Design of Quantum Circuit Using Second Order Poisson Equation for Quantum Image Processing

G. Chinnasamy, S. Sairabanu and A. Sanjay Gandhi

Dept of ECS, Karpagam Academy of Higher Education, Coimbatore.

Abstract

Quantum boundary detection an images plays the crucial role in quantum image processing. Theoretically the construction of quantum circuit provides the wide opportunity for implementing the quantum image processing in quantum computer. In this paper, quantum edge detection was achieved for two dimensional images using the solution of second order Poisson equation. For the simulations of quantum based edge detection, three types of images are experimented (real, synthetic and microscopic). Results of the simulations are compared to other edge operators like Sobel, Prewitt and Canny. And the performances of all edge operators are evaluated using subjective and objective method (Peak Signal-to-Noise Ratio -PSNR). From the evaluation, quantum edge operator gives the best results among other conventional operators such as Sobel, Prewitt and Canny edge detectors.

Key Words: Quantum circuit, quantum image processing, quantum edge detection, PSNR.
1. Introduction

The theory of quantum mechanics was prompted by the failure of classical physics in explaining a number of microphysical phenomena that were observed at the end of nineteenth and early twentieth century’s. In recent years, quantum mechanics has been connected with computer science, information theory in communication and digital signal processing. One believable and exciting approach is Quantum Information Processing (QIP) [1, 2]. The analysis and use of visual information is a first order task for researchers. Due to the architecture of classical computers and to the computational complexity of state-of-the-art algorithms, it is required to find better ways to store, process and retrieve information for image processing. The Quantum Image Processing that how to store an image using a quantum system as well as some of the unique properties of that storage process derived from quantum mechanics laws [3]. The quantum superposition and quantum state collapse theories was a result of random observation which take advantage in quantum edge detection algorithm [4]. M. Gorgon et al [10] proposed that the frame rate due to increasing image resolution together to increasing of the number of single pixel representation is more efficient to computing structures. The most commonly used method to implementing image processing on personal and industrial computes are general purpose processor (GPP). Tseng and Hwang [5] proposed a quantum image edge detection algorithm which takes advantage of quantum superposition and quantum state collapse theories by means of random observation. However, the results of edge detection mainly depend on the edge extraction results by Sobel operator. Li Ying and Jiao Li-cheng [6] says an edge detection algorithm based on the edge detection algorithm based on a quantum evolutionary algorithm. The results depended on the cost function and its computational cost is very high, and easy to fall into the most superior in local areas. Xie Ke-fu [14] proposed a quantum-inspired mathematical morphology operator and applied, it can detect edge of the image corrupted by noise more efficiently than that traditional morphological processing. Lou and Ding [15] introduced the motion concept of quantum particles into boundary extraction, but the method was only estimated with a simple hypothesis and an initial point near the object boundary was needed. However, the results of edge detection mainly depend on the edge extraction results by the Canny operator [7, 8]. Based on the quantum theory the researchers needed as some possible image processing [9]. The fundamental difference between quantum and classical operation are impossible processing in quantum computers. We need to extend our knowledge on fundamental and efficient operation to design fast algorithms for quantum image processing. The N-Sized image, the clearly analysis of quantum circuits show that the complexity is O (log² N) for two-point swapping and O (log N) for the quantum operation, since it can be built by arbitrary geometric transformation, operation take place slower than the process. The local transformation is slower is ones among quantum image [12]. In quantum circuit models of computation, designing such circuits is necessary to realize and analyze any quantum
algorithm. It is well known that any unitary operation or quantum algorithm can be decomposed into a circuit consisting of a succession of basic unitary gates that act on one or two qubits only[13]. Many elementary gates including single qubit gates, controlled-NOT or CNOT and Toffoli gates for quantum computation. The Poisson solver opens up entirely new horizons in solving structured system on quantum computers such as those involving Toeplitz matrices[14]. In this paper, the solution of Second ordered Poisson’s equation is implemented to design a circuit for edge detection application in image processing techniques.

