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*Research Article*

# Analysis on Simplified Method of IoT-based HHL Algorithm Corresponding Quantum Circuit for Quantum Computer Application

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Whether it is a traditional industry or a Frontier field, it has unveiled the trend of industrial IoT construction and application, which plays a vital role in building a strong manufacturing country and promoting high-quality economic development in China. HHL algorithm has become one of the important quantum algorithms, but there are few researches on the construction of quantum circuits and the application of quantum sequencing. In this paper, a model based on the quantum circuit corresponding to the HHL algorithm to deal with the quantum application problem is proposed. A quantum circuit based on HHL algorithm is used to solve the linear system, and the numerical solution of the target partial differential equation is obtained. Finally, the experimental analysis shows that, in the process of processing quantum computer application problems based on quantum circuit, it can reduce the computation amount of quantum circuit corresponding to HHL algorithm, improve the simulation efficiency of quantum circuit, and reduce the occupation of hardware resources, which has a certain effectiveness and superiority. This discussion brings new ideas for intelligent IoT technology and provides implications for the study of simplified methods of HHL algorithms corresponding to quantum circuits to deal with computer application problems.

## 1. Introduction

Along with the development of technology, our country enters into the reform of technology based on the Internet of Things. In addition, artificial intelligence technology is gradually and rapidly developing internationally, gradually forming intelligent IoT system software. Overall, the coming decades will undoubtedly be the era of quantum computing and artificial intelligence, whose research is not only exciting but also full of tests.

At present, the application of quantum algorithms cannot be separated from the process of solving the linear equations, such as partial differential equations corresponding to the problems solved. Solving the linear equations is the basis of solving many problems related to quantum applications. Among them, the HHL algorithm has become one of the important quantum algorithms due to its exponential acceleration effect when solving linear systems [1]. The key to the HHL quantization analysis algorithm is the quantization analysis phase estimation control module, which allows fast exponential value estimation of the characteristic vector material (or phase) of the operator. However, in the process of solving practical problems, how to construct quantum circuits to realize HHL algorithm and realize efficient operation is a very common and difficult problem. Most of the existing solutions are in the theoretical stage, which limits their application scope in the practical application environment [2]. For example, quantum circuits based on the matrix decomposition of the HHL algorithm based on the GLOA (Group Leaders Optimization Algorithm) contain a large number and types of quantum logic gates, resulting in high line complexity, which leads to low simulation efficiency of quantum circuits and high utilization of hardware resources. The practical application value is not high.

## 2. Methods and Principles

*2.1. Quantum Circuit.* Until now, the scientific research of artificial intelligence is basically using traditional computers to implement integrated circuit process of matrix measurement to find. Because this matrix is particularly large, so a long time with a special chip such as a GPU to find it, which is the foothold of quantum computing out. The HHL quantum algorithm is faster than the ordinary computer basically algorithm. When using the problem, only the solution matrix is sparse, the number of preconditions for solving the matrix is relatively low, and the complexity of the time calculation for measuring the absolute value of the solution vector can be reduced from the previous computer's O (NK) to the HHL quantum algorithm [3].

Quantum circuit as an expression of quantum program, also known as quantum logic circuit, is currently the most commonly used general quantum computing model, said abstract concept of quantum bit operation line, its composition includes quantum bits, line (time axis) and various quantum logic gates, and finally often need to perform quantum measurement operation to read out the results.

A true quantum computer is a hybrid structure, consisting of two parts: one is a classical computer, which performs classical calculations and controls; the other part is the quantum device, which is responsible for running quantum programs to perform quantum computations. The quantum program is a series of instructions written by the quantum language such as QRunes language that can be run on the quantum computer, which realizes the support for the quantum logic gate operation and finally, realizes the quantum computation. A quantum program is a series of instructions that operate a quantum logic gate in a certain time sequence [4]. The development of quantum device hardware faces two major problems: a high error rate of quantized bits and a low quantum number of quantum computers.

In practical applications, due to the limitation of the development of quantum equipment hardware, it is usually necessary to conduct quantum computing simulation to verify quantum algorithms and quantum applications. Quantum computing simulation is a process in which the virtual architecture (namely, quantum virtual machine) built with the resources of ordinary computers is used to realize the simulation operation of quantum programs corresponding to specific problems. Often, it is necessary to construct a quantum program that corresponds to a particular problem. The quantum program is a program that represents the quantum bit and its evolution written in classical language, in which the quantum bit and quantum logic gate related to quantum computation are represented by corresponding classical codes.

Quantum circuit as an expression of quantum program, also known as quantum logic circuit, is the most commonly used general quantum computing model, said under the abstract concepts for quantum bit operating line, its composition including quantum bit, a line (timeline), as well as a variety of quantum logic gates, finally often need a quantum measurement operation to the result read out.

Unlike traditional circuits, which are connected by metal wires to transmit voltage or current signals, in a quantum circuit, the wires can be thought of as being connected by time; that is, the state of the qubit evolves naturally over time, following the instructions of the Hamiltonian operator until it meets a logic gate and is operated [5].

*2.2. Quantum Linear Analysis.* With the continuous development of the big data business and the extensive use of artificial intelligence technology and 5G technology, the scale of data has increased explosively. Quantum computing uses quantum superposition and entanglement to solve the daily tasks of measurement and has certain advantages of speeding up when dealing with practical problems.

