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Research on XRII Image Distortion Correction Based on Biharmonic Spline Surface Interpolation ⋆

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Abstract

X-Ray Image Intensifier (XRII) suffers from serve distortion in C-arm CT imaging system. To overcome the challenging problem, this paper proposes a novel XRII correction based on the Biharmonic Spline Surface Interpolation (BSSI) framework. In our study, two functions $X_2 = f(X_1, Y_1)$ and $Y_2 = f(X_1, Y_1)$ are first developed to map the relation between pixels positions in the distorted XRII image and reference image. A bilinear interpolation can then be applied to estimate the corrected pixel intensities to achieve the final image. The proposed approach can well overcome the discontinuities problems in local algorithms and achieve improved accuracy in distortion correction. Experiment results demonstrate that the proposed algorithm is capable of providing XRII images with higher correction precision than classical algorithms.

Keywords: C-arm CT; XRII Image; Biharmonic Spline Surface Interpolation (BSSI); Distortion Correction; Correction Precision

1 Introduction

Currently, C-arm CT imaging system has gained wide applications in computer-aided surgery, diagnosis, positioning and joint replacement kinematics analysis, etc [1–3]. However, due to some reasons, such as earth magnetic field fluctuation and imaging environment changes, the projection data (XRII image) often suffers from severe distortions.

The distortions can be roughly divided into three different types, namely pin-cushion distortion, local distortion and S-distortion [4]. The reason for pin-cushion distortion is the deviation of X-Ray beam from the original position caused by the curved input surface of XRII [4]. The

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manufacture produces the input screen of XRII with local deformation [5,6] that induces the local distortion. External magnetic fields, such as terrestrial magnetic field and peripheral equipment magnetic field [5,6], cause electron deflection inside X-Ray Image Intensifier and the S-distortion.

In the past decade, several algorithms have been proposed to correct the distortion XRII image, including the local correction algorithm [5] and the global calibration algorithm [1, 6–9]. The local correction algorithm segments the image into triangles or quadrilaterals. Each sub-image is first corrected. The final image is then be obtained by fusing all the corrected sub-images. The algorithm is simple and can provide accurate position estimation. Yet it often suffers from discontinuity at patch borders and gains low accuracy at intermediate points [8]. The global calibration algorithm [1,6–9] applies high-order polynomial to fit the coordinate values in distorted XRII image, and its coefficients are obtained via a least square method. The correction algorithm is more accurate than the local correction algorithm [8].

To overcome the discontinuities problems in local algorithms and achieve improved accuracy in distortion correction [6], we develop a Biharmonic Spline Surface Interpolation (BSSI) algorithm to correct the distortion XRII images in this paper. The paper is organized as follows. The BSSI algorithm is introduced in Section 2. Section 3 provides the data acquisition process and experiment results. The conclusion and work plan are given in Section 4.

2 Related Work

The Biharmonic Spline Surface Interpolation is more flexible and robust than the other interpolations since slope and value information can be exploited to find a surface [10]. This interpolation has got wide applications in marine satellite measurement data [10], integration of logging and seismic data [11], image warping [12], manifold learning algorithm [13], tackling problems of moving boundaries [14] and solar radiation mapping [15].

The proposed BSSI algorithm includes two steps. (1) Coordinate transformation: the transformation relationship between the points in the reference image and distorted image is estimated by the interpolation with the Biharmonic Spline Surface. (2) Intensity assignment: for each point

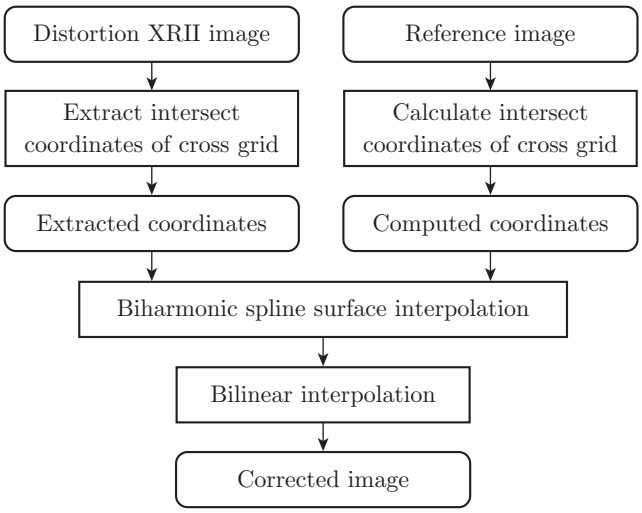

Fig. 1: The algorithm flow chart