A Panoramic Color Photographic Image Registration Method

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Abstract

An image registration method for panoramic image generation is described. For the problem, estimation of overlapping regions is essential and the SSD (Summation of Squared Differences) method has been used as a cost function of the optimal problem. But there are some problems in the SSD method. To resolve the problems we propose an image registration method based on the WMDL (Weighted Minimum Description Length) criterion in which parameters of the problem are optimized. The WMDL criterion is an information criterion proposed by us previously. The efficiency of the method is shown by using real images.

Introduction

In these days, image registration techniques for panoramic image generation by using multiple images have been attracted a great deal of attention because of so much visual presence. We have developed a new registration techniques for panoramic image generation. For the problem, estimation of overlapping regions is essential and the SSD[1)] (Summation of Squared Differences) method has been proposed. The SSD is a measure of similarity between images and used as a cost function of the optimal problem. But there are problems in the SSD Method.

The first problem is that the SSD values of variable windows for estimation of overlapping regions cannot be compared with each other because of model differences. And appropriate criterion for the comparison of different models is necessary.

The second problem is the image distortion caused by the lens distortion. Images created through an optical instrument such as lens have distortion in general. The distortion becomes larger as the point leaves from the center of the image.

To deal with the problems, we have applied the MDL criterion framework to the panoramic image registration problem to resolve the problems of the SSD method. Different models can be compared using the MDL criterion framework, which is based on information theory. Originally, the MDL criterion was derived for model parameter estimation in various statistical problems, such as prediction and estimation. We have generalized the MDL criterion regarding the observation system and have derived the WMDL criterion[2)]. The estimation problem of overlapping regions can be formulated as a prediction problem in which an image is predicted by using the other image, and the parameters of the prediction problem are evaluated by the WMDL criterion.

We have approximated the lens distortion to a quadratic function model of the distance from the center of the image. And we have applied the lens distortion model to derive the weight values used in the WMDL criterion. As the result, the uncertainty caused by the image distortion of the second problem can be absorbed.

In the proposed method, in the first step, overlapping regions in images are estimated by using the WMDL method. In the second step, we compose the two images into a panoramic image without the boundary of these images to be noticeable.

The proposed algorithm is tested on real images.

The WMDL Modeling

The WMDL criterion

The WMDL criterion is formulated as follows:

$$WMDL = -\sum_{i=1}^{n} w_i \log Q_{k,\theta}(i) + (1/2)K \log\left(\sum_{i=1}^{n} w_i\right), \qquad (1)$$

where,

log : natural logarithm,
n : number of observed data,
$\theta := (\theta_1, \theta_2, \ldots, \theta_k)$, a model parameter vector,
k : number of elements,
$Q_{k,\theta}(i)$: a probability distribution.
w_i : generalized observation coefficients, $(i=1,2,\ldots,n)$.

Probability modeling for the prediction problem

Let $I_1(i)$, $I_2(i)$ denotes intensity values in an image 1 and an image 2 indexed by i, respectively. It is assumed that prediction errors subject to a gaussian distribution of zero mean, and each error value is independent. The probability modeling for the prediction problem is as follows:

$$Q_{k,\theta}(i) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{\varepsilon^2(i)}{2\sigma^2}}, \qquad (2)$$

where,

$\theta = \sigma,$

$\varepsilon(\iota) = I_1(i) - I_2(i)\,,$

$\sigma = \varepsilon^2\,.$

Calculation of the WMDL criterion

By applying eq.(2) to eq.(1), the following equation is derived:

$$\begin{aligned} &WMDL \\ &= -\sum_{i=1}^{n} w_i \log Q_{k,\theta}(i) + \frac{1}{2} K \log\left(\sum_{i=1}^{n} w_i\right) \\ &= \left(\sum_{i=1}^{n} w_i\right) \log(\sqrt{2\pi}\sigma) + \frac{1}{2\sigma^2} \sum_{i=1}^{n} w_i \varepsilon^2(i) \\ &\qquad + \frac{1}{2} K \log\left(\sum_{i=1}^{n} w_i\right) \qquad (3) \end{aligned}$$

The second term of eq.(3) corresponds to the SSD value. The WMDL value is normalized by $\sum_{i=1}^{n} w_i$ as follows:

$$WMDL_{nrm} = WMDL \Big/ \sum_{i=1}^{n} w_i\,. \qquad (4)$$

Weighting coefficients calculation

The weighting coefficients of the WMDL criterion are determined based on a lens distortion model (Fig.1). Digital images through an optical system include the lens distortion which is represented by the barrel distortion. In the barrel distortion, the larger distance from the center the larger the distortion.