A quantum program as a whole should have a total quantum circuit, where the total number of quantum bits in the total quantum circuit is the same as the total number of quantum bits in the quantum program. It can be understood that a quantum program can consist of a quantum circuit, measurement operations of quantum bits in the quantum circuit, registers for saving the measurement results and control flow nodes (jump instructions), and a quantum circuit can contain operations of tens, hundreds, or even thousands of quantum logic gates. Figure 1 shows a classical and quantum circuit performing a “non”.

The execution process of a quantum program is the execution process of all quantum logic gates in a certain time sequence. “ Timing” refers to the time sequence in which individual quantum logic gates are executed. In classical computing, the most basic unit is the bit and the most basic form of control is the logic gate [6]. The purpose of the control circuit can be achieved by a combination of logic gates. Similarly, one way to deal with quantum bits is through quantum logic gates. Quantum logic gates allow quantum states to evolve. Quantum logic gates are the basis of quantum circuits and are generally represented by a unitary matrix, which is not only a matrix form, but also an operation and transformation. The effect of a general quantum logic gate on a quantum state is calculated by multiplying the left unitary matrix by the corresponding matrix of the right vector of the quantum state [7].

## 3. Solution Measures and Methods

*3.1. Quantum Circuit Model Based on HHL Algorithm.* The study of the use of quantum computing in AI is particularly important for the development of AI, and there is no doubt that there should be more frequent and close collaboration among AI researchers, quantum scholars, scientists, and electronic computer scientists. Only in this way, quantum AI can be expected to gain more technicality and power development in the developmental link [8].

This paper tries to solve the problem of dimensionality reduction of high-dimensional data by the quantum method

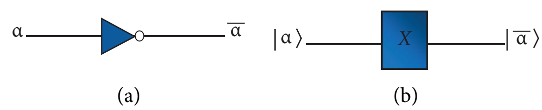


Figure 1: Classical and quantum lines performing "non".

by using the self-developed quantum computing prototype machine, and realizes the sorting application in the prototype machine. We build a quantum circuit based on the HHL algorithm to deal with quantum application problems, as shown in Figure 2.

*3.1.1. The Target Partial Differential Equation Is Discretized to Obtain the Corresponding Linear System.* The solving process of partial differential equations is also the solving process of corresponding quantum application problems. Can according to the target of partial differential equation of boundary conditions, select the corresponding basis function and form a complete set of nodes, target is given a partial differential equation (the target function) of an approximate linear combination (approximating function, namely, the linear system), namely, the approximating function requirements in all nodes and function (i.e., the original target of the partial differential equation) strictly equal, similar in height on the global. Thus, the lower-order basis function is used to complete the high-precision approximation of the equation solution, which can be called the low-order high-precision advantage [9].

Algorithms are the key to artificial intelligence technology. The Internet platform can link all the factors in industrialized production, the whole industrial chain and customer value, and open the way for the conversion of industrial production expertise to industrial production algorithms, providing a better support point for the establishment of the AI technology base [10].

The HHL algorithm solves A problem of solving linear equations: the input is an $N * N$ matrix A and an $n$-dimensional vector $b$, and the output is an n-dimensional vector $x$, which satisfies $\mathrm{A}x = b$, that is, $x = a - 1b$. The matrix A needs to be invertible, and the dimension of vector B, N, can be expressed as A positive integer power of 2 because of the following need to load the data of vector B onto the quantum circuit [11].

The idea of using the HHL algorithm to solve a system of equations over a finite domain is to transform the system of equations over a finite domain into a Boolean linear system of equations over C., which is then solved by the HHL algorithm, and Figure 3 shows the technical route of the transformation process.

The left end term matrix of the linear system directly constructed by the basis function is relatively dense, and the sparsity is often poor, so it is difficult to cope with the situation of high dimension and large scale, that is, the dimension of differential equation will lead to the rapid expansion of the problem size, and the problem size grows exponentially with the dimension [12]. Therefore, the quantum transformation algorithm can be introduced to transform the linear system into a sparse linear system.

Based on the basis function, we use the corresponding quantum transform algorithm. Here, we choose the quantum shift Fourier transform (QSFT)/quantum cosine transform (QCT) [13]. Both QSFT and QCT can construct corresponding quantum circuits through quantum logic gate operation to realize quantum state transformation, and the operation complexity is low and polynomial logarithmic.

Based on the quantum Fourier transforms, the matrix form of the one-dimensional quantum displacement Fourier transform (QSFT) is defined as follows:

$$F_p^s := \frac{1}{\sqrt{p+1}} \sum_{k,l=0}^{p} \exp\left(\frac{2\pi i\,(k - \lfloor p/2 \rfloor)\,(l - (p+1)/2)}{p+1}\right) |l\rangle\langle k|. \tag{1}$$

Therefore, quantum state transformation can be realized

$$\Big|k\rangle \longrightarrow \frac{1}{\sqrt{p+1}} \sum_{k=0}^{p} \exp\left(\frac{2\pi i\,(k - \lfloor p/2 \rfloor)\,(l - (p+1)/2)}{p+1}\right)\Big|l\rangle. \tag{2}$$

