Former books digital processing : image warping

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Abstract

In the present paper, we will discuss the way to correct the text image warping due to old bookbindings which can not open to 180^o. *Two methods have been experimented to measure the surface distortion of the paper. The first method uses a diffracted laser beam and is operational for* $1D$ *distortion measurements. As former bookbindings may also present* $2D$ *distortion, we have developed a second method which uses a light projected network and which gives encouraging results.*

1 Introduction

Former books digital processing raises specific difficulties involved by the state of paper and by the bookbinding. Indeed, the average 120^o opening of a former bookbinding is inappropriate to standard scanner systems. Handling of damaged paper requires moreover great cares.

That's why we suggest to digitalize former books with a camera which is hanged over the book. Hence we will have a more uniform diffused light.

In these conditions, we should correct the deformation of the text, due to the bookbinding and the intrinsic deformation of the old sheet of paper. We may encounter the same kind of difficulties when we use a traditional scanner to digitalize a book which presents inscriptions very close to the binding. Previous work have been done in this case by Haraclick which propose a model to correct the following aspects.

1. physical deformation of the sheet involving perspective distortion of the text.

2. shadow effect near to the binding.

3. optical spread of the text near to the binding

When the acquisition is processed with a camera, which is hanged over the book, several light sources can be used, thus creating a rather uniform light and minimizing the shadow effects.

Moreover, the field depth of the optical lens in front of the camera is large enough to limit the optical spread of the image close to the binding.

Also, when we use a camera hanged over the book, the degradation of the image depends mainly on the physical deformation of the sheet.

Kanungo, Haralick and Phillips [8] propose to correct this kind of the degradation in two steps: They first assume that the sheet deformation close to the binding approaches a cylindrical surface defined by the radius ρ (see figure1).

The $1D$ deformation of the text along the x axis can be corrected using the formula:

$$x_{a'} \quad = x_a + \rho(\theta - \sin(\theta))$$

where the point A maps to the point $A^{'}$ after deformation.

The second part of their work deals with the correction of the perspective effects.

This two steps calculation method requires a good knowledge of the radius of the cylindrical surface which approximates to the bending of the sheet.

This radius ρ is not so easy to measure: it has not the same value for all the sheets of a book and depends on the pressure that one may apply while pressing the book on the glass of the scanner. Last of all the cylindrical approach may not be always relevant, especially with former books which present rigid paper sheets.

That's why we propose to correct the deformation of the text due to the sheet bending using image warping. The surface bending can be measured, sheet by sheet, by a diffracted laser beam or by a light network projection.

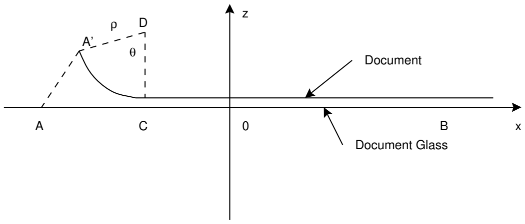

Figure 1. Deformation Model

2 Laser line projection

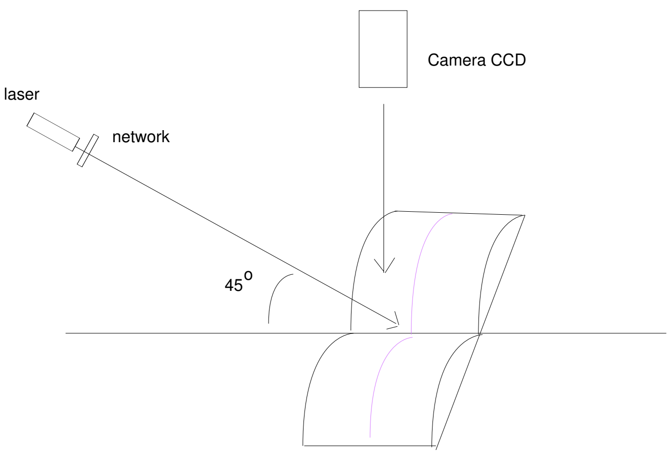

Figure 2. Projection of laser beam

We first use a projected linear laser diffracted beam (see figure 2) with a 45^o incidence angle. Due to the incidence we can visualize the deformation. With a camera which is hanged over the book we obtain a digital image. The noise which is present on the image has been eliminated by filtering process (see fig 3). We binarize the laser track. To compute the deformation we need a one pixel thin line. We consider each line and we compute a new position:

$$y = \frac{y_{max} - y_{min}}{2}$$

This process may induce some line discontinuity due to the ink and to the laser diffracted beam. We have corrected this line by a linear interpolation. The curve obtained is one pixel thick and can be used to generate the morphing file [9].

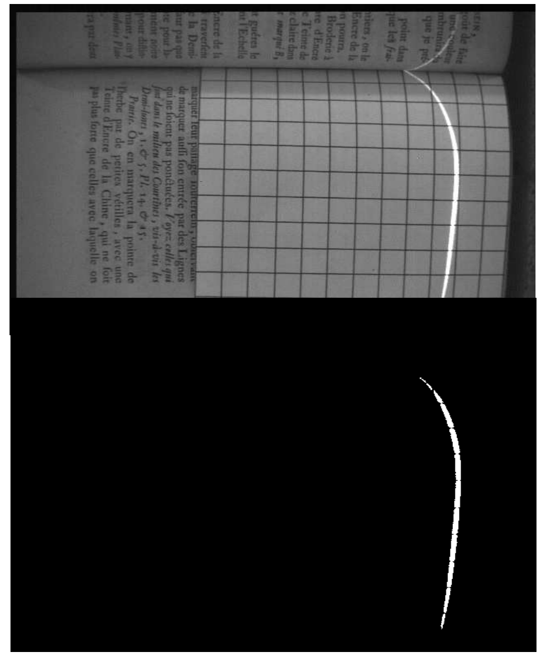

Figure 3. Projection of laser beam

The image was reconstructed with the Fant algorithm, assuming that there is no distortion along the y axis. Thus this method gives good results and is usable when perspective effects are negligible, that is to say, when the size of the book is limited and when the paper presents no intrinsic bending.

When the image presents $2D$ distortions, we suggest to project a light network to measure the bending of the surface.

3 Light network projection

This projection was realized with a 45^o incidence angle using a light source, a mask, and an optical abberation correcting lens.

Further processing should be undertaken to quantify distortion information from the image of the grid. Indeed, the illuminated areas are several pixel thick and countain black pixels induced by the printed text. The bending of the sheet provokes moreover the spread of light lines near to the binding.

In order to correct these two dimension distortions, we have projected a two dimensions light network on the surface sheet (see figure 4).

Several filtering procedures have been tested to improve the quality of the projected network image. The best results were obtained with wavelet transform.

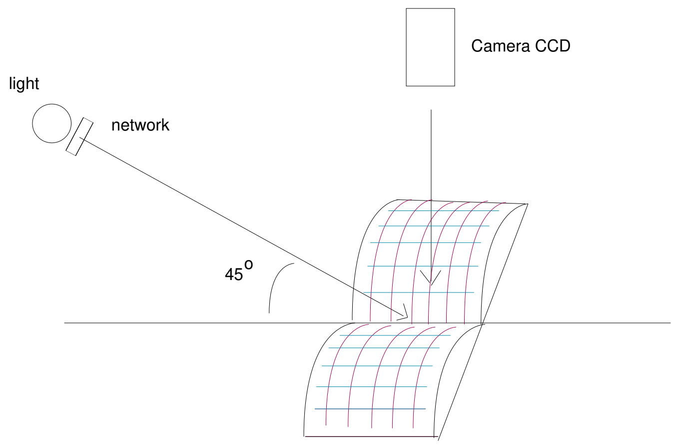

Figure 4. Projection of a light network

4 Wavelet

We have chosen wavelet transform for segmentation because our network projection on the old books needs also an interpolation before edges detection [7] [11].

