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Quantum Image Storage, Retrieval and Teleportation

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***Abstract-** Image storage, retrieval and compression are the basic tasks of an imaging system. Many classical approaches are there to do this task but the results of this paper showed that the use of quantum mechanical approaches give better results. For image storage a quantum machine was used and the quantum states were prepared as the function of θ which itself was a function of the frequency. For image retrieval measurements on the spin of the maximally entangled pairs was done for every pixel. The probabilistic result gives the probability of the presence of a color in an image. Classical approach gave 0.5 probability of retrieving the color whereas quantum mechanical approach gave 0.846 probability of retrieving the two colors. Quantum teleportation was used for image transmission. The teleportation was performed using bell channel for which 100% probabilistic success was obtained.*

***Keywords-** Image storage, Image retrieval, Measurement, Entanglement, Teleportation*

I. INTRODUCTION

Quantum computation has laid new methods for solving arduous problems efficiently. Quantum computation is applied in many fields like neural network, Information sharing and transmission, image processing. In this paper quantum techniques were used for image processing. These are very basic techniques like image storage, image retrieval, image compression and image transmission. However, these techniques are also applicable using classical methods of image processing but the results have showed that the use of quantum techniques in image processing improves the results in terms of speed, security, storage and complexity. [2] showed image storage, retrieval, compression and segmentation in a quantum system. But, the methodology obtained in this paper was unique. To compare between classical and quantum mechanical approaches some illustrations were considered. The paper also brought up some new algorithms for image retrieval, image compression and protocol for successful image transmission. Entanglement is a striking feature of quantum mechanics. Quantum entanglement is defined as the interaction of two quantum particles in which measurement on one particle gives the state of another particle even if the two particles are separated by longer distances. This feature was used during measurements for image retrieval. A two qubit maximally entangled state is given by

$$\frac{|01> - |10>}{\sqrt{2}}$$

Measurement of a component of the spin in any direction for the first particle will be either down or up with probability ½.This result will automatically imply that the spin of second particle will be either up or down in the same direction. Likewise if measurement for the first particle is done in some direction and the measurement of second particle is done at some angle θ with respect to the measurement direction of first particle then the probability that the second particle will have opposite spin is $\cos^2(\frac{\theta}{2})$. And probability that the second particle will have same spin is $\sin^2(\frac{\theta}{2})$. This feature gave the probabilistic results of the measurements on image retrieval. A similar technique was used by Prof. Diptiman Sen (personal communication, October 21st, 2010) to answer questions in quantum games.

For image transmission quantum teleportation was used. It is yet another striking feature of quantum mechanics which uses quantum entanglement. In quantum teleportation the actual state of a particle is kept and its replica is sent through classical operations and local communications. The result showed effectiveness of quantum techniques for image storage, image retrieval, image compression and image transmission. The next sections will be on image storage, retrieval and teleportation in a quantum system.

II. IMAGE STORAGE

An image in a basic form is a function of an illumination source and the reflectance or transmittance function of the object which is to be imaged. The image function IF(x,y) is given by

$$IF(x,y) = I(x,y)\, r(x,y) \qquad (1)$$

However, the IF(x,y) is a raw representation of an image. To convert the image into the digital form a series of sensors are used. To obtain a two dimensional image there should be a relative displacements between the sensor and the area to be imaged. The incoming energy is converted into the voltage form. The voltage signal obtained is sampled and quantized to make the signal into the digital form. A classical image is likely to get affected by imaging artifacts due to imperfection in imaging techniques. Imperfection in illumination source or imaging surface, use of technically erroneous sensors, quantization error are some of the factors which may cause imaging artifacts. Another way of storing an image is by using quantum techniques which is discussed in the next section.

A. STORING AN IMAGE QUANTUM MECHANICALLY

A quantum bit like a classical bit can exist in the states state |0> and |1> but the striking feature of a quantum bit is that it can also exist in the superposition states of |0> and |1>.The superposition state of a quantum bit can be represented as

$$|\omega> = \alpha|0> +\beta|1> \quad (2)$$

Where, $\alpha^2 + \beta^2 = 1$, α^2 is the probability of finding $|\omega>$ in state $|0>$ and β^2 is the probability of finding $|\omega>$ in state $|1>$. Likewise $|\omega>$ can be represented in trigonometric form as shown below

$$|\omega> = \cos\frac{\theta}{2}|0> + \sin\frac{\theta}{2}|1> \quad (3)$$

where, $\cos^2\frac{\theta}{2} + \sin^2\frac{\theta}{2} = 1$

A digital image comprises of a set of pixels containing the intensity values. The intensity value of a pixel determines its colour. The Colour can be represented and analysed by its frequency. Hence, to store an image quantum mechanically a machine capable of detecting frequencies as in [1] can be used. The output of a machine initializes the state of a qubit. The parameter θ in (3) varies with the frequency of the colour. For a frequency a certain state can be prepared. The Fig.1 shows a model of storing an image.