Thus, the Fourier transform of dimensional quantum displacement can be defined as follows:

$$F_p^s := p_{j=1}^{d} F_p^s = \frac{1}{\sqrt{(p+1)^d}} \sum_{\|k\|_\infty, \|l\|_\infty \le p} \prod_{j=1}^{d} e^{\left(2\pi i \left(k_j - \lfloor p/2 \rfloor\right)\left(l_j - (p+1)/2\right)/p+1\right)} \big|l_1 \cdots \big|l_d k_1\big| \cdots k_d\big|. \tag{3}$$

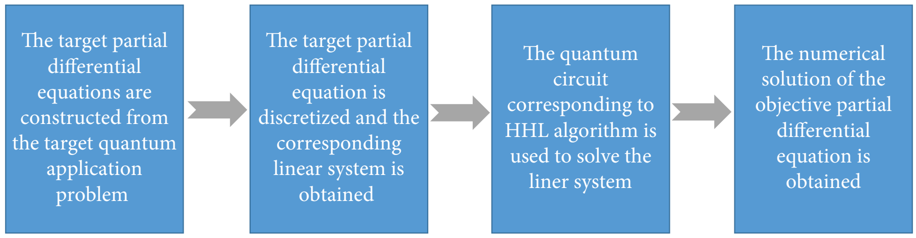


Figure 2: Handling quantum application problems.

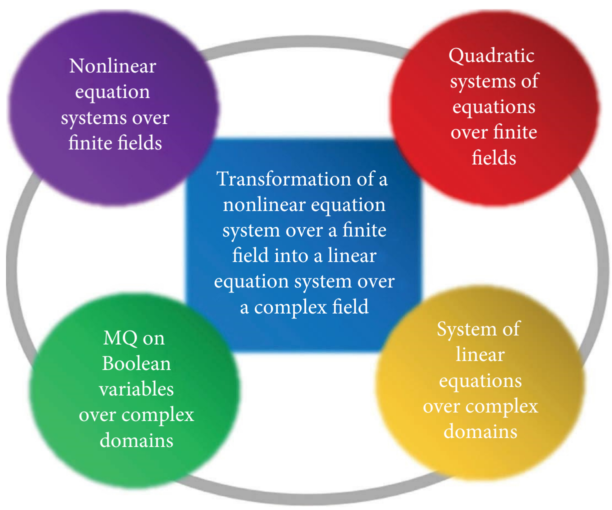


Figure 3: Conversion route of nonlinear and linear equation systems.

Among them, $k = (k_1, \cdots, k_d), k_j \in [p]_0, j \in [d]$,k、 $l$ indicator notation for values 0 through $p$, $|1|k$ represents the corresponding basis vector, $\|k\|_\infty, \|l\|_\infty$ expressed as the infinite norm, $[p]_0$ expressed as the integer set from 0 to $p$, $[d]$ is the integer set of 1 to $d$, and $p$ represent the quantum bit number required for the corresponding quantum line.

In practical application, one-dimensional QSFT can be disassemble:

$$F_p^s = S_p F_p R_p. \quad (4)$$

Among them $F_p$ is the quantum Fourier transform, $S_p$and $R_p$ is the unitary transformation mapped to its own space:

$$S_p = \sum_{k=0}^{p} e^{-(2\pi i \lfloor p/2 \rfloor (l-(p+1)/2)/p+1)} |l\rangle\langle l|,$$
$$F_p = \sum_{k,l=0}^{p} e^{(2\pi ikl/p+1)} |l\rangle\langle k|, \quad (5)$$
$$R_p = \sum_{k=0}^{p} e^{-(2\pi ik(p+1)/2/p+1)} |k\rangle\langle k|.$$

The whole QSFT line is obtained by constructing quantum lines, respectively.

The principle that quantum cosine (QCT) transformation can be defined by the discrete cosine transformation (DCT) as follows:

$$\hat{v}_l = \sqrt{\frac{2}{p}} \sum_{k=0}^{p} \delta_k \delta_l \cos\frac{kl\pi}{p} v_k, v, \hat{v} \in \mathbb{C}^{p+1}, l \in [p+1]_0. \quad (6)$$

Among them, $\mathbb{C}^{n+1}$ represents the complex space of the $(p+1)$ dimension, $v_k$ represents the original signal, $\hat{v}_l$ represents the coefficient after the DCT transformation, $\delta_k, \delta_l$ represents the defined function:

$$\delta_k := \begin{cases} \frac{1}{\sqrt{2}}, k = 0, p, \\ 1, k \in [p-1], \end{cases} \quad \delta_l := \begin{cases} \frac{1}{\sqrt{2}}, l = 0, p, \\ 1, l \in [p-1]. \end{cases} \quad (7)$$

Similarly, the matrix forms of one-dimensional and multidimensional QCT transformations are given, respectively:

$$C_p := \sqrt{\frac{2}{p}} \sum_{k,l=0}^{p} \delta_k \delta_l \cos\frac{kl\pi}{p} |l\rangle\langle k|,$$
$$C_p := \otimes_{j=1}^{d} C_p = \sqrt{\left(\frac{2}{p}\right)^d} \sum_{\|k\|_\infty, \|l\|_\infty \le p} \prod_{j=1}^{d} \delta_{k_j} \delta_{l_j} \cos\frac{k_j l_j \pi}{p} |l_1\rangle \cdots |l_d\rangle\langle k_1| \cdots \langle k_d|, \quad (8)$$
$$k = (k_1, \cdots, k_d),$$
$$l = (l_1, \cdots, l_d), k_j, l_j \in [p+1]_0.$$

Combined with the good properties of the selected basis function and quantum displacement Fourier transform/ quantum cosine transform, the corresponding quantum circuit operation can be constructed to efficiently complete the sparse operation of the linear system [14]. The left end item matrix of the linear system constructed directly by the basis function is relatively dense, and after this transformation, the left end item matrix becomes sparse, which is conducive to solving high-dimensional large-scale problems.