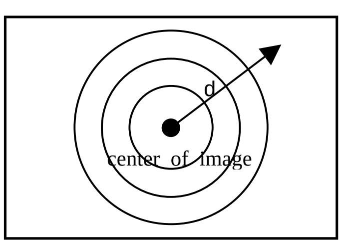

Figure 1. Lens distortion

The distortion can be modeled by a quadric function *f(d)* of a distance parameter *d*. The weighting coefficients of the WMDL criterion are determined based on the distortion function *f(d)*, and uncertainty of image data depending on the parameter *d* is absorbed. The distortion function *f(d)* can be represented as follows:

$$f(d) = 1 - \alpha * (d)^2\,, \qquad (5)$$

where,

α : a camera parameter.

Under the assumption that two images are obtained by the same camera, the distortion functions for each image is as follows:

$$f(d_1) = 1 - \alpha * (d_1)^2 \quad \text{for an image 1,} \qquad (6)$$

$$f(d_2) = 1 - \alpha * (d_2)^2 \quad \text{for an image 2,} \qquad (7)$$

where,

d_1, d_2 : parameter *d* values for overlapped two pixels in an image 1 and an image 2.

So, the distortions in an image 1 and an image 2 are independent that the weighting coefficients are calculated by multiplying the functions $f(d_1)$ and $f(d_2)$ as follows:

$$w = f(d_1) * f(d_2) \qquad (8)$$

Registration Procedure and Details

In this chapter, proposed panoramic image registration procedure and details based on the WMDL modeling are described. Fig.2 shows the registration procedure flow, and in accordance with the flow, the details are described bellow. In the proposed method, some assumptions are posed on as follows.

Assumption

Some assumptions on images is necessary. The first assumption is that objects of images are in the same plane by observing from a distant point of view. On the assumption, the disparity between two images are very small. This assumption is necessary in a registration of two images without considering the disparity. The second assumption is that two images are on the same plane. This assumption is necessary to a registration of two images without coordinate transformation process.

Search process for the optimum overlapping region : step 1

In the searching process for the overlapping region , we call one of the two images a fixed image and the other a sliding image. As shown in Fig.3, the WMDL criterion value of the overlapping region is evaluated with the sliding image over the fixed image. After all search process, the overlapping region which the WMDL criterion value was the least are chosen as the optimum overlapping region.

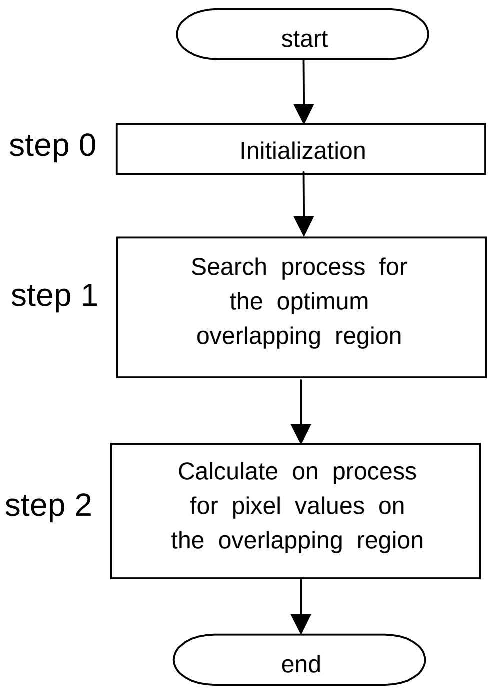

Figure 2. Registration procedure flow

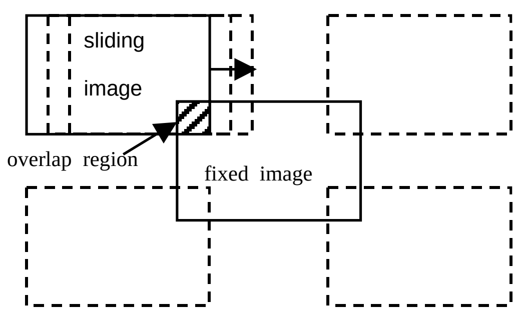

Figure 3. Search process

Calculation process for pixel values : step 2

Following the step 1, the calculation process for pixel values on the overlapping region is executed. The pixel value is calculated using corresponding two pixel values in two images overlapped. Each pixel is represented in RGB color space. The mix ratio is determined depending on distances measured from image boundaries. There are two distance values corresponding to two images, and the smaller one is selected to the distance parameter. The calculation formula is as follows:

$$\left.\begin{aligned} r &= \frac{r_1 \times R_2 + r_2 \times R_1}{R_1 + R_2}, \\ g &= \frac{g_1 \times R_2 + g_2 \times R_1}{R_1 + R_2}, \\ b &= \frac{b_1 \times R_2 + b_2 \times R_1}{R_1 + R_2}, \end{aligned}\right\} \quad (9)$$

where,
r, g, b : color value of overlapping region
r_1, g_1, b_1 : color value of image 1
r_2, g_2, b_2 : color value of image 2
R_1, R_2 : distance from boundary of image 1 and image 2

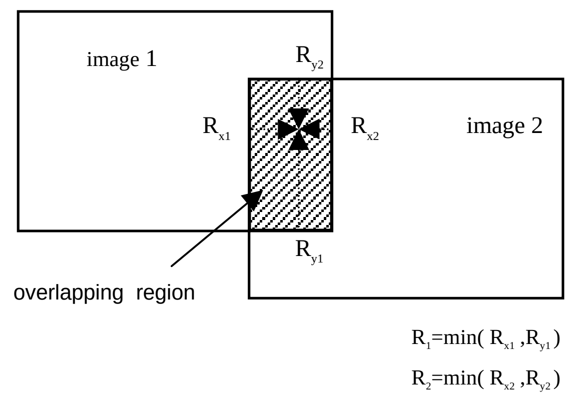

Figure 4. Range between image boundary and pixel position

In this calculation process, so the smaller the distance the larger weighted the pixel value, inversely, the larger the distance the smaller weighted the pixel value that the boundaries of images becomes not noticeable.

Experiment

As described, our framework enables comparison between different overlapping regions which is theoretically impossible for the existing SSD method. Hence, experiments have been performed on the proposed method without comparison with the SSD method.

The images used in this experiment are landscape images shown in Fig.5 and Fig.6. In the experiments, the parameter α was 10^{-6}.

Fig.7 is the registration result of the image 1 and the image 2. The efficiency of the proposed method can be confirmed by subjective evaluation.

Figure 5. Image 1

Figure 6. Image 2

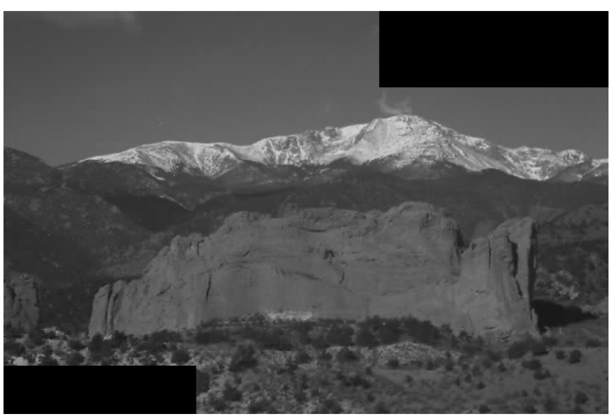

Figure 7. Registration image

Conclusions

A image registration method for panoramic image generation has been described. Panoramic image generation can be formulated as a prediction problem in which an image is predicted by using the other image, and the parameters of the prediction problem are evaluate by the WMDL criterion. We have proposed the WMDL criterion based method to resolve the problems of the SSD method and the lens distortion.

The image registration algorithm has been tested on real images. In the experiment using a real image, we can confirm the effect of the proposed method by subjective evaluation.

In this article, only intensity information of color images are used in the experiments. Hereafter we will apply various color space to the proposed method.

References

1. N.Chiba, Feature-Based Image Registration - panoramic image mosaicing -, SII 4th, Japan, pp.203-208, (1998).
2. N.Matsushiro, Considerations on the weighted minimum description length criterion, J. Inst. Tele. Eng. Japan, **50** (4), 483 (1996).