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Quantum Algorithm for 3-SAT Problem of 11 Variables by Quantum Fourier Transform with Repeat Qubits, and Weight Changes on QCEngine

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Abstract

A quantum algorithm for the 3-SAT problem of 11 variables by the quantum Fourier transform with the repeat qubits, and the weight changes on the QCEngine, and its example are reported. When there are 3 literals with 2 'OR's in each clause, a weight of r-th clause is m_r [m_r is a natural number. $1 \leq r \leq$ (number of clauses) $= d$.], the r-th clause is $C_{u,r}(x_1, x_2, x_3, \ldots, x_n)$ [u is $2^0x_1 + 2^1x_2 + 2^2x_3 + \ldots + 2^{n-1}x_n$. x_1, x_2, x_3, … , and x_n are the variables, and the repeat qubits.], and $S(u)$ is $\Sigma_{r=1\to d}\, m_r \times C_{u,r}(x_1, x_2, x_3, \ldots, x_n)$, mod($S(u)_{max}$) of $S(u)$ [$S(u)_{max}$ is the maximum value of $S(u)$.] is computed, next, for u, the quantum Fourier transform is done. In this time, there are 11 variables, the repeat qubits from 0 to 6, and changed weights. The complexity of this method is able to be several times.

Keywords: Quantum algorithm, 3-SAT problem, 11 variables, quantum Fourier transform, repeat qubits, weight changes, QCEngine.

AMS subject classification: Primary 81-08; Secondary 81-10, 68Q12.

Introduction

Shor discussed the valid quantum algorithm for the factorization. [1] Grover reported the fast quantum algorithm for database search. [2, 3] The complexity of the 3-SAT problem had been discussed by Cook. [4] Quantum computer's example of the 3-SAT problem is reported by Johnston, Harrigan, and Gimeno-Segovia with the QCEngine (free on-line quantum computer simulator). [5] Fujimura discussed a quantum algorithm for the 3-SAT problem by the Shor's Fourier transform with the RAM on the QCEngine. [6] Still more, Fujimura discussed a quantum algorithm for the 3-SAT problem of 10 variables by the quantum Fourier transform with the repeat qubits, and the weight changes on the QCEngine. [7]

According to my advanced study, when the quantum Fourier transform with the repeat qubits, and the weight changes on the QCEngine for the 3-SAT problem of 11 variables is used, the complexity of the 3-SAT problem of 11 variables is able to be several times.

Therefore, the quantum algorithm for the 3-SAT problem of 11 variables is examined by the quantum Fourier transform with the repeat qubits, and the weight changes on the QCEngine, and its result are reported.

3-SAT Problem

In the 3-SAT problem, it is assumed that (i) each value of n variables becomes "TRUE", or "FALSE", "~" is "NOT", "V" is "OR", "&" is "AND", (ii) "V", "~", and 3 different variables are included in each parentheses (= clause) that are connected by "&". If a value of logical formula by the literals, and the logical connectives is "TRUE", it is decided whether there is at least one combination of values of the variables or not. [4-7]

Quantum Algorithm

The following conditions are assumed. (I) Each value of variables x_1, x_2, x_3, … , and x_n becomes "TRUE" [= 1], or "FALSE" [= 0]. "~" is "NOT". "V" is "OR". "&" is "AND". For example, it is assumed in this algorithm that (1 V 1 V 1), (1 V 1 V 0), and (1 V 0 V 0) become 1, and (0 V 0 V 0) becomes 0. (II) "V", "~", and 3 different variables in x_1, x_2, x_3, … , and x_n are included in each clause, and then the clauses are connected by "&". In these conditions, if a value of logical formula by the literals, and the operators is "TRUE", it is searched whether there is at least one combination of values of the variables or not. It is assumed that n is number of qubits, u is $2^0x_1 + 2^1x_2 + 2^2x_3 + \dots + 2^{n-1}x_n$, a weight of r-th clause is m_r [m_r is a natural number. $1 \leq r \leq$ (number of clauses) = d.], the r-th clause is $C_{u,r}$ (x_1, x_2, x_3, … , x_n), and S(u) is $\Sigma_{r = 1 \rightarrow d}\, m_r \times C_{u,r} (x_1, x_2, x_3, \dots, x_n)$, and $S(u)_{max}$ is [the maximum value of S(u)] = k.

First of all, query quantum registers $|x_i\rangle$[$1 \leq i \leq n$. i is an integer. n is the number of variables in the logical formula, and the repeat qubits.], and work1 quantum registers $|w_{1,j}\rangle$ [$1 \leq j \leq t$. j, and t are integers. t is a necessary number for $S(u)_{max} \leq \Sigma_{f = 0 \rightarrow t}\, 2^f$. f is an integer.].

Step 1: The r data are introduced to the RAM [5].

Step 2: Each qubit of $|x_i\rangle$, and $|w_{1,j}\rangle$ is set $|0\rangle$.

Step 3: The Hadamard gate $\boxed{H}$ [1-3, 5-9] acts on each qubit of $|x_i\rangle$. It changes them for entangled states.

Step 4: Each clause is presented by $|x_i\rangle$, $|w_{1,j}\rangle$, add gate, and quantum operators. For $|x_i\rangle$, RAM[r - 1] [RAM has m_r data of r = 1 → d.] is incremented in $|w_{1,j}\rangle$. In a function, $S(u) = \Sigma_{r = 1 \rightarrow d}\, m_r \times C_{u,r} (x_1, x_2, x_3, \dots, x_n)$ is computed. This operation makes entangled data base. In this case, n is 11 variables in the logical formula, and the number of repeat qubits.

Step 5: For $|x_i\rangle$, the quantum Fourier transform (= QFT) [1, 5-9] is done.

Step 6: For $|x_i\rangle$, and $|w_{1,j}\rangle$, the probes are done.