*3.1.2. The Quantum Circuit Corresponding to HHL Algorithm Can Obtain the Numerical Solution of Partial Differential Equations.* The HHL algorithm mainly consists of four subprocesses. As shown in Figure 4, the first step is the phase estimation marked by the dotted line in the figure; the second step is controlled $R$, that is, controlled rotation operation in the middle of the line; the third step is the inverse operation of phase estimation, and the fourth step is quantum measurement. It is firmly believed that with the slow emergence of artificial intelligence out of the small terminal and the stand-alone version of the service mode, it will eventually stimulate the quantum computing sales market, generate a large number of requirements, and open up a broader development prospect [15].

*Step 1.* Establish the first part of the quantum line corresponding to the phase estimation operation to assist in the decomposition of the initial state of the qubit (corresponding to the uppermost timeline in Figure 2), the initial state of the first qubit (corresponding to the timeline in Figure 2), and the initial state of the second qubit (corresponding to the lower timeline in Figure 2). Wherein the cell matrix U corresponding to the aforementioned matrix A is decomposed into a cell matrix corresponding to a single quantum logic gate carrying controlled information. Among them, the cell matrix corresponding to the single quantum logic gate that satisfies the controlled information is the order unit matrix [16]. The number of first qubits $z$ depends on the accuracy of the phase estimation and the probability of success. The number of second qubits is $n$, which is the eigenvector of matrix A with amplitude of matrix A.

*Step 2.* Build the second part of the quantum line corresponding to the controlled rotation operation to extract the value in the ground state onto the quantum state amplitude of the auxiliary quantum bit, and obtain: where the number of auxiliary quantum bits is 1 and C is constant. For example, for four-dimensional vector $b = [b0, b1, b2, b3]$, $N = 4$, you can get $n = 2$.

Then encode the data of vector $b$ onto the amplitude of the quantum state to obtain [1]. Thus, load the data of the vector $b$ onto the quantum state amplitude of two second quantum bits in the quantum line.

*Step 3.* Build the third part of the quantum circuit corresponding to the phase estimation inverse operation to eliminate $|\lambda_j\rangle$ and obtain

$$\sum_{j=0}^{N-1} \beta_j |0\rangle |\mu_j\rangle \left( \sqrt{1 - \left|\frac{C}{\lambda_j}\right|^2} |0\rangle + \frac{C}{\lambda_j} |1\rangle \right). \tag{9}$$

The inverse operation of phase estimation is the reduction process of phase estimation described above, that is, the transposed conjugate operation of phase estimation. The goal is to eliminate, specifically converting the quantum state as

$$\sum_{j=0}^{N-1} \beta_j |0\rangle |\mu_j\rangle \left( \sqrt{1 - \left|\frac{C}{\lambda_j}\right|^2} |0\rangle + \frac{C}{\lambda_j} |1\rangle \right). \tag{10}$$

*Step 4.* To construct a quantum measurement operation for the auxiliary qubit so that the quantum state of the auxiliary qubit can be measured, get

$$|x'\rangle = \frac{1}{\sqrt{\sum_{j=0}^{N-1} C^2 \left|\beta_j\right|^2 / \left|\lambda_j\right|^2}} \sum_{j=0}^{N-1} \frac{C\beta_j}{\lambda_j} |\mu_j\rangle, \tag{11}$$

$|x'\rangle$与$|x\rangle = A^1|b\rangle = \sum_{j=0}^{N-1} \beta_j \lambda_j^{-1} |\mu_j\rangle$, is the corresponding relation of amplitude normalization. After the measurement, the state of the auxiliary qubit collapses to a definite state, one of them, Collapse to$|0\rangle$ is the probability for $1 - |C/\lambda_j|^2$, Collapse to$|1\rangle$ is the probability for $|C/\lambda_j|^2$. When the quantum state of the auxiliary qubit is measured for $|1\rangle$, and when $C = 1$, you can get a definite quantum state:

$$|x'\rangle = \frac{1}{\sqrt{\sum_{j=0}^{N-1} \left|\beta_j\right|^2 / \left|\lambda_j\right|^2}} \sum_{j=0}^{N-1} \frac{\beta_j}{\lambda_j} |\mu_j\rangle. \tag{12}$$

This shows $|x\rangle = A^{-1}|b\rangle = \sum_{j=0}^{N-1} \beta_j \lambda_j^{-1} |\mu_j\rangle$, the corresponding results of amplitude normalization are carried out.

The first part of the quantum line, the second part of the quantum line, the third part of the quantum line and the quantum measurement operation are in turn formed into the quantum line corresponding to the HHL algorithm.