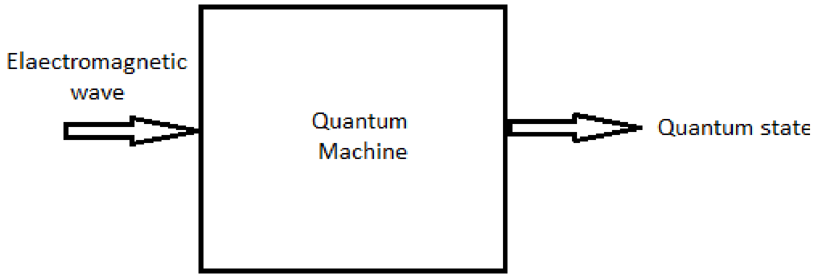


Fig.1 Quantum machine capable of detecting electromagnetic frequencies into quantum states

Thus, for each frequency there is a value of θ which determines the state of a qubit. These qubits can be stored in a qubit lattice Q. To store these qubits in a qubit lattice quantum memory is used. However quantum memory faces a problem of entanglement loss which can be removed by entanglement distillation.

III. IMAGE RETRIEVAL

Image retrieval is a process of retrieving stored images from the database. In this section two methods are discussed for image retrieval. First method is well known classical approach and the second method is a quantum mechanical approach for image retrieval. The comparison between the classical and quantum mechanical approaches of image retrieval as given in section B and C is done by considering an example of a 2x2 image and retrieving its four colours. An algorithm for image retrieval using quantum mechanical approach is discussed in the section A.

A.ALGORITHM FOR QUANTUM MECHANICAL IMAGE RETRIEVAL

The algorithm for quantum mechanical image retrieval is as follows-

(1) Once all the qubits are stored in a qubit lattice Q. First qubit of color C_1will have state $|\emptyset_{11}> = |0>$ and any random qubit of color C_2 will have state $|\emptyset_{ij}> =$ |1>. Traverse the qubit lattice either horizontally or vertically till the sate |0> or |1> comes.
(2) For the states following state |0> prepare copies of two qubit maximally entangled state and measure the two qubit maximally entangled states for the opposite value of spin.
(3) For the states following state |1> prepare copies of two qubit maximally entangled state and measure the two qubit maximally entangled states for the same value of spin.
(4) A probabilistic result for each of the colors in cubic lattices will be obtained.
(5) Colors $C_1$and C_2 can be retrieved as they have states |0> and |1>.

For colors, measurement will be performed in certain directions and the colors will be retrieved on the basis of the probability of the direction of spin. The algorithm for image retrieval proposed above can be better explained by an example. Consider a 2x2 image as shown in fig.2(a).The image contains four colours C_1, C_2, C_3, C_4.Efficiency of the quantum technique is checked by comparing it with classical approach for image retrieval. The next section discusses classical approach for image retrieval.

B. CLASSICAL APPROACH FOR IMAGE RETRIEVAL

The image contains four colours C_1, C_2, C_3, C_4.The two colors lets say $C_1$and C_3 represented by states |0> and |1> can be retrieved. However, colors C_2, C_4 are retrieved with certain probability. Out of two colors C_2, C_4 the probability of retrieving colors C_2, C_4 is 0.5.