Step 7: For $|x_i\rangle$, the read is done.

Step 8: A number of spikes is estimated by the function (https: //oreilly-qc. github. io? p = 12-4 [5]), where the function estimate_num_spikes (spike, range) [spike: read value, range: 2^n] is used.

Step 9: From candidates of the number of spikes, the repeat period P is obtained.

Step 10: From $u = P = 2^0x_1 + 2^1x_2 + 2^2x_3 + \ldots + 2^{n-1}x_n$, when there are $S(P)_{max}$ is $\Sigma_{r=1\rightarrow d}\, m_r\times C_{P,r}\,(x_1, x_2, x_3, \ldots, x_n) = k$, it is the answer [one combination of (value of logical formula) = 1].

Example of Numerical Computation

4-1. 11 Variables, 6 Repeat Qubits, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

For example at $n = 17$ [11 variables, and 6 repeat qubits], it is assumed that a logical formula : $(x_3 \vee x_4 \vee x_5)$ & $(\sim x_1 \vee x_2 \vee x_3)$ & $(\sim x_3 \vee x_4 \vee x_5)$ & $(x_3 \vee \sim x_4 \vee x_5)$ & $(\sim x_2 \vee x_3 \vee \sim x_5)$ & $(\sim x_3 \vee \sim x_4 \vee x_5)$ & $(\sim x_3 \vee x_4 \vee \sim x_5)$ & $(x_3 \vee \sim x_4 \vee \sim x_5)$ & $(\sim x_3 \vee \sim x_4 \vee \sim x_5)$ & $(x_4 \vee \sim x_5 \vee \sim x_6)$ & $(\sim x_5 \vee x_6 \vee \sim x_7)$ & $(x_6 \vee x_7 \vee \sim x_8)$ & $(x_7 \vee x_8 \vee \sim x_9)$ & $(x_8 \vee x_9 \vee \sim x_{10})$ & $(x_9 \vee x_{10} \vee \sim x_{11})$, each value of $x_{1\sim11}$: $x_1 = x_2 = x_3 = x_4 = x_6 = x_7 = x_8 = x_9 = x_{10} = x_{11} = 0$, $x_5 = 1$, $m_1 = 1$, $m_2 = 2$, $m_3 = 3$, $m_4 = 4$, $m_5 = 5$, $m_6 = 6$, $m_7 = 7$, $m_8 = 8$, $m_9 = 9$, $m_{10} = 10$, $m_{11} = 11$, $m_{12} = 12$, $m_{13} = 13$, $m_{14} = 14$, $m_{15} = 15$, $t = 6$, and $k = (15 + 1)15/2 = 120$.

An example of program on the QCEngine is the following.

```
var a = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]; // RAM_a
var query_qubits = 17;
var work1_qubits = 6;
qc.reset(query_qubits + work1_qubits);
var query = qint.new(query_qubits, 'query');
var work1 = qint.new(work1_qubits, 'work1');
qc.label('q'); // set query
query.write(0);
query.hadamard();
qc.label(' ');
qc.label('w1'); // set work1
work1.write(0);
qc.print(' RAM before increment : ' + a + '\n');
var query16 = 16;
var work1_0 = 0;
qc.label('increment');
qc.not(query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
work1.add(a[0],query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
```

```
qc.not(query.bits(0x2)|query.bits(0x4));
work1.add(a[1],query.bits(0x1)|query.bits(0x2)|query.bits(0x4));
qc.not(query.bits(0x2)|query.bits(0x4));
qc.not(query.bits(0x8)|query.bits(0x10));
work1.add(a[2],query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x4)|query.bits(0x10));
work1.add(a[3],query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x4)|query.bits(0x10));
qc.not(query.bits(0x4));
work1.add(a[4],query.bits(0x2)|query.bits(0x4)|query.bits(0x10));
qc.not(query.bits(0x4));
qc.not(query.bits(0x10));
work1.add(a[5],query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x10));
qc.not(query.bits(0x8));
work1.add(a[6],query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x8));
qc.not(query.bits(0x4));
work1.add(a[7],query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x4));
work1.add(a[8],query.bits(0x4)|query.bits(0x8)|query.bits(0x10));
qc.not(query.bits(0x8));
work1.add(a[9],query.bits(0x8)|query.bits(0x10)|query.bits(0x20));
qc.not(query.bits(0x8));
qc.not(query.bits(0x20));
work1.add(a[10],query.bits(0x10)|query.bits(0x20)|query.bits(0x40));
qc.not(query.bits(0x20));
qc.not(query.bits(0x20)|query.bits(0x40));
work1.add(a[11],query.bits(0x20)|query.bits(0x40)|query.bits(0x80));
qc.not(query.bits(0x20)|query.bits(0x40));
qc.not(query.bits(0x40)|query.bits(0x80));
work1.add(a[12],query.bits(0x40)|query.bits(0x80)|query.bits(0x100));
qc.not(query.bits(0x40)|query.bits(0x80));
qc.not(query.bits(0x80)|query.bits(0x100));
work1.add(a[13],query.bits(0x80)|query.bits(0x100)|query.bits(0x200));
qc.not(query.bits(0x80)|query.bits(0x100));
qc.not(query.bits(0x100)|query.bits(0x200));
work1.add(a[14],query.bits(0x100)|query.bits(0x200)|query.bits(0x400));
qc.not(query.bits(0x100)|query.bits(0x200));
qc.label('QFT');
query.QFT();
var prob16 = 0;
prob16 += query.peekProbability(query16);
// Print output query-Prob
```

```
qc.print(' Prob_query16: ' + prob16);
var prob0 = 0;
prob0 += work1.peekProbability(work1_0);
// Print output work1-Prob
qc.print(' Prob_work1_0: ' + prob0);
//read
qc.label('Rq');
var b2 = query.read();
// Print output result
qc.print(' Read query = ' + b2 +'.');
// end
```

When this program is copied on Programming Quantum Computers https: //oreilly-qc. github. io/# [free on-line quantum computation simulator QCEngine] [5], you can run it. [Caution!: Please delate the line numbers.]