*3.2. Quantum Line Construction Law Corresponding to HHL Algorithm.* The application of artificial intelligence technology in the Internet of Things is bound to bring more changes to the Internet of Things. In order to facilitate the integration of these changes, it is necessary to actively find the best nodes for the scientific research of artificial intelligence technology and Internet of Things technology [17]. The first strategy to improve the whole process of classical optimization is to take the optimization parameters of small systems as the original parameters of large systems. Table 1 proposes the strategy flow of the qubit recursion algorithm.

*3.2.1. The Matrix Structure Corresponding to the First Column of the Unitary Matrix of the Quantum Circuit*

*(1) One-Bit Quantum Circuit.* The line unitary matrix has only one element (2, 1) to be set to 0, just construct a specific quantum logic gate $\{C_1\} = \{V\}$ to make $\{V\} \bullet U = I_N$;

*(2) Two-Bit Quantum Circuit.* Using recursive thinking [18]. That is, the recursion or function (or procedure or program segment) calls directly (or indirectly) on the implementation of its own procedure. Recursion to define endless object

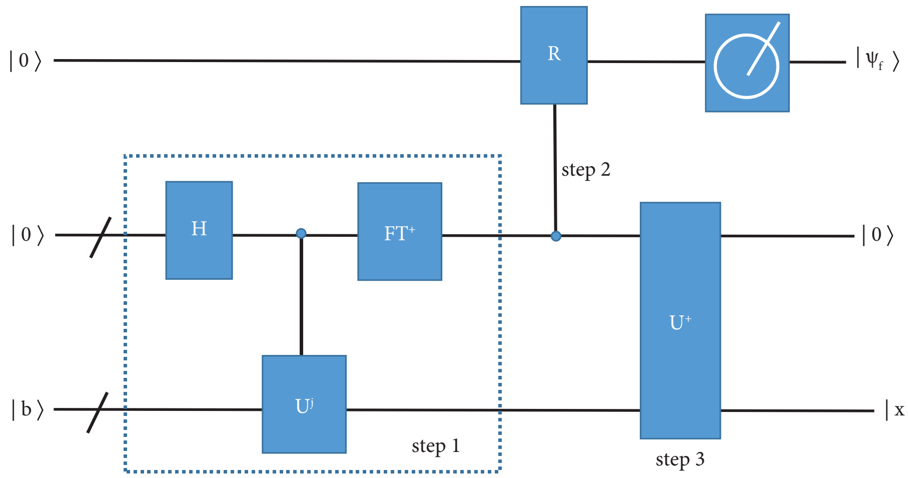


Figure 4: Quantum circuit diagram constructed by the HHL algorithm.

Table 1: Qubit recursion algorithm strategy flow.

| |
|---|
| Date: system size $N$, number of target circuit layers $M$ |
| (1) Initial parameters ⟵ system size $N/2$ tained parameters |
| (2) **While** fidelity at training convergence < threshold **do** |
| (3) **If** the number of layers of the current circuit < the number of layers of the target circuit $M_{VQE}$ **then** |
| (4) Parameters⟵last layer of parameters |
| (5) **End** |
| (6) Train the variational circuit until the classical optimization process converges, convergence fidelity F is obtained |
| (7) $M_{VQE} \longleftarrow M_{VQE}+1$ |
| (8) **End** |

union with a relatively limited sentence. The recursion is characterized by the call itself. Referring to the 1 bit quantum circuit, the unitary matrix of the circuit, except for the last to-be-set 0 element (3, 1), corresponds to the specific quantum logic gate $\{C_n \cdots C_m \cdots C_1\} = \{C_2C_1\} = \{C_2V\}$;

For the upper part (2, 1) of the unitary matrix, the most significant qubit is set to be uncontrolled, that is, (2, 1): $\{C_2V\} = * V\}$; for the lower part (4, 1), determine whether the lower qubit corresponds to 1, if it is not 1, then (4, 1): $\{C_2V\} = \{1V\}$:, otherwise $\{C_2V\} = \{* V\}$; the judgment can be: (4, 1) corresponds to (2, 1) of 1 bit quantum circuit: $\{C_2C_1\} = \{C_2V\} = \{1V\}$;

The last to-be-placed 0 element (3, 1) is directly set as: $\{C_2C_1\} = \{V *\}$.

*(3) Three-Bit Quantum Circuit.* Recursion is divided into immediate recursion and indirect recursion [19]. When you call yourself in a function (or procedure), it's called immediate recursion. If function a calls function $b$, and function $b$ calls function a, this is called indirect recursion.

Corresponding to the constructed specific quantum logic gate $\{C_n \cdots C_m \cdots C_1\} = \{C_3C_2C_1\}$, the upper half of the circuit unitary matrix refers to the 2 bit quantum circuit, and the highest qubit is still set as uncontrolled, that is, $\{C_3C_2C_1\} = \{* C_2C_1\}$, we can get: (2, 1) corresponds to (2, 1) of 2 bit quantum circuit: $\{C_3C_2C_1\} = \{* C_2C_1\} = \{* * V\}$; (4, 1) corresponds to (4, 1) of 2 bit quantum circuit: $\{C_3C_2C_1\} = \{* C_2C_1\} = \{* 1V\}$; (3, 1) corresponds to (3, 1) of 2 bit quantum circuit: $\{C_3C_2C_1\} = \{* C_2C_1\} = \{* V *\}$.