2. Quantum Image Processing

The qubit is the basic memory unit in a quantum computer. The state of a qubit is a unfounded belief of two quantum states \( |0\rangle \) and \( |1\rangle \), i.e.

\[
|\phi\rangle = \alpha|0\rangle + \beta|1\rangle \quad \text{............................ (1)}
\]

Where \( \alpha \) and \( \beta \) are probability amplitudes of states \( |0\rangle \) and \( |1\rangle \), and \( |\alpha|^2 \), \( |\beta|^2 \) are the measurement probability of state \( |0\rangle \) and \( |1\rangle \) respectively. They must persuade the relation of \( |\alpha|^2 + |\beta|^2 = 1 \);

\( |0\rangle \) and \( |1\rangle \) are the two ground states in one qubit system. According to the principle of quantum states superposition, then, the state of the \( n \) qubits quantum subsystem is the tensor product state of \( n \) qubits, which is defined

\[
|\psi\rangle = |\phi\rangle \otimes |\phi\rangle \otimes \cdots |\phi\rangle = \sum_{b_1} \sum_{b_2} \cdots \sum_{b_n} a_{b_1} a_{b_2} \cdots a_{b_n} |00\ldots0\rangle + a_{b_1} a_{b_2} \cdots a_{b_n} |00\ldots1\rangle + \cdots |1\ldots1\rangle = \sum_{i} w_i |\psi_i\rangle \quad \text{.................. (2)}
\]

Where the state vector \( |b_i\rangle \) is the \( i^{th} \) ground state in the \( n \)-qubit system, \( b_i \) is the \( n \)-bit binary number, \( w_i \) is the probability amplitudes of the \( i^{th} \) ground state \( |w_i|^2 \) is the probability of the \( i^{th} \) ground state. They must assure the normalizing condition

\[
\sum_{i=0}^{2^n - 1} |w_i|^2 = 1 \quad \text{................................. (3)}
\]

2.1. Storing an Image in a Quantum System

The theoretical and technological assumptions of classical computers that make sense of standard specify colors used to color models. In the case of quantum computers, the parameters of a qubit allows us to store information without having to pre-process it. This approach has a clear advantage over color models: every color can be studied and analyzed using the actual values of its physical parameter (frequency), rather than a representation of it (e.g. a linear combination of RGB).

Although, using classical analog computers instead of quantum computers could be an attractive choice in terms of how much information can be stored in a single unit of storage.
Storing an image using Dirac (Bra- ket) by solving Schrodinger’s equation

\[ i\hbar \frac{\partial \psi}{\partial t} = -\frac{\hbar^2}{2m} \frac{\partial^2 \psi}{\partial t^2} + v(x)\psi \]  
………………………(4)

If we consider two energy level

\[ \Psi_n(x,t) = \alpha_1 \frac{2}{L} \sin (k_1 x) e^{-i/hE_1 t} + \alpha_2 \frac{2}{L} \sin (k_2 x) e^{-i/hE_2 t} \]

\[ |0\rangle = \frac{2}{L} \sin (k_1 x) \]

\[ |1\rangle = \frac{2}{L} \sin (k_2 x) \]

\[ a(t) = e^{-i/hE_1 t}, \ b(t) = e^{-i/hE_2 t} \]

\[ \text{Qubit} = a(t)|0\rangle + b(t)|1\rangle \]  
………………………… (5)

3. Quantum Enhancement

Owing to the highly complex imaging mechanics, the images are usually of the characteristics such as low contrast, containing noise, more dark, blurry and complex and so on. However, practical edges are usually blurred, low contrast because of the impact of optics, sampling, and other imaging imperfections. Therefore, the real edges are more like a ramp profile. In order to detect edge effectively, image enhancement for images is needed to obtain high contrast and eliminate noise to some degree. In our method, an image enhancement operator based on the quantum probability statistics was proposed firstly, which combines with gray correlative characteristic of pixels in the 3×3 neighborhood window. There are eight ground states in a three qubits system, which are |000>, |001>, |010>, |011>, |100>, |101>, |110> and |111>. According to the three qubits direct product state equation in QIP, it can calculate the probability amplitudes of each ground state in the three qubits system.

Let \( P_i \) be the current \((m, n)\) pixel and \( P_i \) denotes the arbitrary pixel in the 3 × 3 neighborhood of \( P_i \). \( F \) is the normalized gray value of the corresponding pixel, \( F_i \in [0, 1] \). In the horizontal direction of the 3 × 3 neighborhood window, the state vector in the three qubits subsystem \(|Q_1 Q_2 Q_3\rangle\) is computed by

\[ |Q_1 Q_2 Q_3\rangle = \sqrt{(1-F_x)(1-F_y)}|000\rangle + \sqrt{(1-F_x)(1-F_y)}|001\rangle + \sqrt{(1-F_x)(1-F_y)}|010\rangle + \sqrt{(1-F_x)(1-F_y)}|011\rangle + \sqrt{(1-F_x)(1-F_y)}|100\rangle + \sqrt{(1-F_x)(1-F_y)}|101\rangle + \sqrt{(1-F_x)(1-F_y)}|110\rangle + \sqrt{(1-F_x)(1-F_y)}|111\rangle \]

\[ = \sum_{m=0}^{1} |i\rangle \]  
………………………………………………………(7)
Location Relationship of Pixels in the 3x3 Neighborhood

