IMAGE PREPROCESSING FOR 3-D RECONSTRUCTION FROM BIPLANE ANGIOGRAMS

Andreas Wahle, Ulrich Krauß, Helmut Oswald, Eckart Fleck

German Heart Institute Berlin, and Virchow-Klinikum of Humboldt-University Berlin, Internal Medicine / Cardiology, Augustenburger Platz 1, D-13353 Berlin, Germany

E-mail: {andreas,krauss}@pmi.dhzb.de

Abstract **– The accuracies of systems for Quantitative Coronary Angiography, as well as for 3-D reconstruction from biplane angiograms, strongly depend on the quality of the used image data. To complete our highly accurate reconstruction system, we developed several methods for equalizing gray value contrasts to enhance vessel detection, and improved algorithms for elimination of geometric image distortions. Conventional rectification algorithms using a regular grid mostly neglect dynamic influences like the magnetic field of the earth. To avoid the necessity of determining the distortion for each possible angulation individually, we interpolate a specific rectification polynomial from two extrema.**

I. INTRODUCTION

For the assessment of coronary artery diseases, biplane angiography is currently the gold standard in cardiology. We have developed a highly accurate system to reconstruct the spatial morphology of vessel systems from two projections for the purposes of quantitative evaluations and visualizations. This system was already described in detail elsewhere [1], [2].

Images are either digitally acquired or digitized from conventional cine film. Before the reconstruction can take place, the image data retrieved from the modality must be preprocessed. On one hand, disturbing hard contrasts resulting from the digitizing process have to be equalized; on the other hand, geometrical distortions occur during imaging that have to be rectified. The first effect mainly influences the accuracy of the vessel detection algorithm, which extracts the topology from both projections. Heavy contrasts in digitized angiograms can be reduced by balancing two different exposures, resulting in one image of sufficient quality.

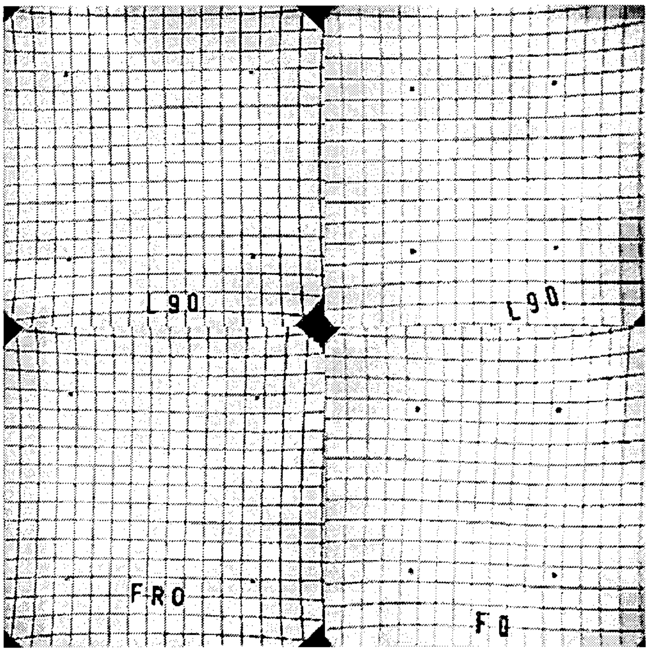

Figure 1: Distorted Grids in Standard Projections from two different Biplane Angiographic Devices

While errors in vessel detection can be corrected manually, geometric image distortions directly influence the quality of the reconstruction process. The irregular displacements of vessel points lead to inaccurate reconstructions of projection rays, which result in inaccurate quantifications. The effects of image distortions are well known and treated by assessing the distortion patterns with a regular grid. Main experiences were made in conventional Quantitative Coronary Angiography that evaluates local stenoses [3]. Assuming stable distortion patterns is not correct, since they are the results of several static and dynamic effects superimposing each other [4]. Thus, these effects have to be analyzed, and a solution has to be found that considers dynamic behaviours with a minimum of effort to setup an angiographic x-ray system.