A result of this program is the following.

The probability probe value of $|w_{1,j}\rangle = 0$: ≈ 0.00048828 (≈ 1/2048).
The probability probe value of $|x_i\rangle = 16$: ≈ 0.0000000.
The example of 50 times test : The read value of $|x_i\rangle$; R_q = 10624, 16384, 15360, 0, 12288, 124928, 0, 122880, 8192, 128640, 129024, 32576, 122624, 100480, 3072, 122880, 16576, 3840, 112640, 76544, 122880, 4096, 125952, 7168, 7168, 127104, 16448, 114688, 112960, 8960, 121856, 8192, 86016, 1024, 122624, 8192, 4096, 49344, 40960, 13312, 15616, 29440, 119040, 86272, 3840, 0, 122304, 117376, 81920, 129344. (=spike)

The candidates of number of spikes are estimated by the function [the function estimate_num_spikes (spike, range) [spike : read value, range : $2^n = 2^{17} = 131072$]] : R_q → candidates ; 10624 → 12, 25, … ; 16384 → 8, 16, … ; 15360 → 9, 17, … ; 0 → nothingness ; 12288 → 11, 21, … ; 124928 → 21, … ; 122880 → 16, … ; 8192 → 16, … ; 128640 → 54, … ; 129024 → 64, … ; 32576 → 4, 8, 12, 16, … ; 122624 → 16, … ; 100480 → 4, 9, 13, 17, … ; 3072 → 43, … ; 16576 → 8, 16, ... ; 3840 → 34, … ; 112640 → 7, 14, 21, … ; 76544 → 3, 5, 7, 12, 24, … ; 4096 → 32, … ; 125952 → 26, … ; 7168 → 18, … ; 127104 → 33, … ; 16448 → 8, 16, … ; 114688 → 8, 16, …; 112960 → 7, 14, 22, … ; 8960 → 15, 29, … ; 121856 → 14, 28, … ; 86016 → 3, 6, 9, 12, 15, 17, … ; 1024 → 128, … ; 49344 → 3, 5, 8, 16, … ; 40960 → 3, 6, 10, 13, 16, … ; 13312 → 10, 20, … ; 15616 → 8, 17, … ; 29440 → 5, 9, 18, … ; 119040 → 11, 22, … ; 86272 → 3, 6, 9, 12, 15, 18, … ; 3840 → 34, … ; 122304 → 15, 30, … ; 117376 → 10, 19 … ; 81920 → 3, 5, 8, 16, … ; 129344 → 76, … .

When u is 16 ($2^0x_1 + 2^1x_2 + 2^2x_3 + 2^3x_4 + 2^4x_5 + 2^5x_6 + 2^6x_7 + 2^7x_8 + 2^8x_9 + 2^9x_{10} + 2^{10}x_{11} + 2^{11}x_{12} + 2^{12}x_{13} + 2^{13}x_{14} + 2^{14}x_{15} + 2^{15}x_{16} + 2^{16}x_{17} = 2^0\times0 + 2^1\times0 + 2^2\times0 + 2^3\times0 + 2^4\times1 + 2^5\times0 + 2^6\times0 + 2^7\times0 + 2^8\times0 + 2^9\times0 + 2^{10}\times0 + 2^{11}\times0 + 2^{12}\times0 + 2^{13}\times0 + 2^{14}\times0 + 2^{15}\times0 + 2^{16}\times0 = 16$), the value of logical formula is 1. Therefore, it is the answer.

4-2. 11 Variables, 5 Repeat Qubits, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

For example at $n = 16$ [11 variables, and 5 repeat qubits], it is assumed that the logical formula, each value of $x_{1\sim11}$, each value of $m_{1\sim15}$, t, and k are same in the section 4-1.

A result of this problem is the following.

The probability probe value of $|w_{1,j}\rangle = 0$: ≈ 0.00048828 (≈ 1/2048).

The probability probe value of $|x_i\rangle = 16$: ≈ 0.0000000.

The example of 50 times test : The read value of $|x_i\rangle$; R_q = 62720, 22016, 63744, 62976, 23040, 60384, 37120, 2304, 56320, 10048, 65408, 63488, 0, 1280, 96, 14176, 63744, 64768, 41440, 61344, 2048, 48896, 2016, 61440, 51136, 63328, 6656, 0, 55040, 8064, 44544, 3520, 2176, 64256, 52736, 0, 23808, 28608, 3328, 15616, 5888, 36864, 39040, 57344, 16320, 4096, 38912, 2048, 16256, 1024. (=spike)

The candidates of number of spikes are estimated by the function [the function estimate_num_spikes (spike, range) [spike : read value, range : $2^n = 2^{16} = 65536$]] : R_q → candidates ; 62720 → 23, … ; 22016 → 3, 6, 9, 12, 15, 18, … ; 63744 → 37, … ; 62976 → 26, … ; 23040 → 3, 6, 9, 11, 14, 17, … ; 60384 → 13, 25, … ; 37120 → 2, 5, 7, 14, 16, … ; 2304 → 28, … ; 56320 → 7, 14, 21, … ; 10048 → 7, 13, 26, … ; 65408 → 512, … ; 63488 → 32, … ; 0→ nothingness ; 1280 → 51, … ; 96 → 683, … ; 14176 → 5, 9, 14, 23, … ; 63744 → 37, … ; 64768 → 85, … ; 41440 → 3, 5, 8, 11, 19, … ; 61344 → 16, … ; 2048 → 32, … ; 48896 → 4, 8, 12, 16, … ; 2016 → 33, … ; 61440 → 16, … ; 51136 → 5, 9, 18, … ; 63328 → 30, … ; 6656 → 10, 20, … ; 55040 → 6, 13, 19, … ; 8064 → 8, 16, … ; 44544 → 3, 6, 9, 13, 16, … ; 3520 → 19, … ; 2176 → 30, … ; 64256 → 51, … ; 52736 → 5, 10, 15, 20, … ; 23808 → 3, 6, 8, 11, 22, … ; 28608 → 2, 5, 7, 9, 16, … ; 3328→ 20, … ; 15616 → 4, 8, 13, 17, … ; 5888 → 11, 22, … ; 36864 → 2, 5, 7, 9, 16, … ; 39040 → 3, 5, 10, 15, 20, … ; 57344 → 8, 16, … ; 16320 → 4, 8, 12, 16, … ; 4096 → 16, … ; 38912 → 3, 5, 10, 15, 17, … ; 2048 → 32, … ; 16256 → 4, 8, 12, 16, … ; 1024 → 64, … .