<table>
<thead>
<tr>
<th>Q7</th>
<th>Q6</th>
<th>Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q8</td>
<td>Q1</td>
<td>Q4</td>
</tr>
<tr>
<td>Q9</td>
<td>Q2</td>
<td>Q3</td>
</tr>
</tbody>
</table>

Where \(|w_i|^2\) is the probability of the corresponding ground state in three qubits subsystem, composed of \(Q_8\), \(Q_1\), \(Q_4\) pixels. Image edges are usually of strong directivity and tight correlation with the neighboring pixels, but the noise is relative isolative in the 3x3 neighborhood. In the horizontal direction, our operator counts the probability of the \(|0^*1>, |1^*0>\) ground states, which have much more relation with the ramp-like edge information.

### 3.1 Solution of Second Order Poisson Equation

In two dimensions the Poisson equation is

\[-\frac{\partial^2 u(x, y)}{\partial x^2} - \frac{\partial^2 u(x, y)}{\partial y^2} = f(x, y), (x, y) \in (0, 1)^2 \]

\(u(x, 0) = u(0, y) = u(x, 1) = u(1, y) = 0, x, y \in [0, 1]\)

We discretize this equation using a grid with mesh size \(h = 1/M\); see Figure 1. Each node is indexed \(u_{j,k}\) (Figure 1(a) and (b)). We approximate the second derivatives using

\[\frac{\partial^2 u}{\partial x^2}(x, y) \approx \frac{u(x-h, y) - 2u(x, y) + u(x+h, y)}{h^2}\]

\[\frac{\partial^2 u}{\partial y^2}(x, y) \approx \frac{u(x, y-h) - 2u(x, y) + u(x, y+h)}{h^2}\]

Omitting the truncation error, and denoting by \(-\nabla_h\) the discretize Laplacian we are led to solve

\[h^{-2}\left((-v_{j-1,k} + 2v_{j,k} - v_{j+1,k}) + (-v_{j,k-1} + 2v_{j,k} - v_{j,k+1})\right) = f_{j,k}, \ldots (9)\]

Where \(f_{j,k} = f(jh, kh), j, k = 1, 2, \ldots, M-1\) and \(v_{j,k} = 0\) if \(j\) or \(k \in \{0, M\}\) i.e., when we have a point that belongs to the boundary.

Using the fact that the solution is zero at the boundary, we re-index to obtain

\[h - 2(4v_i - v_{i-1} - v_{i+1} - v_{i,M-1} - v_{i,M-1}) = f_i, i = 1, 2 \ldots (M-1)^2\]

Equivalently, we denote this system by

\[-\nabla_h \tilde{v} = \tilde{f}_h, \ldots (10)\]

Where \(\nabla_h\) is the discretized Laplacian.
For example, when $M = 4$, as in Figure 1, we have that $\tilde{v} = [v^1 \ldots \ v^9]^T$. Furthermore (10) becomes

$$Ah - A_{h,2} = \frac{\Delta f}{\Delta v}.$$ 

In the 3x3 identity matrix, B is

$$
\begin{pmatrix}
4 & -1 \\
-1 & 4 & -1 \\
-1 & 4 & -1
\end{pmatrix}
$$

Hermitian matrix with a particular block structure that is independent of $M$. In particular, on a square grid with mesh size $h = \frac{1}{M}$ we have

$$-\nabla_h = h^{-2}A.$$

and $A$ can be expressed in terms of $L_h$ as follows:

$$A =
\begin{pmatrix}
Lh + 2I & -I & 0 & \cdots & \cdots & 0 \\
-I & Lh + 2I & -I & 0 & \cdots & 0 \\
0 & -I & \ddots & \ddots & \ddots & 0 \\
\vdots & \vdots & 0 & \ddots & \ddots & -I \\
\vdots & \vdots & \vdots & 0 & -I & Lh + 2I - I \\
0 & 0 & \cdots & 0 & -I & Lh + 2I
\end{pmatrix}
$$