II. IMAGE RECTIFICATION

Figure 1 shows x-ray images of a regular grid from two different projections (frontal and lateral), imaged on two angiographic devices of different locations, orientations, and ages. Some static and dynamic effects can already be discriminated visually: the pin-cushion distortion due to the curveness of the image intensifier entrance field statically spreads the image in the corners; if the image intensifier is turned from a parallel to a perpendicular orientation related to the magnetic field of the earth, the image is twisted variably. Further effects complicate the distortion pattern additionally.

The common way to determine the distortion is to use the set of intersecting points of the grid to generate polynomials for correction:

$$x = \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} a_{ij} (x')^i (y')^j \ ; \quad y = \sum_{i=0}^{n-1} \sum_{j=0}^{n-1} b_{ij} (x')^i (y')^j$$

For each displaced point (x',y'), a polynomial of order *n* is to be found with a set of coefficients *a* and *b*, so that the corresponding points (x,y) match a regular grid. This task is mathematically solved [3]. The problem occurs that for each possible angulation of the x-ray device a separate set of coefficients has to be determined, and to be selected for image rectification [4]. The dynamic portion of the distortion seems to be mainly dependent on the orientation of the image intensifier. Thus, the problem can be reduced to the determination of (at least) two extreme situations, interpolating intermediate orientations.

In figure 2 the dependencies of the axial twist from the angulation for one of the devices can be seen. Thus, the two extrema are the lateral orientation (image intensifier parallel to magnetic field) with a minimum twist, and the frontal orientation orthogonal to the magnetic field as the maximum. Apart from a small shift of the zero line, the relations of the twist in three different distances from the image center were found to be stable. This distortion pattern was confirmed by analyses on the other angiographic device as well.

We mounted four markers in a square on each of the image intensifier entrance fields, adjusted according to spatial axes and central beams. For the orientations of both minimum and maximum twists, the rectification polynomials are determined as well as the rotation of the four markers. The rectification polynomial for a concrete angulation is then determined as follows:

- the reference twist is determined from the image;
- a weighting factor is calculated from the relation of the reference twist to the minimum and maximum situation;
- a new set of polynomial coefficients is calculated by applying the weighting factor to the a and b.

The resulting set of polynomial coefficients can then be used to rectify the image as it was described before. The four markers can afterwards be used to center the image and to consider small remaining twists, what is required for 3-D reconstruction from biplane angiograms [5].

III. Results and Conclusions

In first studies the rectification was sufficiently performed. Further research involving all devices of the four cath labs in German Heart Institute and Virchow-Klinikum is still under way to obtain a reliable base for statistics. The quality of the interpolated rectifications can be determined by comparison of the derived polynomial coefficients with those of the direct assessment by using the grid image for a specific orientation.

Approximating the distortion patterns of a specific orientation by interpolation from extrema is feasible to provide sufficient accuracy for quantitative analyses and 3-D reconstructions from angiograms. Since the estimation of rectification data for each possible angulation in each frame of time is not applicable in clinical routine, we found a pragmatic solution with minimum expense.

References

[1] A. Wahle, E. Wellnhofer, I. Mugaragu, H. U. Sauer, H. Oswald, E. Fleck: "Assessment of Diffuse Coronary Artery Disease by Quantitative Analysis of Coronary Morphology based upon 3-D Reconstruction from Biplane Angiograms", *IEEE Transactions on Medical Imaging*, IEEE press, vol. 14, no. 2, pp. 230-241, June 1995

[2] A. Wahle, H. Oswald, E. Fleck: "3-D Heart-Vessel Reconstruction from Biplane Angiograms", *Applications in Surgery and Therapy,* in: *IEEE Computer Graphics and Applications*, IEEE press, vol. 16, no. 1, pp. 65-73, January 1996