When u is 16 ($2^0x_1 + 2^1x_2 + 2^2x_3 + 2^3x_4 + 2^4x_5 + 2^5x_6 + 2^6x_7 + 2^7x_8 + 2^8x_9 + 2^9x_{10} + 2^{10}x_{11} + 2^{11}x_{12} + 2^{12}x_{13} + 2^{13}x_{14} + 2^{14}x_{15} + 2^{15}x_{16} = 2^0\times0 + 2^1\times0 + 2^2\times0 + 2^3\times0 + 2^4\times1 + 2^5\times0 + 2^6\times0 + 2^7\times0 + 2^8\times0 + 2^9\times0 + 2^{10}\times0 + 2^{11}\times0 + 2^{12}\times0 + 2^{13}\times0 + 2^{14}\times0 + 2^{15}\times0 = 16$), the value of logical formula is 1. Therefore, it is the answer.

4-3. 11 Variables, 4 Repeat Qubits, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

For example at $n = 15$ [11 variables, and 4 repeat qubits], it is assumed that the logical formula, each value of $x_{1\sim11}$, each value of $m_{1\sim15}$, t, and k are same in the section 4-1.

A result of this problem is the following.

The probability probe value of $|w_{1,j}\rangle = 0$: ≈ 0.00048828 (≈ 1/2048).

The probability probe value of $|x_i\rangle = 16$: ≈ 0.0017658.

The example of 50 times test : The read value of $|x_i\rangle$; R_q = 4352, 30656, 27968, 4304, 2816, 3072, 12288, 30208, 5504, 31744, 31232, 5120, 2560, 15776, 32192, 22464, 1024, 3136, 30208, 31616, 23552, 10944, 31488, 1488, 12160, 2656, 31232, 31904, 31760, 6720, 31040, 10176, 31104, 20416, 30752, 512, 2112, 11440, 31744, 2752, 160, 32464, 2688, 4608, 400, 3328, 22560, 27648, 30720, 11264. (=spike)

The candidates of number of spikes are estimated by the function [the function estimate_num_spikes (spike, range) [spike : read value, range : $2^n = 2^{15} = 32768$]] : R_q → candidates ; 4352 → 8, 15, 30, … ; 30656 → 16, … ; 27968 → 7, 14, 20, … ; 4304 → 8, 15, 23, … ; 2816 → 12, 23, … ; 3072 → 11, 21, … ; 12288 → 3, 5, 8, 16, … ; 30208 → 13, 26, … ; 5504 → 6, 12, 18, … ; 31744 → 32, … ; 31232 → 21, … ; 5120 → 6, 13, 19, … ; 2560 → 13, 26, …; 15776 → 2, 4, 6, 8, 10, 12, 15, 17, … ; 32192 → 57, … ; 22464 → 3, 6, 10, 13, 16, … ; 1024 → 32, … ; 3136 → 10, 21, … ; 30208 → 13, 26, … ; 31616 → 28, … ; 23552 → 4, 7, 14, 18, … ; 10944 → 3, 6, 9, 12, 15, 18, … ; 31488 → 26, … ; 1488 → 22, … ; 12160 → 3, 5, 8, 16, … ; 2656 → 12, 25, … ; 31232 → 21, … ; 31904 → 38, … ; 31760 → 33, … ; 6720 → 5, 10, 15, 20, … ; 31040 → 19, … ; 10176 → 3, 6, 10, 13, 16, … ; 31104 → 20, … ; 20416 → 3, 5, 8, 16, … ; 30752 → 16, … ; 512 → 64, … ; 2112 → 16, … ; 11440 → 3, 6, 9, 11, 14, 17, … ; 31744 → 32, … ; 2752 → 12, 24, … ; 160 → 205, … ; 32464 → 108, … ; 2688 → 12, 24, … ; 4608 → 7, 14, 21, … ; 400 → 82, … ; 3328 → 10, 20, … ; 22560 → 3, 6, 10, 13, 16, … ; 27648 → 6, 13, 19, … ; 30720 → 16, … ; 11264→ 3, 6, 9, 12, 15, 17, … .

When u is 16 ($2^0x_1 + 2^1x_2 + 2^2x_3 + 2^3x_4 + 2^4x_5 + 2^5x_6 + 2^6x_7 + 2^7x_8 + 2^8x_9 + 2^9x_{10} + 2^{10}x_{11} + 2^{11}x_{12} + 2^{12}x_{13} + 2^{13}x_{14} + 2^{14}x_{15} = 2^0×0 + 2^1×0 + 2^2×0 + 2^3×0 + 2^4×1 + 2^5×0 + 2^6×0 + 2^7×0 + 2^8×0 + 2^9×0 + 2^{10}×0 + 2^{11}×0 + 2^{12}×0 + 2^{13}×0 + 2^{14}×0 = 16$), the value of logical formula is 1. Therefore, it is the answer.