and its size is $(M - 1)^2 \times (M - 1)^2$. Recall that $L_h$ is the $(M - 1) \times (M - 1)$ matrix shown in (6) and I is the $(M - 1) \times (M - 1)$ identity matrix. Moreover, $A$ can be expressed using Kronecker products as follows

$$A = L_h \otimes I + I \otimes L_h.$$

3.2. Design of Quantum Circuit

Quantum circuit is designed by solving the system $\Delta_h \tilde{u} = \frac{\Delta f}{\Delta v}$, where $h = 1/M$ and without loss of generality. $M$ is a power of two and the system with error $O(\epsilon)$. The following steps are followed to compute quantum circuits.
In this above figure, ‘N’ number of qubits (two dimensional qubits x and y) are applied for the preparation of superposition ‘M’.

(i) The right hand side of vector $\mathbf{f}_h$ has been prepared quantum mechanically as a quantum state $|\mathbf{f}_h\rangle$ and stored in the quantum register $B$.

$$|\mathbf{f}_h\rangle = \sum_{j=0}^{M-1} \beta_j |u_j\rangle$$

where $|u_j\rangle$ denote the eigenstates of $-\Delta_h$ and $\beta_j$ are the coefficients.

(ii) Perform phase estimation using the state $|\mathbf{f}_h\rangle$ in the bottom register and the unitary matrix $e^{-2\pi\mathbf{h}/E}$, where $\log_2 E = \lfloor \log d \rfloor + \log(4M^2)$. The number of qubits in the top register of phase estimation is $n = O(\log(E/\varepsilon))$.

(iii) Compute an approximation of the inverse of an eigenvalues $\lambda_j$. Store the result on a register L composed of $b=3\lfloor \log \varepsilon^{-1} \rfloor$ qubits. The approximation error of the reciprocals is at most $\varepsilon$.

(iv) Introduce an ancilla qubit to the system. Apply a controlled rotation on the ancilla qubit. The rotation operation is controlled by the register L which stores the reciprocals of the eigenvalues of $-\Delta_h$. The controlled rotation results to $\sqrt{1-(C_d/\lambda_j)^2}|0\rangle + (C_d/\lambda_j)|1\rangle$, where $C_d$ is a constant.

(v) Uncompute all other qubits on the system except the qubit introduced on the previous item.

(vi) Measure the ancilla qubit. If the outcome is 1, the bottom register of phase estimation collapses to the state $|\mathbf{f}_h\rangle = \sum_{j=0}^{M-1} \beta_j |u_j\rangle$ up to a normalization factor. If the outcome is 0, the algorithm has failed and we have to repeat it.
4. **Simulation Experiment-I for the Real Images**

Two real images with 256x256 pixels are taken for the experiment and the above chapter 6.2, 6.3 and 6.4 are done using MATLAB R2010a version software. Comparative performance of the conventional edge detection and quantum edge detection is studied from the following results.

![Figure 1](image1.png)

Figure 1: The original real image (from left), qubit storage of the image, Sobel edge operator, Prewitt operator, Canny operator and quantum edge operator

![Figure 2](image2.png)

Figure 2: The original real image (from left), qubit storage of the image, Sobel edge operator, Prewitt operator, Canny operator and quantum edge operator

From Images 1 and 2 show subjective (visual) method of results of the edge operators. From the visual analyse of the conventional edge operator like Sobel and Prewitt shows the poor performance than the other methods. In the case of Canny edge operator, it gives the moderate results as compared with the quantum edge operator. The proposed edge detection provides the best results among other operators. It exhibits the edges clearly but other operator fails to show those edges. An objective measurement for edge operators is done to evaluate the performance of edge operators.

| Table 1: MSE Values of Different Edge Operators for Real Images |
|-----------------|----------------|----------------|----------------|----------------|
| Photo           | 0.1063         | 0.1232         | 0.0569         | 0.0549         |
| Rose            | 0.1291         | 0.1356         | 0.0689         | 0.0674         |
Figure 3: Graph between Edge Operator and MSE of Real Images

Table 1 it shows the MSE (Mean Squared Error) values of different edge operator as well as quantum edge operation. Fig. 3 is the test results of edge detection algorithms for real images and its MSE values.