[3] J. Beier, H. Oswald, E. Fleck: "Edge Detection for Coronary Angiograms: Error Correction and Impact of Derivatives", *IEEE Computers in Cardiology 1991*, Venice/Italy, IEEE press, pp. 513-516, 1991

[4] J. H. C. Reiber, D. J. H. Meyer, P. M. J. van der Zwet: "Automated and Accurate Assessment of the Distribution, Magnitude and Direction of Pin-Cushion Distortion in Angiographic Images", *XVIIth Congress of the European Society of Cardiology,* in: Supplement *European Heart Journal,* vol. 16, p. 253, abstr. 1435, 1995

[5] D. G. W. Onnasch, G. P. M. Prause: "Geometric Image Correction and Isocenter Calibration at Oblique Biplane Angiographic Views", *IEEE Computers in Cardiology 1992*, Durham NC, IEEE press, pp. 647-650, 1992/93

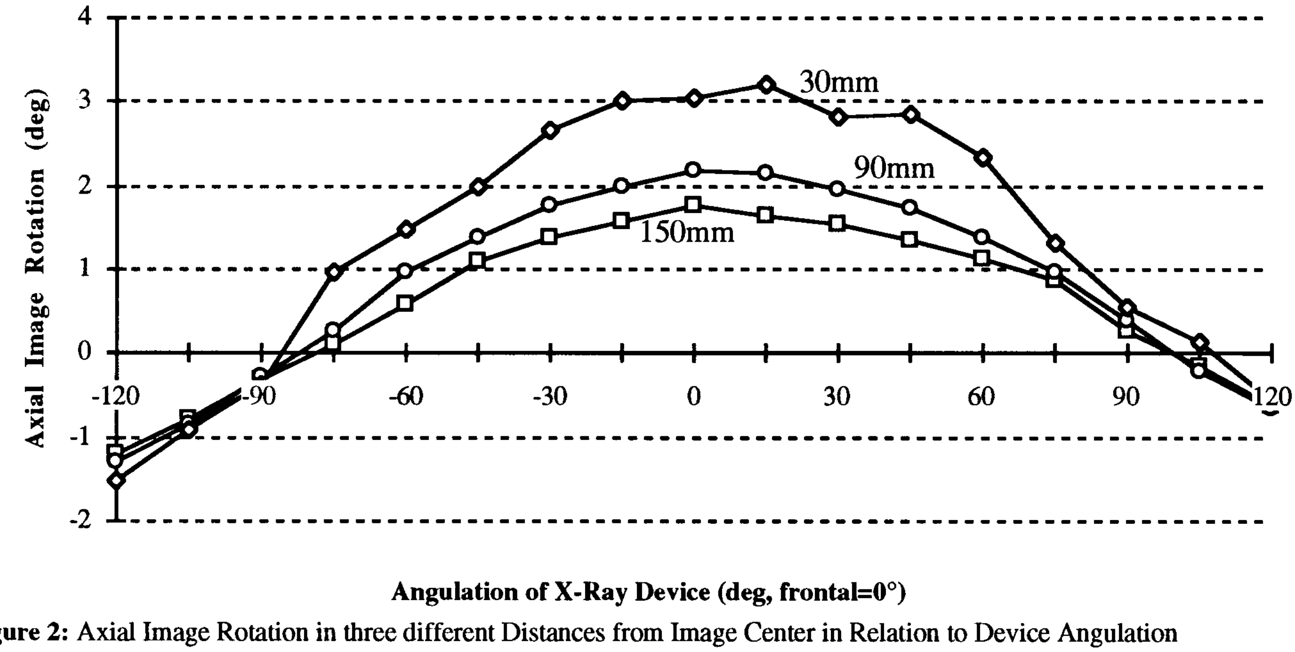

Figure 2: Axial Image Rotation in three different Distances from Image Center in Relation to Device Angulation