4-4. 11 Variables, 3 Repeat Qubits, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

For example at $n = 14$ [11 variables, and 3 repeat qubits], it is assumed that the logical formula, each value of $x_{1\sim11}$, each value of $m_{1\sim15}$, t, and k are same in the section 4-1.

A result of this problem is the following.

The probability probe value of $|w_{1,j}\rangle = 0$: ≈ 0.00048828 (≈ 1/2048).

The probability probe value of $|x_i\rangle = 16$: ≈ 0.0014952.

The example of 50 times test : The read value of $|x_i\rangle$; R_q = 2064, 1120, 3648, 256, 536, 15448, 0, 7552, 0, 2048, 15936, 16232, 3072, 15904, 1024, 8192, 12256, 0, 2176, 15872, 11744, 1536, 0, 15744, 0, 10368, 1024, 128, 4528, 1472, 192, 0, 15040, 928, 6168, 14880, 2880, 704, 3848, 0, 1088, 12640, 272, 512, 1616, 832, 15872, 15744, 160, 0. (=spike)

The candidates of number of spikes are estimated by the function [the function estimate_num_spikes (spike, range) [spike : read value, range : $2^n = 2^{14} = 16384$]] : R_q → candidates ; 2064 → 8, 16, … ; 1120 → 15, 29, … ; 3648 → 5, 9, 18, … ; 256 → 64, … ; 536 → 31, … ; 15448 → 18, … ; 0 → nothingness ; 7552 → 2, 4, 7, 9, 11, 13, 26, … ; 2048 → 8, 16, … ; 15936 → 37, … ; 16232 → 108, … ; 3072 → 5, 11, 16, … ; 15904→ 34, … ; 1024 → 16, …; 8192 → 2, 4, 6, 8, 10, 12, 14, 16, … ; 12256 → 4, 8, 12, 16, … ; 2176 → 8, 15, 30, … ; 15872 → 32, … ; 11744 → 4, 7, 14, 21, … ; 1536 → 11, 21, … ; 15744 → 26, … ; 10368 → 3, 5, 8, 11, 19, … ; 128 → 128, … ; 4528 → 4, 7, 11, 18, … ; 1472 → 11, 22, … ; 192 → 85, … ; 15040 → 12, 24, … ; 928 → 18, … ; 6168 → 3, 5, 8, 16, … ; 14880→ 11, 22, … ; 2880 → 6, 11, 17, … ; 704 → 23, … ; 3848 → 4, 9, 13, 17, … ; 1088 → 15, 30, … ; 12640 → 4, 9, 13, 22,

… ; 272 → 60, … ; 512 → 32, … ; 1616 → 10, 20, … ; 832 → 20, … ; 15872 → 32, … ; 15744 → 26, … ; 160 → 102, … .

When u is 16 ($2^0x_1 + 2^1x_2 + 2^2x_3 + 2^3x_4 + 2^4x_5 + 2^5x_6 + 2^6x_7 + 2^7x_8 + 2^8x_9 + 2^9x_{10} + 2^{10}x_{11} + 2^{11}x_{12} + 2^{12}x_{13} + 2^{13}x_{14} = 2^0\times0 + 2^1\times0 + 2^2\times0 + 2^3\times0 + 2^4\times1 + 2^5\times0 + 2^6\times0 + 2^7\times0 + 2^8\times0 + 2^9\times0 + 2^{10}\times0 + 2^{11}\times0 + 2^{12}\times0 + 2^{13}\times0 = 16$), the value of logical formula is 1. Therefore, it is the answer.

4-5. 11 Variables, 2 Repeat Qubits, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

For example at n = 13 [11 variables, and 2 repeat qubits], it is assumed that the logical formula, each value of $x_{1\sim11}$, each value of $m_{1\sim15}$, t, and k are same in the section 4-1.

A result of this problem is the following.

The probability probe value of $|w_{1,j}\rangle = 0$: ≈ 0.00048828 (≈ 1/2048).

The probability probe value of $|x_i\rangle = 16$: ≈ 0.0024470.

The example of 50 times test : The read value of $|x_i\rangle$; R_q = 6912, 640, 260, 1276, 7616, 256, 2560, 8000, 268, 7776, 2944, 5864, 5376, 7936, 5184, 2568, 0, 7744, 0, 6536, 6136, 7948, 672, 1152, 1548, 7932, 128, 1088, 7616, 7920, 640, 256, 1032, 3056, 5392, 0, 2080, 384, 2708, 2376, 512, 0, 7936, 112, 5248, 1280, 7616, 3776, 544, 2744. (=spike)

The candidates of number of spikes are estimated by the function [the function estimate_num_spikes (spike, range) [spike : read value, range : $2^n = 2^{13} = 8192$]] : R_q → candidates ; 6912 → 6, 13, 19, … ; 640 → 13, 26, … ; 260 → 32, … ; 1276 → 6, 13, 26, … ; 7616 → 14, 28, … ; 256 → 32, … ; 2560 → 3, 6, 10, 13, 16, … ; 8000 → 43, … ; 268 → 31, … ; 7776 → 20, … ; 2944 → 3, 6, 8, 11, 14, 25, … ; 5864 → 4, 7, 14, 21, … ; 5376 → 3, 6, 9, 12, 15, 17, … ; 7936→ 32, … ; 5184 → 3, 5, 8, 11, 19, … ; 2568 → 3, 6, 10, 13, 16, … ; 0 → nothingness ; 7744 → 18, … ; 6536 → 5, 10, 15, 20, … ; 6136 → 4, 8, 12, 16, … ; 7948 → 34, … ; 672 → 12, 24, … ; 1152 → 7, 14, 21, … ; 1548 → 5, 11, 16, … ; 7932 → 32, … ; 128 → 64, … ; 1088 → 8, 15, 30, … ; 7616 → 14, 28, … ; 7920 → 30, … ; 640→ 13, 26, … ; 1032 → 8, 16, … ; 3056 → 3, 5, 8, 16, … ; 5392 → 3, 6, 9, 12, 15, 18, … ; 2080 → 4, 8, 12, 16, … ; 384 → 21, … ; 2708 → 3, 6, 9, 12, 15, 18, … ; 2376 → 4, 7, 14, 17, … ; 512→ 16, … ; 7936 → 32, … ; 112 → 73, … ; 5248 → 3, 6, 8, 11, 14, 25, … ; 1280 → 6, 13, 19 … ; 7616 →14, 28, … ; 3776 → 2, 4, 7, 9, 11, 13, 26, … ; 544 → 15, 30, … ; 2744 → 3, 6, 9, 12, 15, 18, … .