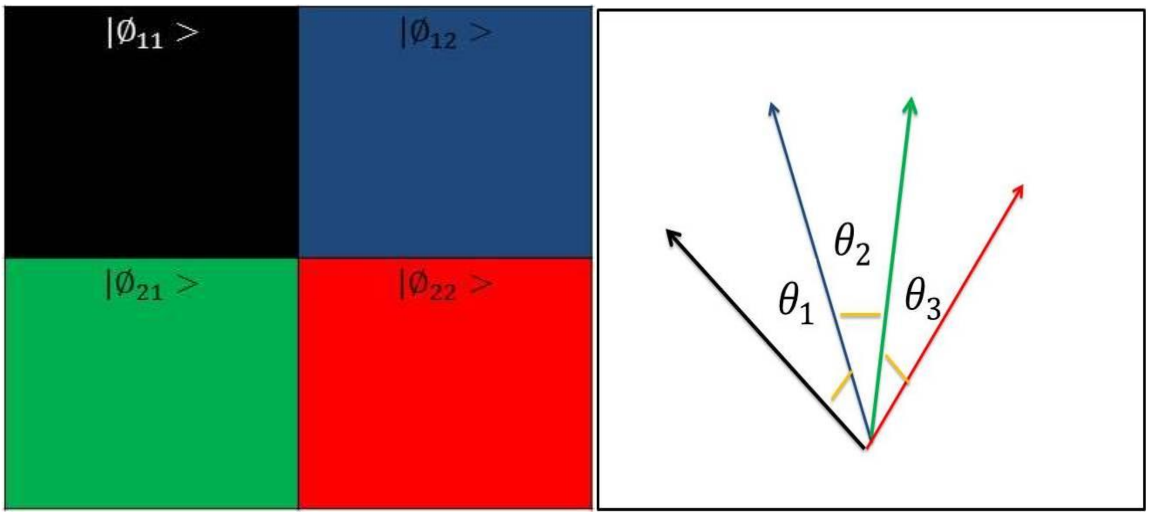
C. QUANTUM MECHANICAL APPROACH FOR IMAGE RETRIEVAL

Consider a 2x2 image as shown in fig.2 (a) stored in a qubit lattice Q. $|\emptyset_{ij}>$ are the quantum states of colorsC_1, C_2, C_3, C_4 stored in the qubit lattice. The image contains four different colors out of which colors $C_1$and C_3 have states |0> and |1> repectively. After the storage of an image in the qubit lattice the image can be retrieved efficiently using a quantum mechanical approach. The algorithm proposed for image retrieval can be used for image retrieval.

(1). Traversing the qubit lattice row wise. The state of color black is $|\emptyset_{11}>$ = |0> and the state of colour green is $|\emptyset_{21}>$ = |1>

(2). Since, the state $|\emptyset_{12}>$ follows state |0> hence, preparing a two qubit maximally entangled state for the state $|\emptyset_{12}>$ with the color of state |0> and storing them in another qubit lattice.
(3). Again traversing the qubit lattice from the state $|\emptyset_{21}>$ and preparing a two qubit maximally entangled state for the state $|\emptyset_{22}>$ with the color of state |1> and storing them in the qubit lattice.
(4). Colors black and green are known by their states whereas the colors blue and red are unknown as they are in the superposition states.
(5). To retrieve colors blue and red measurements are done on the spin of the maximally entangled states.

After the known state $|\emptyset_{11}>$ = |0> and the state $|\emptyset_{21}>$ = |1>. The state $|\emptyset_{12}>$ will have a color either C_2 or C_4 and similarly state $|\emptyset_{22}>$ will have a color either C_2 or C_4.Hence, measurement will performed using the fig.2 (b)



(a) (b)

Fig.2 (a) Qubit lattice (b) Arrow diagram for doing measurements

For the two qubit maximally entangled state prepared for the state $|\emptyset_{12}>$ measurement will be done for the opposite value of spin.Whereas, for the state $|\emptyset_{22}>$ measurement will be done for the same value of spin.With this strategy the expression for their probabilistic measurements is given by

$$\frac{1}{4}[\cos^2\left(\frac{\theta_1}{2}\right)+\cos^2\left(\frac{\theta_1+\theta_2}{2}\right)+\sin^2\left(\frac{\theta_3}{2}\right)+\sin^2\left(\frac{\theta_3+\theta_2}{2}\right)]$$

Maximizing the above expression with respect to θ_1, $\theta_2$and $\theta_3$we get the the expression is maximum for $\theta_1=\frac{\pi}{4}$, $\theta_2=\frac{-\pi}{2}$, $\theta_3=\frac{\pi}{4}$

Hence, the probability of measuring the color C_2 is $\cos^2\left(\frac{\pi}{8}\right)$ = 0.846

And, the probability of measuring the color C_4 is $\cos^2\left(\frac{\pi/4-\pi/2}{2}\right)$ = 0.846

IV. IMAGE COMPRESSION

Image compression is a technique of reducing the redundant data and transmitting the data containing relevant information. This increases the data rate as well as reduces the size of storing the data. In classical communication image compression is a prerequisite step for speedy communication. Image compression is of two types lossless compression and lossy compression. Lossless compression is compression technique that allows the original data to be reconstructed from the compressed data.

