

Chapter 3

Quantum Geometric Transformations

ABSTRACT

Geometric transformations are basic operations in image processing. This chapter describes geometric transformations of images and videos. These geometric transformations include two-point swapping, symmetric flip, local flip, orthogonal rotation, and translation.

INTRODUCTION

Many applications in both 2D and 3D biomedical imaging require efficient techniques for geometric transformations of images (Arce-Santana & Alba, 2009; Dooley, Stewart, Durrani, Setarehdan, & Soraghan, 2004). Quantum geometric transformations provides a feasible method to implement efficient geometric transformation. Geometric transformations, such as two-point swapping, flip, orthogonal rotation, and restricted geometric transformation, are applied to images based on FRQI (Iliyasu, Le, Dong, & Hirota, 2012; Le, Iliyasu, Dong, & Hirota, 2010, 2011). Next, quantum geometric transformations of images and videos based on NASS were proposed (Fan, Zhou, Jing, & Li, 2016). This chapter introduces quantum geometric transformations of images and videos based on NASS, which include two-point swapping, symmetric flip, local flip, orthogonal rotation, and translation.

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TWO-POINT SWAPPING

Definition 4.1. A two-point swapping operator G_s^t for images and videos is defined as

$$G_s^t = |s\rangle\langle t| + |t\rangle\langle s| + \sum_{i=0, i \neq s, t}^{2^n-1} |i\rangle\langle i|, \quad (4.1)$$

where $|s\rangle$ and $|t\rangle$ encode the coordinates of the two swapped pixels. The binary expansions of the integers s , t , and i are $s=s_1, \dots, s_n$, $t=t_1, \dots, t_n$, and $i=i_1, \dots, i_n$, respectively.

The NASS state $|\psi\rangle$ represents a multi-dimensional image (i.e., a 2D image or a 3D video) with 2^n pixels,

$$|\psi\rangle = \sum_{j=0}^{2^n-1} \theta_j |j\rangle. \quad (4.2)$$

Applying G_s^t on the NASS state $|\psi\rangle$ implements the two-point swapping of a multi-dimensional image,

$$G_s^t |\psi\rangle = \sum_{i=0}^{2^n-1} \theta_i G_s^t |i\rangle = \theta_s |t\rangle + \theta_t |s\rangle + \sum_{i=0, i \neq s, t}^{2^n-1} \theta_i |i\rangle. \quad (4.3)$$

To design the quantum circuit of the two-point swapping operator G_s^t , we first introduce Gray code (Nielsen & Chuang, 2000). Suppose that s and t are two distinct binary numbers, then a Gray code that connects s and t is a sequence of binary numbers, which starts with s and ends with t , where adjacent members in the list differ by exactly one bit. For example, when n bit binary numbers $s=0\dots 0\dots 0$ and $t=1\dots 1\dots 1$ are the binary expansions of the integers 0 and $2^n - 1$, respectively, the Gray code is as follows,

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