When u is 16 ($2^0x_1 + 2^1x_2 + 2^2x_3 + 2^3x_4 + 2^4x_5 + 2^5x_6 + 2^6x_7 + 2^7x_8 + 2^8x_9 + 2^9x_{10} + 2^{10}x_{11} + 2^{11}x_{12} + 2^{12}x_{13} = 2^0\times0 + 2^1\times0 + 2^2\times0 + 2^3\times0 + 2^4\times1 + 2^5\times0 + 2^6\times0 + 2^7\times0 + 2^8\times0 + 2^9\times0 + 2^{10}\times0 + 2^{11}\times0 + 2^{12}\times0 = 16$), the value of logical formula is 1. Therefore, it is the answer.

4-6. 11 Variables, 1 Repeat Qubit, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

For example at n = 12 [11 variables, and 1 repeat qubit], it is assumed that the logical formula, each value of $x_{1\sim11}$, each value of $m_{1\sim15}$, t, and k are same in the section 4-1.

A result of this problem is the following.

The probability probe value of $|w_{1,j}\rangle = 0$: ≈ 0.00048828 (≈ 1/2048).

The probability probe value of $|x_i\rangle = 16$: ≈ 0.0027172.
The example of 50 times test : The read value of $|x_i\rangle$; R_q = 3664, 3872, 1466, 236, 4080, 2976, 450, 32, 2410, 2344, 764, 3848, 3568, 128, 1664, 1988, 512, 2366, 3680, 1660, 2896, 1388, 624, 992, 3956, 492, 128, 0, 232, 448, 3970, 116, 4088, 3400, 128, 192, 688, 3652, 512, 192, 0, 3584, 152, 3408, 3972, 1312, 3816, 1296, 0, 3724. (=spike)

The candidates of number of spikes are estimated by the function [the function estimate_num_spikes (spike, range) [spike : read value, range : $2^n = 2^{12} = 4096$]] : R_q → candidates ; 3664 → 10, 19, … ; 3872 → 18, … ; 1466 → 3, 6, 8, 11, 14, 28, … ; 236 → 17, … ; 4080 → 256, … ; 2976 → 4, 7, 11, 22, … ; 450 → 9, 18, … ; 32 → 128, … ; 2410→ 3, 5, 10, 12, 17, … ; 2344 → 2, 5, 7, 14, 21, … ; 764 → 5, 11, 16, … ; 3848 → 17, … ; 3568 → 8, 16, … ; 128 → 32, … ; 1664 → 3, 5, 10, 15, 17, … ; 1988 → 2, 4, 6, 8, 10, 12, 14, 16, … ; 512 → 8, 16, … ; 2366 → 2, 5, 7, 12, 19, … ; 3680 → 10, 20, … ; 1660 → 3, 5, 10, 15, 20, … ; 2896 → 3, 7, 10, 17, … ; 1388 → 3, 6, 9, 12, 15, 18, … ; 624 →7, 13, 26, … ; 992 → 4, 8, 12, 17, … ; 3956 → 29, … ; 492 → 8, 17, … ; 128 → 32, … ; 0→ nothingness ; 232 → 18, … ; 448 → 9, 18, … ; 3970 → 33, … ; 116 → 35, … ; 4088 → 512, … ; 3400 → 6, 12, 18, … ; 192 → 21, … ; 688 → 6, 12, 18, … ; 3652 → 9, 18, … ; 192 → 21, … ; 3584 → 8, 16, … ; 152 → 27, … ; 3408 → 6, 12, 18, … ; 3972 → 33, … ; 1312 → 3, 6, 9, 13, 16, … ; 3816 → 15, 29, … ; 1296 → 3, 6, 10, 13, 16, … ; 3724 → 11, 22, … .

When u is 16 ($2^0x_1 + 2^1x_2 + 2^2x_3 + 2^3x_4 + 2^4x_5 + 2^5x_6 + 2^6x_7 + 2^7x_8 + 2^8x_9 + 2^9x_{10} + 2^{10}x_{11} + 2^{11}x_{12} = 2^0\times0 + 2^1\times0 + 2^2\times0 + 2^3\times0 + 2^4\times1 + 2^5\times0 + 2^6\times0 + 2^7\times0 + 2^8\times0 + 2^9\times0 + 2^{10}\times0 + 2^{11}\times0 = 16$), the value of logical formula is 1. Therefore, it is the answer.

4-7. 11 Variables, 0 Repeat Qubit, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

For example at $n = 11$ [11 variables, and 0 repeat qubit], it is assumed that the logical formula, each value of $x_{1\sim11}$, each value of $m_{1\sim15}$, t, and k are same in the section 4-1.