Table 2: PSNR Values of Different Edge Operators for Real Images

<table>
<thead>
<tr>
<th>PSNR in db</th>
<th>Sobel</th>
<th>Prewitt</th>
<th>Canny</th>
<th>Quantum Edge detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photo</td>
<td>9.5983</td>
<td>8.6695</td>
<td>10.9409</td>
<td>11.397</td>
</tr>
<tr>
<td>Rose</td>
<td>8.9047</td>
<td>8.0288</td>
<td>9.7931</td>
<td>9.812</td>
</tr>
</tbody>
</table>

Figure 4: Graph between Edge Operator and PSNR of Real Images

Normally, the lowest value of MSE provides higher PSNR values. Because Mean Squared Error is inversely proportional to PSNR values. From the above table 1, 2 and figure 3, 4 show the performance of the edge operators. Normally, the lowest value of MSE provides higher PSNR values for the images. The proposed method provides the best results as compared with other edge operators. For the first real image (photo.jpg), Prewitt edge operator has higher MSE value (0.1232) followed by Sobel (0.1063), Canny (0.0569) and quantum edge detection (0.549). Likewise the corresponding PSNR values are tabulated and graphically shown table 2 and figure 4. Prewitt operator has the lowest
PSNR value (8.0288) and it shows the poor quality of edge detection among others. And for the second real image (rose.jpg) also prewitt operator has high MSE value and low PSNR value compared with other methods. From above tables and graphs, it is clearly evident that quantum edge detection provides the lowest MSE value (0.0549 and 0.674 respectively) and high PSNR values. The proposed method renders the best results among other methods.

**Simulation Experiment-II for the Synthetic Images**

![Image](image1)

Figure 5: The synthetic image (from left), qubit storage of the image, Sobel edge operator, Prewitt operator, Canny operator and quantum edge operator

![Image](image2)

Figure 6: The synthetic image (from left), qubit storage of the image, Sobel edge operator, Prewitt operator, Canny operator and quantum edge operator

From images 5 and 6 shows subjective (visual) method of results of the edge operators. From the visual analyse of the conventional edge operator like Sobel and Prewitt shows the poor performance than the other methods. In the case of Canny edge operator, it gives the moderate results as compared with the quantum edge operator. The proposed edge detection provides the best results among other operators. It exhibits the edges clearly but other operator fails to show those edges. An objective measurement for edge operators is done to evaluate the performance of edge operators.

**Table 3: MSE Values of Different Edge Operators for Synthetic Images**

<table>
<thead>
<tr>
<th></th>
<th>MSE</th>
<th>Sobel</th>
<th>Prewitt</th>
<th>Canny</th>
<th>Quantum Edge detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logo1</td>
<td>0.0750</td>
<td>0.0723</td>
<td>0.0604</td>
<td>0.0525</td>
<td></td>
</tr>
<tr>
<td>Logo2</td>
<td>0.0973</td>
<td>0.1173</td>
<td>0.0704</td>
<td>0.0576</td>
<td></td>
</tr>
</tbody>
</table>
Table 4: PSNR Values of Different Edge Operators for Synthetic Images

<table>
<thead>
<tr>
<th>PSNR in db</th>
<th>Sobel</th>
<th>Prewitt</th>
<th>Canny</th>
<th>Quantum Edge detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logo2</td>
<td>6.719</td>
<td>7.253</td>
<td>9.4523</td>
<td>10.197</td>
</tr>
</tbody>
</table>

Figure 8: Graph between Edge Operator and PSNR for Synthetic Images

Table 3 it shows the MSE (Mean Squared Error) values of different edge operator as well as quantum edge operation. Figure 7 is the test results of edge detection algorithms for synthetic images and its MSE values. Likewise, Table 4 it shows the PSNR (Peak Signal to Noise Ratio) values of different edge operator as well as quantum edge operation. Figure 8 is the test results of edge detection algorithms for synthetic images and its PSNR values. Above tables and graphs proves that the proposed quantum edge detector gives the best result for synthetic images. For the first synthetic image (Logo1.jpg), Sobel edge operator has higher MSE value (0.0750) followed by Prewitt (0.0723), Canny (0.0604) and quantum edge detection (0.0525). Likewise the corresponding PSNR values are tabulated and also graphically shown (table 3 and figure 7). Sobel operator has the lowest PSNR value (9.159 db) and it shows the poor quality of edge detection among others. And for the second synthetic image...
Sobel operator has high MSE value (0.0973) and low PSNR value (6.719 db) compared with other methods. From above tables and graphs, it is clearly evident that quantum edge detection provides the lowest MSE value (0.0525 and 0.0576 respectively) and high PSNR values (11.4057 db and 10.197 db). The proposed method renders the best results among other methods.

