Quantum Models for Data Structures and Computing

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Abstract – **The qubit (quantum) data structures and computational processes are proposed to significantly improve the performance in solving problems of discrete optimization and fault-tolerant design. A quantum device prototype is implemented by programmable logic.**

Keywords – **quantum computer, qubit, fault-tolerant design, programmable logic.**

1. INTRODUCTION

The market appeal of quantum (qubit) models is based on the high parallelism of solving almost all problems of discrete optimization, factoring, minimization of Boolean functions, effective compression, compact representation and teleportation of data, fault-tolerant design [1-3]. Hardware-oriented models for parallel (one cycle) calculating the set of all subsets on the universe of n primitives for solving problems of coverage, minimization of Boolean functions, data compression, analysis and synthesis of digital systems through the implementation of the processor structure in the form of the Hasse diagram.

II. QUBIT (QUANTUM) PROCESSOR

The goal of creating qubit-processor is significant reduction of time for solving optimization problems by parallel computing vector logical operations on the set of all subsets of primitive components due to increase memory to store intermediate data.

As an example, it is proposed the problem for searching the optimal unit coverage of all the columns by a minimal number of the matrix M rows (Fig.1). It is necessary to examine all 255 combinations: from 8 elements by one, two, three, four, five, six, seven and eight rows. The minimum number of primitives (rows) forming the coverage is an optimal solution. There may be several such decisions. The Hasse diagram is a compromise proposal with respect to time and memory. For each coverage table involving n primitives (rows), it is necessary to generate a multiprocessor structure in the form of the Hasse diagram, which then must be used to solve almost parallel NP-complete problem. For example, the Hasse diagram (multiprocessor structure) for four rows of the

M	1	2	3	4	5	6	7	8
a	1	.	.	.	.	1	.	.
b	.	.	1	.	.	.	1	.
c	1	.	.	.	1	.	1	.
d	.	1	.	1	.	.	.	1
e	.	1	.	.	1	.	.	.
f	1	.	1	.	.	1	1	.
g	.	1	.	1	.	.	.	1
h	.	.	1	.	1	.	.	.

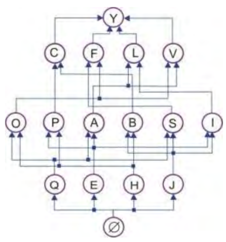

Fig. 1. Hasse-structure of computational processes

coverage table is shown in Fig. 1. The optimal solution of coverage problem for the matrix M are represented by row combination: C=fgh∨efg∨cdf. The advantages of Cubit Hasse Processor (CHP) are the ability to use only two-input gates for vector logic operations (and, or, xor), and thus substantially reducing the circuit complexity by Quine, when implementing processing elements (nodes) and memory, through the use of sequential calculations and small increase the processing time of all Hasse graph nodes. For each node the criterion of the coverage quality is used – the presence of all 1's in the coordinates of the vector-result. If the quality criterion is satisfied, then all the calculations can not be produced, because the Hasse diagram is a strictly hierarchical structure on the number of combinations in each level. The hardware costs for implementing the CHP depends on the total number of Hasse nodes and the number of bits (digits) in the coverage table row: $H = 2^n \times k \times m$, where k – coefficient of the hardware implementation (complexity) of one bit of binary vector logic operation and subsequent calculation command for the criterion of coverage quality. Model of a quantum unit is developed by Verilog language. The CPU cell involves two register gates. The unit is implemented on FPGA Xilinx xc3s1600e-4-fg484.

III. CONCLUSION

The implementation of a quantum processor based on the structure of the Hasse enabled to reduce hardware costs n times, which reduced the processor speed n times too. It is necessary to find new data structures for reducing the hardware cost of quantum computing, or more intelligent algorithms for solving the coverage problem in the Hasse diagram. The scientific novelty is new data model and hardware implementation of a quantum computer, which is characterized by using the Hasse structure that makes it possible to improve significantly (x100) the performance of solving the discrete optimization problems. The practical value is significant increase the speed of solving the coverage problem and other discrete optimization problems by increasing the hardware cost for parallel executing vector logic operations on the Hasse-structure of quantum computer.

REFERENCES

[1] R.W. Keyes, "Challenges for quantum computing with solid-state devices," *Computer*, Vol. 38, Issue 1, pp. 65 – 69, Jan. 2005.

[2] A. Glassner, "Quantum computing. 3," *IEEE Computer Graphics and Applications*, Vol. 21, Issue 6, pp. 72 – 82, Nov/Dec 2001.

[3] D.C. Marinescu, "The Promise of Quantum Computing and Quantum Information Theory – Quantum Parallelism," *Proceedings of the 19th IEEE International Parallel and Distributed Processing Symposium (IPDPS'05)*, pp. 112-114, 2005.