Wavelet Transform is a useful tool to decompose a function into a set of coefficients which depends on scale and location.

The wavelet transform of a continuous function $f(x)$ is :

$$WT(a,b) = \frac{1}{\sqrt{a}} \int f(x)\psi^*(\frac{x-b}{a})dx \quad (1)$$

Where $\psi(x)$ is the analyzing wavelet. The analyzing wavelet is scaled, translated and convolved with the signal to compute the transform. a is the scaling parameter and b is the translation parameter. The translation moves a window over the function signal, and the scaling which is named dilation in the context of wavelet, scales the bandwidth of the filter.

Generally analyzing wavelets does not provide an orthogonal basis. Multiresolution analysis introduced by Mallat and further developed by Daubechies [1] provides orthonormal basis of $L_2(R)$. A multiresolution analysis gives an approximation of the function $f(x)$ in a space V_{2^j} with resolution 2^j related to a scaling function $\phi(x)$ and a wavelet function $\psi(x)$.

Consequently the discrete approximation of the function $f(x)$ at resolution 2^j can be written [11]:

$$P_m f = \sum_n r_m[n]\phi_{m,n}(x) \;\; m,n \in Z \quad (2)$$

$$\phi_{m,n}(x) = 2^{\frac{-m}{2}}\phi(2^{-m}x - n) \quad (3)$$

The discrete detail of the function $f(x)$ at resolution 2^j can be written

$$Q_m f = \sum_n d_m[n]\psi_{m,n}(x) \;\; m,n \in Z \quad (4)$$

$$\psi_{m,n}(x) = 2^{\frac{-m}{2}}\psi(2^{-m}x - n) \quad (5)$$

The transformation between a discrete sequence $r_m[n]$ and its lower resolution sequences $r_{m+1}[n]$ and $d_{m+1}[n]$ can be obtain:

$$r_{m+1}[n] = \sum_k h[k-2n]r_m[k] \quad (6)$$

$$d_{m+1}[n] = \sum_k g[k-2n]r_m[k] \quad (7)$$

where h and g are respectively low pass and high pass filters. Usually the low frequency portion is related to the characteristics of interpolated surface.

The filtering process proposed by Forthoffer is summarized in figure 5, assuming H and G to be the Fourier Transform of h and g.

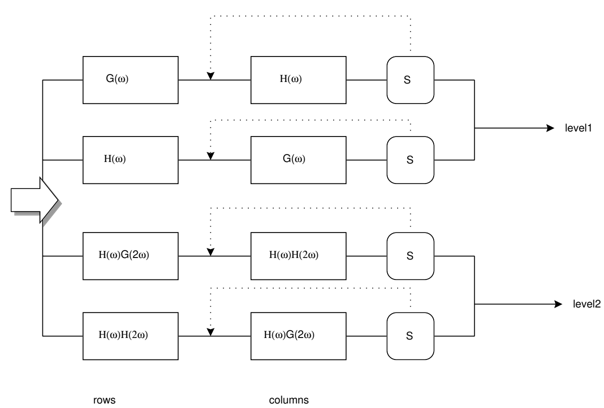

Figure 5. Wavelet

High pass and low pass filters are combined for two levels of resolution. The filter $H(2\omega)$ was build introducing zero values between the coefficients of the filter $H(\omega)$.

4.1 Digital processing

We have used Daubechies filters with 5 and 7 taps. Haar basis and spline wavelets have also been tested, but they proofed less efficiency.