For the lower half, except for the last 0 element (5, 1) to be set, it corresponds to the upper half in order one-to-one, and judges whether the upper two qubits corresponding to the lower two qubits are not 1, if they are both If it is not 1, then $\{C_3C_2C_1\} = \{1C_2C_1\}$, otherwise $\{C_3C_2C_1\} = \{* C_2C_1\}$; the judgment can be:

(6, 1) corresponding to $\{C_3C_2C_1\}$, and (2, 1) corresponding to, the same, that is $^*$, $V$, and none of them are 1, we can get: $\{C_3C_2C_1\} = \{C_3 * V\} = \{1 * V\}$.

Similarly, (8, 1) corresponds to (4,1): $\{C_3C_2C_1\} = \{C_31V\} = \{* 1V\}$; (7, 1) corresponds to (3, 1): $\{C_3C_2C_1\} = \{C_3V *\} = \{1V *\}$.

The last to-be-placed 0 element (5, 1) is directly set as: $\{C_3C_2C_1\} = \{V * *\}$.

By analogy, the matrix structure corresponding to the first column of the unitary matrix of any bit quantum circuit can be realized.

*3.2.2. The Matrix Structure Corresponding to the Second Column to the N/2th Column of the Unitary Matrix of the Quantum Circuit. (1) Two-Bit Quantum Circuit,* $n=2$. The second column, column subscript $l=2$, binary representation 01, binary low bit $l_1 = 1$, high bit $l_2 = 0$; according to the preset inequality $2^{x-1} < l \leq 2^x$, obtain $x=1$; The bottom half corresponds to the bottom half of the previous column in order, (3, 2): $\{C_2C_1\} = \{1V\}$; (4, 2): It is the last element to be set to 0 in this column, refer to the corresponding $\{V *\}$ in the first column (3,1): treat * in $\{V *\}$ as 0, perform binary plus 1 operation, * becomes 1, Get $\{C_2C_1\} = \{V1\}$ corresponding to (3, 2).

*(2) Three-Bit Quantum Circuit, $n = 3$.* The second column, column subscript $l = 2$, binary representation 01, $l_1 = 1, l_2 = 0$; according to $2^{x-1} < l \leq 2^x$, get $x = 1$, the upper part (3, 2), (4, 2) refers to the two-bit quantum circuit:

In the $\{C_3C_2C_1\}$ corresponding to (3, 2), the value of $C_2C_1$ is the same as the $\{C_2C_1\} = \{1V\}$ corresponding to (3, 2) of the two-bit quantum circuit, and $C_3$ is set to *, that is: $\{C_3C_2C_1\} = \{* 1V\}$ corresponding to (3, 2); In the $\{C_3C_2C_1\}$ corresponding to (4, 2), the value of $C_2C_1$ is the same as the $\{C_2C_1\} = \{V1\}$ corresponding to (4, 2) of the two-bit quantum circuit, and $C_3$ is set to *, that is: $\{C_3C_2C_1\} = \{* V1\}$ corresponding to (3, 2); The lower part corresponds to the lower part of the first column in order. The matrix $\{C_3C_2C_1\}$ is constructed as follows:

(5, 2) Corresponding $\{C_3C_2C_1\} = \{1 * V\}$;
(6, 2) Corresponding $\{C_3C_2C_1\} = \{V * 1\}$;
(7, 2) Corresponding $\{C_3C_2C_1\} = \{* 1V\}$;
(8, 2) Corresponding $\{C_3C_2C_1\} = \{1V *\}$;

The same can be obtained, the third column:

The upper part: (4, 3) corresponds to $\{* 1V\}$; the lower part: (8, 3) corresponds to $\{1 * V\}$, (6, 3) corresponds to $\{10V\}$, (5, 3) corresponds to $\{1V *\}$; the last element in this column to be set to 0 (7, 3) Corresponding to $\{V1 *\}$;

The fourth column will not be repeated; it can be seen that in the lower half, except for the last element to be set to 0 in each column, the even-numbered column corresponds to the matrix structure of the previous column (odd-numbered column), and the matrix of the odd-numbered column is determined by referring to the first column.

*3.2.3. The Matrix Structure Corresponding to the $(N/2 + 1)$th Column to the Last Column of the Quantum Circuit Unitary Matrix.* Refer to the first half of the column 1 to the upper half of the $N/2$th column, in the order of one-to-one correspondence, change the most significant * to 1, and the rest remain unchanged. Taking the above 3 bit quantum circuit as an example, we can get:

Column 5: $\{1V *\}$;
Column 6: $\{1V1\}$;
Column 7: $\{11V\}$;
No in column 8.

By analogy, the matrix structure corresponding to all the columns of the unitary matrix of any bit quantum circuit can be realized. Specifically, $\{C_n \cdots C_m \cdots C_1\} = I_N + V_n \otimes \cdots V_m \cdots \otimes V_1$, where $V_m$ is equal to: $|0\rangle\langle 0|$, if $C_m = 0$; $|1\rangle\langle 1|$, if $C_m = 1$; $V - I_2$, if $C_m = V$; $I_2$, if $C_m$ is *.

*3.3. Simulated Test.* The use of power circuit model simulation quantum computer to complete quantum information computing data visualization is an intricate subject of research in computer technology system, which mainly includes interdisciplinary theories and technologies.