**Simulation Experiment-III for the Microscopic Images**

![Figure 9: The SEM image(from left), qubit storage of the image, Sobel edge operator, Prewitt operator, Canny operator and quantum edge operator](image1)

![Figure 10: The SEM image(from left), qubit storage of the image, Sobel edge operator, Prewitt operator, Canny operator and quantum edge operator](image2)

From images 9 and 10 shows subjective (visual) method of results of the edge operators. From the visual analyse of the conventional edge operator like Sobel and Prewitt shows the poor performance than the other methods. In the case of Canny edge operator, it gives the moderate results as compared with the quantum edge operator. The proposed edge detection provides the best results among other operators. It exhibits the edges clearly but other operator fails to show those edges. An objective measurement for edge operators is done to evaluate the performance of edge operators.

<table>
<thead>
<tr>
<th></th>
<th>MSE</th>
<th>Sobel</th>
<th>Prewitt</th>
<th>Canny</th>
<th>Quantum Edge detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEM1</td>
<td>0.0845</td>
<td>0.0684</td>
<td>0.0458</td>
<td>0.0341</td>
<td></td>
</tr>
<tr>
<td>SEM2</td>
<td>0.1232</td>
<td>0.0789</td>
<td>0.0591</td>
<td>0.0453</td>
<td></td>
</tr>
</tbody>
</table>
Figure 11: Graph between Edge Operators and MSE Values for Microscopic Images

Table 6: PSNR Values of Different Edge Operators for Microscopic Images

<table>
<thead>
<tr>
<th>PSNR in db</th>
<th>Sobel</th>
<th>Prewitt</th>
<th>Canny</th>
<th>Quantum Edge detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEM1</td>
<td>9.852</td>
<td>9.7327</td>
<td>11.397</td>
<td>13.5232</td>
</tr>
<tr>
<td>SEM2</td>
<td>8.698</td>
<td>9.0254</td>
<td>10.4321</td>
<td>12.3037</td>
</tr>
</tbody>
</table>

Figure 12: Graph between Edge Operators and PSNR Values for Microscopic Images

Table 6 it shows the MSE (Mean Squared Error) values of different edge operator as well as quantum edge operation. Figure 11 is the test results of edge detection algorithms for microscopic images and its MSE values. Likewise, Table 6 it shows the PSNR (Peak Signal to Noise Ratio) values of different edge operator as well as quantum edge operation. Figure 12 is the test results of edge detection algorithms for microscopic images and its PSNR values. Above tables and graphs proves that the proposed quantum edge detector gives the best results for microscopic images. For the figure 9, microscopic image (SEM1.jpg), Sobel edge operator has higher MSE value (0.0845) followed by Prewitt (0.0684), Canny (0.0458) and quantum edge detection (0.0341). Likewise the corresponding PSNR values are tabulated and also graphically shown (table 3 and figure 7). Sobel operator has the lowest PSNR value (9.852 db) and it shows the poor quality of edge detection among others. And for the second
microscopic image, (figure 10, SEM2.jpg), Sobel operator has high MSE value (0.1232 and low PSNR value (8.698 db) compared with other methods. From above tables and graphs, it is clearly evident that quantum edge detection provides the lowest MSE value (0.0341 and 0.0453 respectively) and high PSNR values (13.5232 db and 12.3037 db). The proposed method renders the best results among other methods.

Conclusion

In this work, quantum edge detection algorithm and circuit is formulated from the approximation of second order Poisson’s equation. The proposed algorithm is implemented in the classical computer to speed up the performance of quantum image processing. The suggested quantum circuit helps to improve the design of quantum computer in classical computer. This approach reduces the complexity of the algorithm. The performance of quantum edge detection algorithm and circuit is studied by implementing the algorithm in various images (i.e. Real, Synthetic and Microscopic). Results of this approach are evaluated using peak-signal to noise ratio with conventional operators (Sobel, Prewitt and Canny). The proposed quantum edge detection method and its circuit gives the best results for the all three types of images (i.e real, synthetic, and microscopic) as compared to Sobel, Prewitt and Canny edge operator. From these three types, microscopic images furnish the best result because of its high resolution and less noise among others. In the case of synthetic image, the proposed method gives good result. For the real image, the proposed operator is worked well but the noise and resolution causes high MSE and low PSNR values among other images. Second order Poisson’s solution based quantum edge detection contributes the best results.

References


