The Development of Undistortion Digital Image Application using Backpropogation Neural Network Model

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ABSTRACT
This paper reports our study in digital image geometrical distortion correction. The Artificial Neural Network (ANN) was employed to correct the distorted digital image which is simulated in computer. The ANN was trained to map the distorted points to the distortion-free points. As the results, our proposed technique can correct the detected distort-points with $1.7196\times10^{-4}\pm1.3027\pm10^{-2}$ pixel of mean square error along the *x* axis and $1.5281\times10^{-4}\pm1.2439\pm10^{-2}$ pixel of mean square error along the *y* axis.

Keywords
Geometrical Distortion, Artificial Neural Network, Undistortion

1. INTRODUCTION
Currently, the x-ray computers are being increasingly popular. It can reduce the radiation dose per examination. The process of examination is quick without any chemical process on patients. The information of examination can be easily stored in digital and quickly be restored from database. The accuracy of diagnosis is reliable with safety.

In light capture process the optical lens is an important part that is necessary to be used for gathering light and projecting on camera image sensor. The image, which is captured from cheap and wide-angle lens, is usually distorted with high geometrical distortion and need to be corrected [1]. A geometrical distortion causes the error to data points in image. The algorithms to correct geometrical distortion are proposed with various methods. A solution to correct the geometrical distortion in image is typically used mathematical algorithm of polynomial equations to estimate and interpolate coordination of image [2-5]. An artificial neural network (ANN) is widely applied to solve various engineering problems such as pattern recognition, optimization and modeling [6, 7] and also in computer vision [8, 9]. The ANN is suitable to be employed for solving the problems that require complex models. This research has proposed the application of artificial neural network to correct the geometrical distortion image.

2. METHODOLOGY
2.1 Data Study
In this study the 10X10 chessboard with no distortion which was simulated in computer was used in our experiment as shown in Figure 1. This image was also used as standard pattern of free distortion data for verifying the algorithm. The size of chessboard is 1000×1000 pixels. The coordination on the image plane is mapped from points on camera frame with transformation in equation (1).

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ 1 \end{bmatrix} \quad (1)$$

where (u,v) is the distortion-free image point on the image plane, (x_c,y_c) is a point in camera frame, (u_o,v_o) is camera principle point, (α, β) are two scalars in the two image axes, and γ describes the skewness of the image. The distorted image was generated from chessboard using distortion equations in eq. (2) and (3) [10].

$$u_d = \alpha x f(r) + \gamma y f(r) + u_0 \quad (2)$$

$$v_d = (v - v_0) f(r) + v_0 \quad (3)$$

where (u_d,v_d) is a distorted image point in pixel coordinate, (u,v) is a distortion-free image point in pixel coordinate. From distortion equation $f(r)$ is a distortion model. Radial distortion causes the defect in the radius of curvature of the lens, which can be obtained from model expressed in equation (4).

$$f(r) = 1 + \sum k_i r^{2i} \quad (4)$$

where k_i are Radial distortion coefficients and r is a radius of the distortion .The distortion model used in this study can be presented in equation (5).

$$f(r) = 1 + k_1 r^2 \quad (5)$$

The data used in network modeling were a chessboard [3, 11] with 81 coordinates which were obtained from the corner detection process via OpenCV function [13]. The data of distorted image after corner detection process can be shown in Figure 2. The training set consists of 41 selected points and the testing set contains all 40 remaining points.

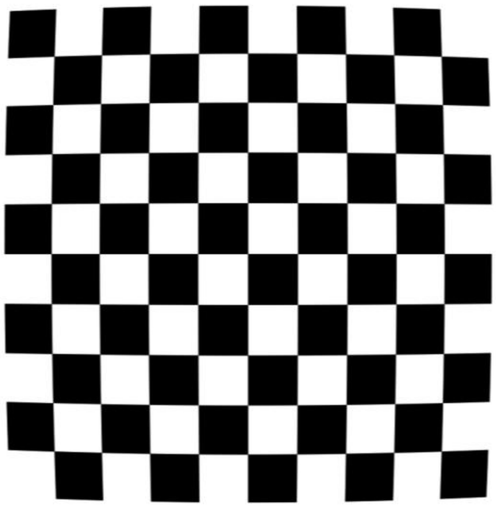


Figure 1. A distorted chessboard

2.2 Artificial Neural Network Design

In this study the backpropagation (BPP) network was employed as undistortion model. The BPP network has multi-layers and back-propagate errors through the network to adjust weights of the network. The network was simulated on MATLAB with Neural Network Toolbox. The details of network design can be explained as follows:

