pp. 1309–1321.

Helferty, J., Zhang, C., McLennan, G., & Higgins, W., 2001. Videoendoscopic distortion correction and its application to virtual guidance of endoscopy. *IEEE Transaction on Medical Imaging*, vol. 20, n. 7, pp. 605–617.

Kannala, J. & Brandt, S., 2006. A generic camera model and calibration method for conventional, wide-angle and fish-eye lenses. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 28, n. 8, pp. 1335–1340.

Möller, T. & Haines, E., 2002. *Real-Time Redering*. Editorial Sales, 2 edition.

Stehle, T., Truhn, D., Aach, T., Trautwein, C., & Tischendorf, J., 2007. Camera calibration for fish-eye lenses in endoscopy with an application to 3d reconstrution. *IEEE Transaction on Biomedical Imaging*, pp. 1176–1179.