The simulation experimental quantum Bolyea transform line is shown in Figure 5, and Table 2 showed the simulation experimental results.

As can be seen from Table 2, both the variation of running time and $n$ cause a consequent increase in the length of the quantum line. As can be seen from the quantum circuit construction law corresponding to HHL algorithm, the computational simulation schematic of HHL algorithm corresponding to quantum circuit is shown in Figure 6, and the quantum circuit sequencing application based on HHL quantum algorithm.

According to the high-speed development of traditional type CMOS process integrated circuit chip has faced shortage, new type of nanomaterials and quantum measurement added new technology enhancement. Along with the high speed development of electronic device design automation, fully automated simulation and integrated optimization algorithms for quantum steganography and quantum metacellular automata suffer from the specific scientific research of intelligent computing methods [20].

To test based on corresponding HHL algorithm and application effect of quantum circuit processing application problems, we use the original quantum cloud platform to implement the HHL algorithm, the parameters of the model were first set, 2 bits HHL algorithm, for example, need two quantum bits and a classic register to hold a measured value, the programming interface, as shown in Figure 7, Parameter configuration is shown in Figure 8. Add relevant quantum logic gate on the main programming interface.

As shown in Figure 9, a simple 2 bit HHL algorithm is implemented on the cloud platform. So this is a bar graph that shows the different measurements on the horizontal axis, and the vertical axis shows the probability that the pair of measurements should be, and here we have a 1, which is 100%, which is what we expected.

*3.4. Quantum Artificial Intelligence.* In addition, at the present stage, the technical manufacturing process is still far from being able to achieve the mass production and operation of traditional computers at room temperature, which indirectly limits the commercial use of subcomputers. In this environment, the native quantum has developed a cloud computing service based on subcomputing-quantum cloud service platform, which can provide online computing the daily tasks for users and major enterprises and research institutions [21]. The user can submit daily tasks to the quantum technology computer deployed at a remote location through the quantum cloud service platform via the scheduling web server and the Internet, and the subcomputer will then return the results to the user via the scheduling web server and the Internet after such tasks are processed and completed. Figure 10 shows the flow chart of quantum computing.

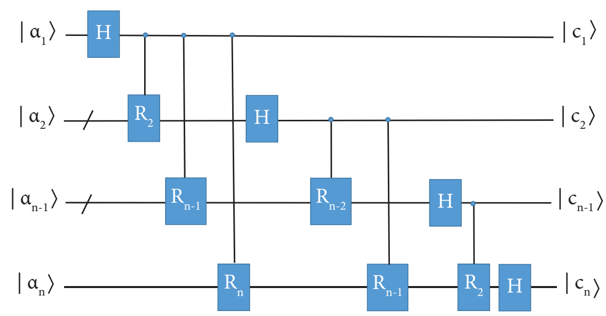


Figure 5: $n$-quantum bit QFT circuit logic diagram.

Table 2: Simulation experiments.

| Quantum bits | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|
| Minute(s) | 1 | 3 | 7 | 16 | 34 | 89 | 197 | 435 | 918 |

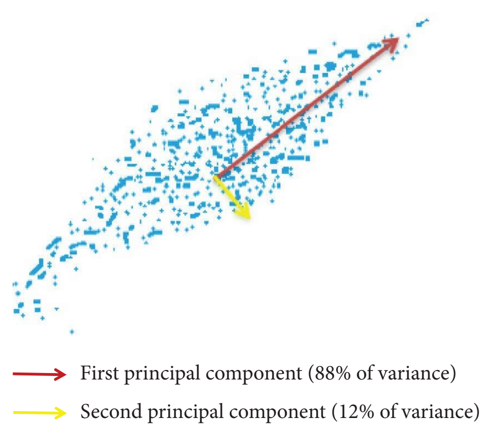


Figure 6: Simulation diagram of quantum circuit calculation by HHL algorithm.

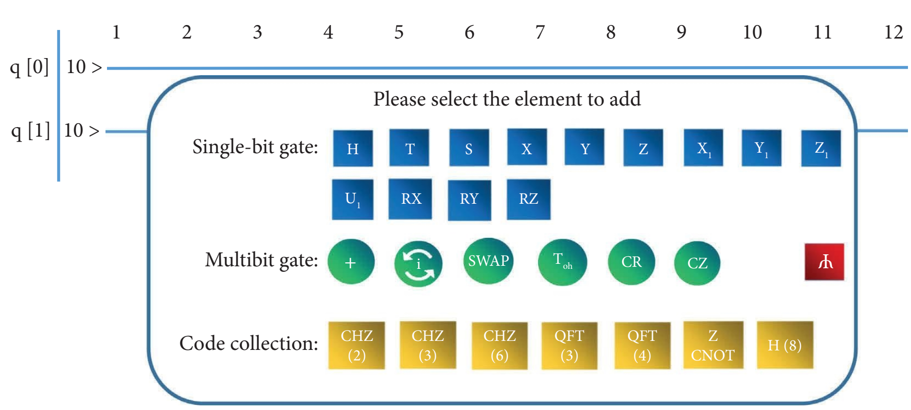


Figure 7: Programming interface of the original quantum cloud platform.

