Fast Affine Transform for Real-Time Machine Vision Applications

Sunyoung Lee[1], Gwang-Gook Lee[2], Euee S. Jang[1], and Whol-Yul Kim[2]

[1] Digital Media Lab., College of Information and Communications, Hanyang University
17 Haengdang-dong, Seongdong-gu, Seoul, 133-791, Korea
sunnykr@ihanyang.ac.kr, esjang@hanyang.ac.kr

[2] Image Engineering Lab., College of Engineering, Hanyang University
17 Haengdang-dong, Seongdong-gu, Seoul, 133-791, Korea
gglee@vision.hanyang.ac.kr, wykim@hanyang.ac.kr
http://vision.hanyang.ac.kr/

Abstract. In this paper, we have proposed a fast affine transform method for real-time machine vision applications. Inspection of parts by machine vision requires accurate, fast, reliable, and consistent operations, where the transform of visual images plays an important role. Image transform is generally expensive in computation for real-time applications. For example, a transform including rotation and scaling would require four multiplications and four additions per pixel, which is going to be a great burden to process a large image. Our proposed method reduces the complexity substantially by removing four multiplications per pixel, which exploits the relationship between two neighboring pixels. In addition, this paper shows that the affine transform can be performed by fixed point operations with marginal error. Two interpolation methods are also tried on top of the proposed method in order to test the feasibility of fixed point operations. Experimental results indicated that the proposed algorithm was about six times faster than conventional ones without any interpolation and five times faster with bilinear interpolation.

1 Introduction

In a few applications, such as machine vision, it is required that images are to be rotated, sheared, and scaled while preserving the image integrity. Thanks to the rapid rise of cost-performance efficiency of image acquisition systems, the major focus in machine vision is not only on accuracy, but also on the computational complexity for real-time imaging. The most time consuming, and therefore complex operations are (affine) image transforms including rotation and scaling. This problem is getting worse when the size of the input image increases, which poses a common problem for today's machine vision system.

Affine transform is applied for rotating, scaling, and shearing images, which generally needs four multiplications and four additions per pixel [1]-[6]. Image rotation is the most time consuming and tricky part, which eventually affects the quality of the rotated image. Image rotation process maps each discrete pixel in the transformed image to a spatial location in the input image and computes the intensity using interpolation [7][8]. Popular interpolation methods include the nearest neighbor and bilinear interpolations.

D.-S. Huang, K. Li, and G.W. Irwin (Eds.): ICIC 2006, LNCS 4113, pp. 1180 – 1190, 2006.

In implementing a rotation transform, there are non-separable and separable rotations. Non-separable rotation methods become impractical for high order models because of the increase of the reference pixels, which can lead to high computational complexity. To address this problem, a separable rotation method decomposes the rotation into two or more 1D transformations along the x and y directions. There are several decompositions: two-pass and three-pass algorithms [9][10][11]. The separable method can reduce the use of the memory because of accessing data in one row or column at one time and also reduce complexity when using high order interpolations. A multi-pass algorithm, however, requires intermediate data contraction, which may complicate implementation, introduce errors, and increase complexity. This may not fit in zero order interpolation and bilinear interpolation. It can not be a fast method for real-time operation and is going to be a great burden to process a large image.

In this paper, we showed a fast affine transform which reduces the complexity substantially by removing four multiplications per pixel by exploiting the relationship between two neighboring pixels. In addition, this paper showed that the affine transform can be performed by fixed point operations with marginal error in which its coefficients are in bounds. Lastly, we tried to combine the aforementioned two methods. To estimate the feasibility of the proposed methods, we used zero order interpolation and bilinear interpolation. The feasibility of the proposed methods is all evaluated by error analysis.

The remainder of this paper is as follows. Section 2 describes the affine transform of two dimensional images. In Section 3, our proposed methods, interpolation, and error analysis are explained and experimental results are given in Section 4. Finally, we summarize this paper in Section 5.

2 Affine Transform of 2D Image

A matrix **A** represents a 2D image affine transform such as rotation, scaling, and translation. A transformed pixel $\mathbf{v} = \begin{pmatrix} x' \\ y' \end{pmatrix}$ on an image **D** is acquired by a pixel $\mathbf{u} = \begin{pmatrix} x \\ y \end{pmatrix}$ of an original image **S** and transform matrix **A**:

$$\mathbf{v} = \mathbf{A}\mathbf{u} = \begin{pmatrix} a_{00} & a_{01} & a_{02} \\ a_{10} & a_{11} & a_{12} \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} = \begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} \tag{1}$$

Equation (1) is represented by two Equations in (2-a) and (2-b).

$$x' = a_{00}x + a_{01}y + a_{02} \tag{2-a}$$

$$y' = a_{10}x + a_{11}y + a_{12} \tag{2-b}$$

When all pixels of the original image **S** are transformed by Equations (2-a) and (2-b), we can obtain the transformed image **D**, where all the pixels on images **S** and **D** are represented as discrete integer values. Fig. 1-(a) shows an example of affine transform from image **S** to image **D**. Not all parts of image **D** is filled by the pixels of image **S**.