

## 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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