The development and design of artificial intelligence algorithms for the rapid development of artificial intelligence is particularly important, which requires quantum physicists and artificial intelligence researchers, computer experts and scientists to work closely together to generate services to support and hope for the rapid development of artificial intelligence.

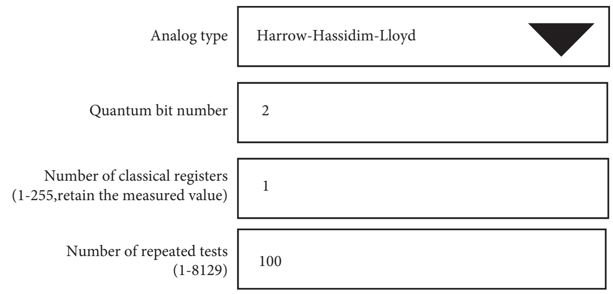


Figure 8: Configuration parameters.

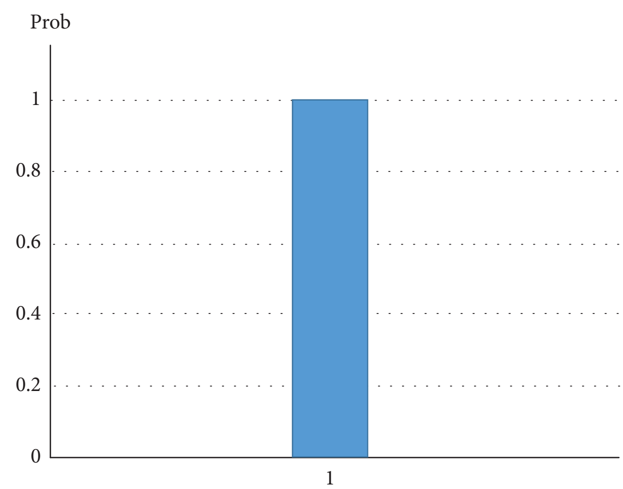


Figure 9: Analysis results of HHL algorithm.

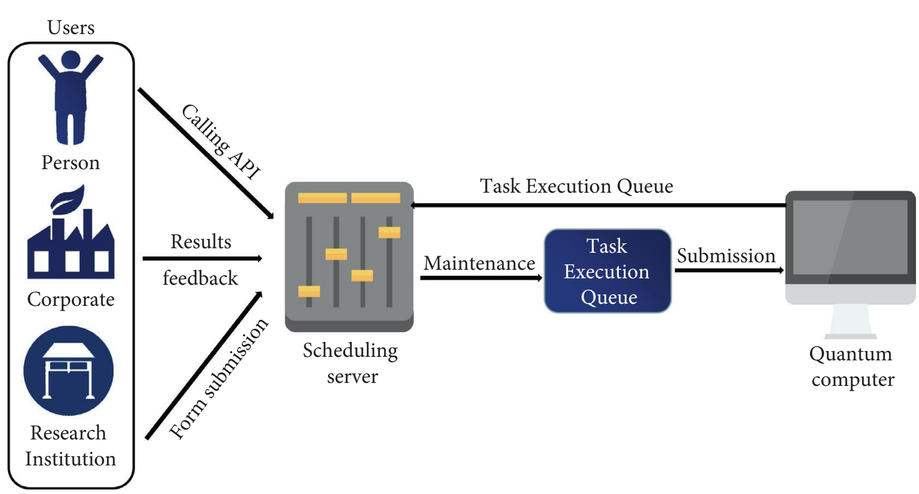


Figure 10: Quantum computing flowchart.

## 4. Conclusion

Internet technology represents the necessity to analyze and solve massive amounts of information in real time, and the integration of industrial IoT and artificial intelligence is a key development.

Quantum lines include quantum logic gate operations, and the HHL algorithm has become one of the important quantum algorithms. In this paper, a model based on HHL algorithm corresponding quantum lines processing quantum application problems is constructed: by obtaining the target partial differential equation corresponding to the objective quantum application problem, a linear system is obtained by discretizing the target partial differential equation. The numerical solution of the partial differential equation of the target is obtained by solving the linear system using a quantum line based on the corresponding HHL algorithm.

Finally, by analyzing the law of the unitary matrix construction of the quantum line corresponding to the HHL algorithm and experimental measurement data, it is possible to reduce the computational workload of quantum lines corresponding to the HHL algorithm in the process of processing quantum computer applications based on quantum lines, improve the simulation efficiency of quantum lines, at the same time reducing hardware resources. Occupy, has certain validity and superiority. Quantum computing has an exciting future, but reaching this market prospect has many more tests to come. Along with increased awareness comes increased ability to manipulate quantum computing. There is also a lot to be done to produce and manufacture a good working quantum computer. It is difficult to predict and analyze how the future development of quantum computing should trend at what rate. At present, origin quantum has developed a quantum sorting application based on the HHL quantum algorithm, which will provide an important reference for predicting the next spreading point of a novel Coronavirus. The next trend in intelligent IoT technology is to share traditional data in an intelligent app that can be done with the help of artificial intelligence technology. In general, the next few decades will undoubtedly be the era of quantum computing and artificial intelligence, whose research is not only exciting but also full of tests.

## Data Availability

The labeled dataset used to support the findings of this study are available from the corresponding author upon request.

## Conflicts of Interest

The authors declare that there are no conflicts of interest.

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