A result of this problem is the following.
The probability probe value of $|w_{1,j}\rangle = 0$: ≈ 0.00048828 (≈ 1/2048).
The probability probe value of $|x_i\rangle = 16$: ≈ 0.0049731.
The example of 50 times test : The read value of $|x_i\rangle$; R_q = 1476, 332, 616, 1994, 61, 1940, 0, 840, 464, 1919, 1712, 2028, 144, 31, 704, 2000, 1914, 1640, 1872, 2000, 1388, 1932, 124, 384, 1854, 2043, 65, 66, 1924, 1792, 2047, 1904, 288, 188, 224, 1340, 2046, 164, 594, 176, 0, 20, 1918, 1324, 193, 1672, 1808, 596, 1984, 58. (=spike)

The candidates of number of spikes are estimated by the function [the function estimate_num_spikes (spike, range) [spike : read value, range : $2^n = 2^{11} = 2048$]] : R_q → candidates ; 1476 → 4, 7, 14, 18, … ; 332 → 6, 12, 19, … ; 616 → 3, 7, 10, 20, … ; 1994 → 38, … ; 61 → 34, … ; 1940 → 19, … ; 0 → nothingness ; 840 → 3, 5, 10, 12, 17, … ; 464 → 4, 9, 13, 22, … ; 1919→ 16, … ; 1712 → 6, 12, 18, …; 2028 → 102, … ; 144 → 14, 28, … ; 31 → 66, … ; 704 → 3, 6, 9, 12, 15, 17, … ; 2000 → 43, … ; 1914 → 15, 31, … ; 1640 → 5, 10, 15, 20, … ; 1872 → 12, 23, … ; 1388 → 3, 6, 9, 12, 16, … ; 1932 → 18, … ; 124 → 17, … ; 384 → 5, 11, 16, … ; 1854 → 11, 21,

… ; 2043 → 410, … ; 65 → 32, … ; 66 → 31, … ; 1924 → 17, … ; 1792 → 8, 16, … ; 2047 → nothingness ; 1904 → 14, 28, … ; 288 → 7, 14, 21, … ; 188→ 11, 22, … ; 224 → 9, 18, …; 1340 → 3, 6, 9, 12, 14, 17, … ; 2046 → 1024 ; 164 → 13, 25, … ; 594 → 4, 7, 14, 17, … ; 176 → 12, 23, … ; 20 → 102, … ; 1918 → 16, … ; 1324→ 3, 6, 9, 11, 14, 17, … ; 193 → 11, 21, … ; 1672 → 4, 11, 22, … ; 1808 → 9, 17, … ; 596 → 4, 7, 14, 17, … ; 1984 → 32, … ; 58 → 35, … .

When u is 16 ($2^0x_1 + 2^1x_2 + 2^2x_3 + 2^3x_4 + 2^4x_5 + 2^5x_6 + 2^6x_7 + 2^7x_8 + 2^8x_9 + 2^9x_{10} + 2^{10}x_{11} = 2^0\times0 + 2^1\times0 + 2^2\times0 + 2^3\times0 + 2^4\times1 + 2^5\times0 + 2^6\times0 + 2^7\times0 + 2^8\times0 + 2^9\times0 + 2^{10}\times0 = 16$), the value of logical formula is 1. Therefore, it is the answer.

Discussion

In the 3-SAT problem, when [(the logical formula) = 1] is obtained, there is only one combination.

5-1. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]

In the section 4, there is RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15]. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. When N is 2^{11}, in the Grover's method, the complexity is $N^{1/2} = 2^{11/2} \approx 45$, in the new method, for (variables, repeat qubits) = (11, 0), it is 50/5 = 10, for (11, 1), it is 50/8 ≈ 6, for (11, 2), it is 50/8 ≈ 6, for (11, 3), it is 50/8 ≈ 6, for (11, 4), it is 50/10 = 5, for (11, 5), it is 50/12 ≈ 4, and for (11, 6), it is 50/16 ≈ 3.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 6), the probability is the maximum value 32%.

5-2. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 1]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 1], t = 6, and k = 106. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/10 = 5, for (11, 1), it is 50/6 ≈ 8, for (11, 2), it is 50/8 ≈ 6, for (11, 3), it is 50/8 ≈ 6, for (11, 4), it is 50/13 ≈ 4, for (11, 5), it is 50/6 ≈ 8, and for (11, 6), it is 50/6 ≈ 8.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 4), the probability is the maximum value 26%.

5-3. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 1, 2]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 1, 2], t = 6, and k = 94. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/10 = 5, for (11, 1), it is 50/10 = 5, for (11, 2), it is 50/11 ≈ 5, for (11, 3), it is 50/6 ≈ 8, for (11, 4), it is 50/9 ≈ 6, for (11, 5), it is 50/7 ≈ 7, and for (11, 6), it is 50/11 ≈ 5.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 2), and (11, 6), the probability is the maximum value 22%.

5-4. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 1, 2, 3], t = 6, and k = 84. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/5 = 10, for (11, 1), it is 50/5 = 10, for (11, 2), it is 50/5 = 10, for (11, 3), it is 50/8 ≈ 6, for (11, 4), it is 50/9 ≈ 6, for (11, 5), it is 50/9 ≈ 6, and for (11, 6), it is 50/12 ≈ 4.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 6), the probability is the maximum value 24%.

5-5. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 1, 2, 3, 4]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 1, 2, 3, 4], t = 6, and k = 76. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/15 ≈ 3, for (11, 1), it is 50/11 ≈ 5, for (11, 2), it is 50/6 ≈ 8, for (11, 3), it is 50/7 ≈ 7, for (11, 4), it is 50/4 ≈ 13, for (11, 5), it is 50/11 ≈ 5, and for (11, 6), it is 50/8 ≈ 6.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 0), the probability is the maximum value 30%.

5-6. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 1, 2, 3, 4, 5]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 1, 2, 3, 4, 5], t = 6, and k = 70. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/4 ≈ 13, for (11, 1), it is 50/8 ≈ 6, for (11, 2), it is 50/7 ≈ 7, for (11, 3), it is 50/8 ≈ 6, for (11, 4), it is 50/4 ≈ 13, for (11, 5), it is 50/12 ≈ 4, and for (11, 6), it is 50/5 = 10.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 5), the probability is the maximum value 24%.

