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

$$G_s^t = \left|s\right\rangle\langle t\,| + \left|t\right\rangle\langle s\,| + \sum_{i=0, i\neq s,t}^{2^n-1} \left|i\right\rangle\langle i\,|, \tag{4.1}$$

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 $s=s_1,\ldots,s_n$, $t=t_1,\ldots,t_n$, and $i=i_1,\ldots,i_n$, respectively.

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

$$\left|\psi\right\rangle = \sum_{j=0}^{2^n-1} \theta_j \left|j\right\rangle. \tag{4.2}$$

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

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

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 $s=0\ldots0\ldots0$ and $t=1\ldots1\ldots1$ are the binary expansions of the integers 0 and $2^n - 1$, respectively, the Gray code is as follows,

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