This technique is free from compression artifacts and thus useful in medical imaging where the quality of an image cannot be compromised and the image should be free from artifacts. Lossless compression has some limitations like it cannot be used to compress all set of data. On the other hand lossy compression is an encoding technique that compresses the data by removing the redundant information contained in an image. Lossy compression in contrast with lossless compression faces a problem of compression artifact as the original image cannot be reconstructed from the compressed image. Hence, loss of information takes place.

As seen both the compression techniques have their limitations in compressing the data. A technique for image compression is also discussed in [2]. In the next section a new approach is adopted for data compression. The approach is a quantum mechanical approach which uses quantum superposition states for efficient data compression.

A.ALGORITHM FOR QUANTUM MECHANICAL IMAGE COMPRESSION

An algorithm for image compression has been proposed. The algorithm is as follows-

(1) Once all the qubits are stored in a qubit lattice Q of size n x n. Traverse the qubit lattice either horizontally or vertically.
(2) If the states $|\emptyset_{ij}>$ are repeating then drop the repeating states and entangle the state with the qubit states $|\tau>$ representing integers.
(3) The qubit states $|\tau>$ are used to show the number of times a state has been repeated.

$|\tau\rangle = \{|\tau_1\rangle, |\tau_2\rangle, |\tau_3\rangle \ldots\ldots\ldots\ldots |\tau_n\rangle\}$ and $|\emptyset_{ij}\rangle \neg\in \{|0\rangle, |1\rangle\}$

(4) The final qubit lattice Q' obtained from step 2 will be a compressed qubit lattice. Fig.3 (b) shows the structure of a compressed qubit lattice Q'.

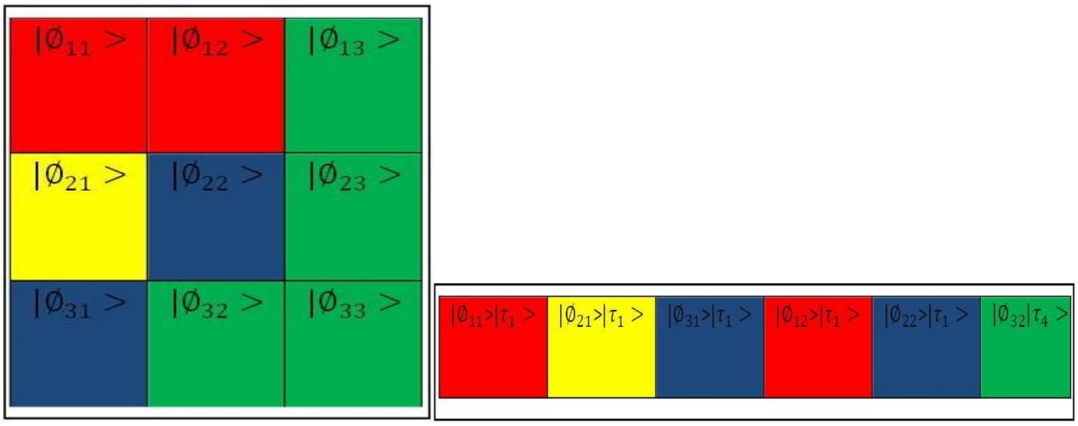
The algorithm for image compression proposed above can be better explained by an example. Fig.3 (a) shows a 3x3 image stored in a qubit lattice Q. $|\emptyset_{ij}\rangle$ are the quantum states stored in the qubit lattice. Following the algorithm 2 for image compression.

(1).Traversed the image coulumnwise as maximum compression was achieved.

(2).Colors red, yellow, blue were repeated once whereas color green repeated four times hence, dropped the intermediate quantum states of color green.

(3).The states $|\emptyset_{ij}\rangle$ was entangled with the states $|\tau\rangle$ representing integers.

(4).The qubit lattice Q' obtained as shown in fig.3 (b) is a compressed qubit lattice.



(a) (b)

Fig.3 (a) Qubit Lattice Q (b) Compressed Qubit Lattice Q'

V. IMAGE TRANSMISSION

In the applications of television broadcasting or in communication an image transmission is done through a classical channel. For transmission, an image which is in the form of bits after compression is converted into the continuous pulses using line coding techniques. Then by using an appropriate modulation technique the image is transmitted to the receivers end. A reverse procedure is applied at the receiver end and the image is acquired. However this classical method of image transmission has some drawbacks like slow data rate, inefficient compression technique, error in the transmission channel, information loss in image due to inefficient compressor. These drawbacks are practically inevitable. One of the major drawbacks in classical method is insecure transmission. In this paper a quantum mechanical method is discussed for image transmission. The method uses quantum teleportation technique. The technique is discussed in the next section.