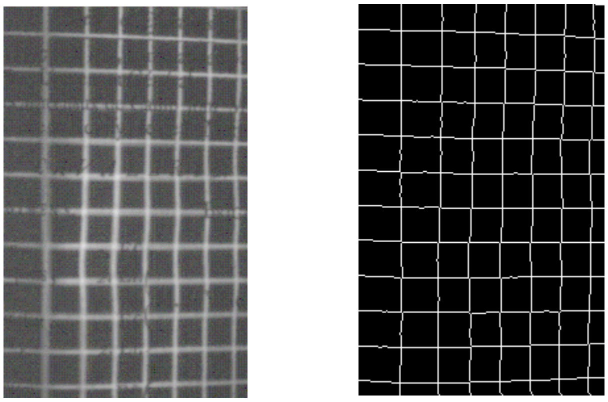

Figure 6. The network before and after wavelet segmentation

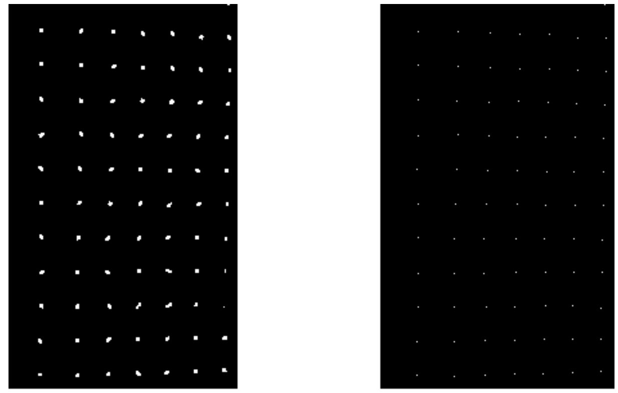

Figure 7. The vertex of the network before and after filtering

The efficiency of the multiresolution process depicted in figure 5 depends statistically on the resume and detail distribution of the coefficients, which should correspond to a low level of statistical entropy. Indeed, calculation can be processed faster if non significant coefficients are deleted. That's why we preferred to select the most significant coefficients above a cut off level.

Our images contain noise and fuzziness, which were both eliminate with multiresolution recombination. The images were then binarized and processed with simple morphological operators.

To restore the document we use the coordinates of the points of intersection on the book. We know the initial position of these points (the grid). With the new position we can compute the deformation. The coordinates of the points of intersection were determined with a two steps digital process. Pixel clusters corresponding to the line intersections are first detected with a median filter. The centers of gravity of these clusters can be calculated, yielding to the determination of a single pixel for each intersection area (see figure 7).

Coordinates of these pixels are then incorporated in the morphing file.

In fact we do not compute the deformation. We use the initial grid and the coordinates of intersection points on the book as control points for a morphing algorithm. We corrected two dimension distortions of the surface paper with a two pass mesh warping. The algorithm proposed by Smythe [9] accepts a source image and two 2-D arrays of coordinates. For us the two 2-D arrays of coordinates are the initial grid and the coordinates of intersection points on the book. The first array, specifies the coordinates of control points in the destination image. Smythe has the same dimension in order to establish a one-to-one correspondence. The 2-D arrays in which the control point are stored impose a rectangular topology to the mesh. Each control point, no matter where it lies, is referenced by integer indices. This permit to fit any bivariate function to them in order to produce a continuous mapping from the discrete set of correspondence points given by Smythe. The only constraint is that the meshes is defined by two arrays topologically equivalent, i.e. no folding or discontinuities. Results obtained by this methods are shown figure 8.

5 Conclusion

Our two methods give good results but we can manage large book only with the light network projection. These methods are however limited by the quality of the network image which could be optically improved. Optimization of optical experiments have been undertaken.

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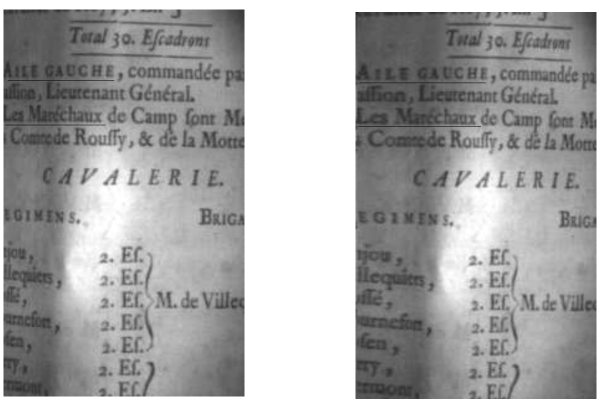

Figure 8. The image transformation