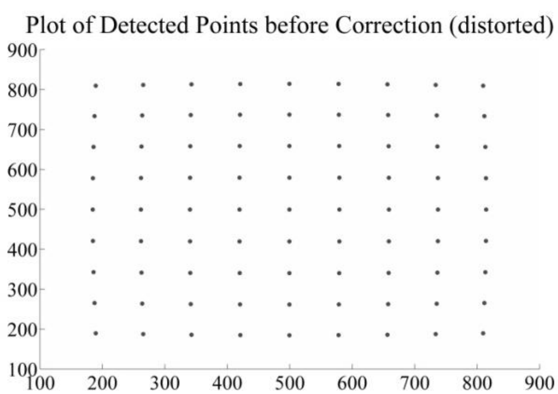


Figure 2. Plot of detected points before correction

2.2.1 *Artificial Neural Network Structure*

Our BPP network was designed with two hidden layers that can be shown in Figure 3. The network input contains 2 neurons (*X* and *Y*) for *x* and *y* coordinates of training data. The first hidden layer next contains *I* neurons and the index of each neuron is denoted by *i*. The second hidden layer contains *J* neurons and the index of each neuron is expressed with *j*. The output layer consists of 2 neurons which produced the result of network expressed with *X'*and *Y'*. The outputs of BPP network present the estimated coordinates after undistortion. The weight from the input layer to the 1st hidden layer is expressed with w_{ih}. The weight from the 1st hidden layer to the 2nd hidden layer is expressed with w_{ji}. The weight from the 2nd hidden layer to the output layer is expressed with w_{kj}.

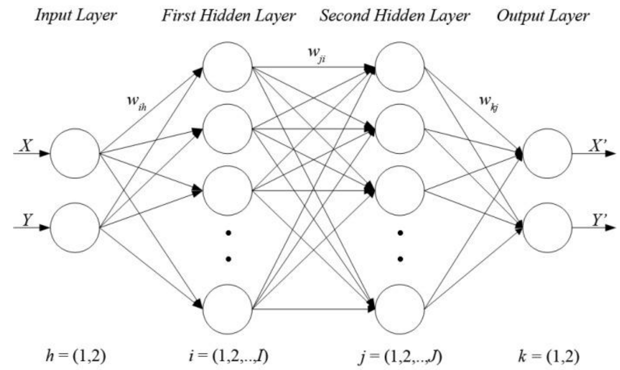


Figure 3. The backpropagation network with 2 hidden layers

In our experiment the number of neurons in each layer was varied for finding the proper networks for correcting distortion. The number of neurons in each layer varies from 10 neurons to 20 neurons with 5 increasing step. The activation functions in our designed network were hyperbolic tangent sigmoid (tansig) for the 1st and 2nd layers and Linear (purelin) for output layer.

2.2.2 *Training and Testing Method*

The network inputs are 41 points selected from 81 points in Figure 2 for network training. For network generalization and increasing speed of training, the coordinates of inputs were normalized before feeding to the network. In this study the Levenberg-Marquardt (LM) algorithm was employed to update and optimize in weight training method. The LM method is fast and efficient method for minimizing of nonlinear function. The LM method is a combination between Gradient Descent Method and Gauss-Newton Method which takes the advantages of both methods. The target of training was set to the performance gradient at 1×10^{-9}. Then the normalized coordinates of 40 remaining points in Figure 2 were used to test the network. Finally the outputs of network were then anti-normalized to coordinate in pixel. The performance of network was measured from the mean square error (MSE) and standard deviation of error (STD_{err}) in both *x* and *y* direction.

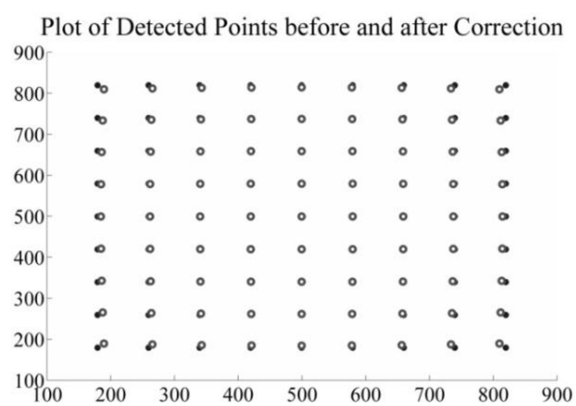
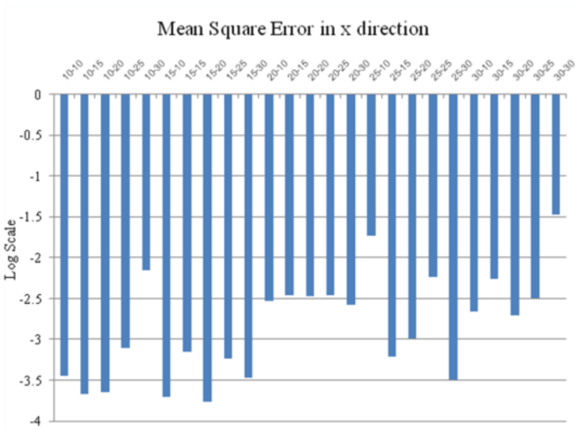