A. IMAGE TRANSMISSION USING QUANTUM TELEPORTATION

Quantum teleportation is a phenomenon in which a particle can be transmitted from one location to another without actually being transmitted through the channel. This process takes place at a superluminal speed. Therefore to use this in communication a local communication between the sender and a receiver takes place. The steps required in teleportation are

(1).The sender entangles the state to be sent through the quantum channel.

(2).The sender performs measurements on his qubits, yielding classical bits of information.

(3).Using classical medium the bits are sent from sender to receiver.

(4).On the basis of received bits, the receiver performs local operations on the received qubit state and the desired state is obtained.

In this paper a protocol for teleporting an image is discussed. The protocol is described for the 2x2 image shown in fig.2 (a). The protocol uses a bell channel for teleporting an image. The bell state is given by

$$\frac{|00\rangle + |11\rangle}{\sqrt{2}}$$

First qubit inside the ket operator is of the sender and second qubit is of the receiver. The state of an image of an image is given by

$$|\omega\rangle = [|0\rangle|\varphi_{11}\rangle] \otimes [(\alpha_1|0\rangle + \beta_1|1\rangle)|\varphi_{12}\rangle] \otimes [|1\rangle|\varphi_{21}\rangle] \otimes [(\alpha_2|0\rangle + \beta_2|1\rangle)|\varphi_{22}\rangle] \quad (4)$$

The states $|\varphi_{ij}\rangle$ represents the location of the qubits in the qubit lattice.All the qubits in the state is of the sender.The sender entangles the state with bell state. The entangled state is given by

$$|\omega\rangle \otimes \left[\frac{|00\rangle + |11\rangle}{\sqrt{2}}\right]$$

The sender applies a hadamard gate on his qubit the state obtained is

$$|\omega> \otimes \left[\frac{|00>+|10>+|01>-|11>}{2}\right]$$

On the above state the sender performs measurements in computational basis |0> and |1>.The measurement results of the sender is shown in table I. The receiver also does measurements in computational basis |0> and |1>.The measurement results of the receiver are shown in table I. Through local communication the sender tells the receiver to apply local operations get the desired state $|\omega>$.

The above protocol can be used for an image of any size. The image was teleported with 100% probability of success.

Table I shows results of teleportation

Senders measurement	Results of sender	Receivers measurement	Results of receiver
|0>	$|\omega> \otimes \left[\frac{|0>+|1>}{2}\right]$	|0>	$\frac{|\omega>}{2}$
		|1>	$\frac{|\omega>}{2}$
|1>	$|\omega> \otimes \left[\frac{|0>-|1>}{2}\right]$	|0>	$\frac{|\omega>}{2}$
		|1>	$-\frac{|\omega>}{2}$

VI. RESULT

The algorithms proposed for image retrieval and image compression were successfully implemented using illustrations. The classical method of image retrieval gave 0.5 probability of retrieving a color whereas the quantum mechanical approach gave 0.846 Probability of retrieving both the colors. The protocol proposed for image transformation using teleportation was successfully implemented and 100% probabilistic result was obtained.

REFERENCES

[1]. Salvador Elias Venegas-Andraca (2005). "*Discrete Quantum Walks and Quantum Image Processing*". Ph.D. thesis. University of Oxford.

[2]. Hai-Sheng Li, Zhu Qingxin, Song Lan, Chen-Yi Shen, Rigui Zhou, Jia Mo (2013). "*Image storage, retrieval, compression and segmentation in a quantum system*". Quantum Information Processing. 12, 2269–2290. doi: 10.1007/s11128-012-0521-5

[3]. Prasath, S, Muralidharan, S. Panigrahi P.K., Mitra, C. "*Multipartite entangled Magnon states as quantum communication channels*", eprintquant-pH/0905.1233v2.

[4]. Nielsen, M.A., Chuang, I.L.: "*Quantum Computation and Quantum Information*". Cambridge University Press, Cambridge (2002).

[5]. Furusa WA, A. et al." *Unconditional quantum teleportation*". Science 282, 706-709 (1998).

[6]. Vidal, G. & Werner, R.F. "*Computable measure of entanglement*". Phys. Rev. A 65, 032314(2002).