5-7. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 1, 2, 3, 4, 5, 6]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 1, 2, 3, 4, 5, 6], t = 6, and k = 66. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/11 ≈ 5, for (11, 1), it is 50/9 ≈ 6, for (11, 2), it is 50/9 ≈ 6, for (11, 3), it is 50/10 = 5, for (11, 4), it is 50/16 ≈ 3, for (11, 5), it is 50/10 = 5, and for (11, 6), it is 50/10 = 5.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 4), the probability is the maximum value 32%.

5-8. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 8, 1, 2, 3, 4, 5, 6, 7]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 8, 1, 2, 3, 4, 5, 6, 7], t = 6, and k = 64. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/4 ≈ 13, for (11, 1), it is 50/10 = 5, for (11, 2), it is 50/8 ≈ 6, for (11, 3), it is 50/7 ≈ 7, for (11, 4), it is 50/5 = 10, for (11, 5), it is 50/9 ≈ 6, and for (11, 6), it is 50/4 ≈ 13.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 1), the probability is the maximum value 20%.

5-9. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 7, 1, 2, 3, 4, 5, 6, 7, 1]

There are RAM = [1, 2, 3, 4, 5, 6, 7, 1, 2, 3, 4, 5, 6, 7, 1], t = 5, and k = 57. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/6 ≈ 8, for (11, 1), it is 50/11 ≈ 5, for (11, 2), it is 50/8 ≈ 6, for (11, 3), it is 50/5 = 10, for (11, 4), it is 50/6 ≈ 8, for (11, 5), it is 50/9 ≈ 6, and for (11, 6), it is 50/7 ≈ 7.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 1), the probability is the maximum value 22%.

5-10. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5, 6, 1, 2, 3]

There are RAM = [1, 2, 3, 4, 5, 6, 1, 2, 3, 4, 5, 6, 1, 2, 3], t = 5, and k = 48. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/6 ≈ 8, for (11, 1), it is 50/10 = 5, for (11, 2), it is 50/10 = 5, for (11, 3), it is 50/5 = 10, for (11, 4), it is 50/3 ≈ 17, for (11, 5), it is 50/5 = 10, and for (11, 6), it is 50/7 ≈ 7.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 1), and (11, 2), the probability is the maximum value 20%.

5-11. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 5, 1, 2, 3, 4, 5, 1, 2, 3, 4, 5]

There are RAM = [1, 2, 3, 4, 5, 1, 2, 3, 4, 5, 1, 2, 3, 4, 5], t = 5, and k = 45. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/3 ≈ 17, for (11, 1), it is 50/11 ≈ 5, for (11, 2), it is 50/11 ≈ 5, for (11, 3), it is 50/4 ≈ 13, for (11, 4), it is 50/8 ≈ 6, for (11, 5), it is 50/6 ≈ 8, and for (11, 6), it is 50/8 ≈ 6.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 1), and (11, 2) the probability is the maximum value 22%.

5-12. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3]

There are RAM = [1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3, 4, 1, 2, 3], t = 5, and k = 36. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/6 ≈ 8, for (11, 1), it is 50/10 = 5, for (11, 2), it is 50/7 ≈ 7, for (11, 3), it is 50/11 ≈ 5, for (11, 4), it is 50/7 ≈ 7, for (11, 5), it is 50/5 = 10, and for (11, 6), it is 50/8 ≈ 6.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 3), the probability is the maximum value 22%.

5-13. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 3, 1, 2, 3, 1, 2, 3, 1, 2, 3, 1, 2, 3]

There are RAM = [1, 2, 3, 1, 2, 3, 1, 2, 3, 1, 2, 3, 1, 2, 3], t = 4, and k = 30. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/7 ≈ 7, for (11, 1), it is 50/8 ≈ 6, for (11, 2), it is 50/8 ≈ 6, for (11, 3), it is 50/5 = 10, for (11, 4), it is 50/9 ≈ 6, for (11, 5), it is 50/10 = 5, and for (11, 6), it is 50/8 ≈ 6.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 5), the probability is the maximum value 20%.

5-14. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 2, 1, 2, 1, 2, 1, 2, 1, 2, 1, 2, 1, 2, 1]

There are RAM = [1, 2, 1, 2, 1, 2, 1, 2, 1, 2, 1, 2, 1, 2, 1], t = 4, and k = 22. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/9 ≈ 6, for (11, 1), it is 50/11 ≈ 5, for (11, 2), it is 50/10 = 5, for (11, 3), it is 50/7 ≈ 7, for (11, 4), it is 50/10 = 5, for (11, 5), it is 50/6 ≈ 8, and for (11, 6), it is 50/8 ≈ 6.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 1), the probability is the maximum value 22%.

5-15. 11 Variables, Repeat Qubits from 0 to 6, and RAM = [1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1]

There are RAM = [1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1], t = 3, and k = 15. And then, [(the logical formula) = 1] of combination of variables is selected, and the computation of repeats is done. In the new method, for (11, 0), it is 50/4 ≈ 13, for (11, 1), it is 50/3 ≈ 17, for (11, 2), it is 50/6 ≈ 8, for (11, 3), it is 50/3 ≈ 17, for (11, 4), it is 50/5 = 10, for (11, 5), it is 50/7 ≈ 7, and for (11, 6), it is 50/4 ≈ 13.

In this range, the new method is less than the complexity of the Grover's method, and then, in for (11, 5), the probability is the maximum value 14%.

Summary

The quantum algorithm for the 3-SAT problem of 11 variables by the quantum Fourier transform with the repeat qubits, and the weight changes on the QCEngine, and its example are reported.

The complexity of this method is several times, and then, in for (11, 6) of RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15], and in for (11, 4) of RAM = [1, 2, 3, 4, 5, 6, 7, 8, 9, 1, 2, 3, 4, 5, 6], the probability is the maximum value 32%.

I will apply this method for other problems.

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