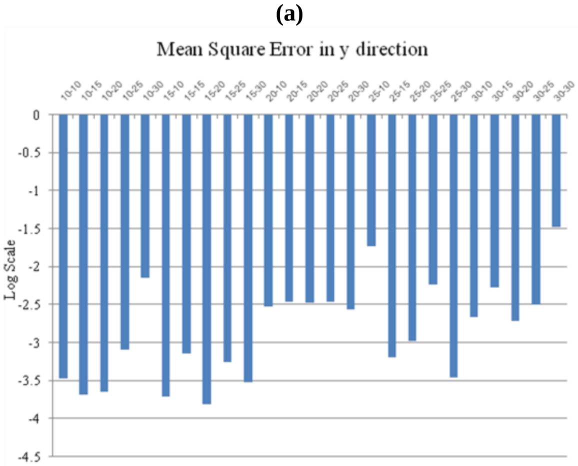
Figure 4 Plot of distorted points and results from ANNs

3. EXPERIMENTAL RESULTS

From our experiment, all distortion correction can be shown in table 1. Artificial Neural Network correction result can be illustrated in Figure 4 which circle mark (○) presents distorted points and filled circle mark presents results from artificial neural network. Table 1 shows the network performances of all studied experiments. Figure 5 illustrates the plot of MSE in *x* and *y* direction. From Figure 4 and 5, it can be seen that the BPP model with 15 neurons in the 1st layer and 20 neurons in the 2nd layer gave the highest performance with MSE in *x* direction and *y* direction are $1.7196\times10^{-4}\pm1.3027\times10^{-2}$ pixel and $1.5281\times10^{-4}\pm1.2439\times10^{-2}$ pixel in respectively.



(a)



(b)

Figure 5. Plot of Mean Square Error: (a) x direction (b) y direction

4. DISCUSSION AND CONCLUSION

This study proposes the undistortion method to correct the geometrical distorted points in computer simulated digital image. The BPP artificial neural network with 2 hidden layers was designed in distortion correction model. As the results the network with 15 neurons in 1st layer and 20 neurons in 2nd layer gave the best performance in our study. The highest performance is with MSE of $1.7196\times10^{-4}\pm1.3027\times10^{-2}$ pixel and $1.5281\times10^{-4}\pm1.2439\times10^{-2}$ pixel in *x* and *y* direction in respectively.

Table.1 Results of Network Testing

	Test	
Layers	**$MSE_x \pm STD_{errx}$**	**$MSE_y \pm STD_{erry}$**
10-10	0.000354 ± 0.018882	0.000334 ± 0.018375
10-15	0.000215 ± 0.014155	0.000207 ± 0.014304
10-20	0.000225 ± 0.015090	0.000226 ± 0.014865
10-25	0.000779 ± 0.027923	0.000797 ± 0.028392
10-30	0.007062 ± 0.083421	0.007021 ± 0.083481
15-10	0.000200 ± 0.014228	0.000195 ± 0.013861
15-15	0.000707 ± 0.026473	0.000714 ± 0.026838
15-20	0.000172 ± 0.013027	0.000153 ± 0.012439
15-25	0.000576 ± 0.024152	0.000557 ± 0.023655
15-30	0.000339 ± 0.017989	0.000302 ± 0.017345
20-10	0.002935 ± 0.053754	0.002970 ± 0.053671
20-15	0.003462 ± 0.058111	0.003430 ± 0.058210
20-20	0.003358 ± 0.057523	0.003310 ± 0.057405
20-25	0.003465 ± 0.058739	0.003430 ± 0.058673
20-30	0.002665 ± 0.051945	0.002707 ± 0.052325
25-10	0.018727 ± 0.136380	0.018735 ± 0.136670
25-15	0.000606 ± 0.024751	0.000638 ± 0.025211
25-20	0.001033 ± 0.032024	0.001040 ± 0.031747
25-25	0.005835 ± 0.076061	0.005783 ± 0.075984
25-30	0.000318 ± 0.017718	0.000344 ± 0.017998
30-10	0.002158 ± 0.046481	0.002152 ± 0.046148
30-15	0.005457 ± 0.073374	0.005384 ± 0.073166
30-20	0.001943 ± 0.043605	0.001916 ± 0.043632
30-25	0.003198 ± 0.056501	0.003137 ± 0.056159
30-30	0.033278 ± 0.181590	0.033388 ± 0.182160

5. ACKNOWLEDGMENTS

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