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Scalable Quantum Computing to Solve Optimization Problems

A team of Stanford researchers has developed an efficient, scalable quantum computing system designed to quickly solve combinatorial optimization problems using off-the-shelf components operating at room temperature. This technology employs optical parametric oscillators (OPOs) and an electronic circuit to simulate an Ising machine that computes nondeterministic polynomial (NP)-complete problems - a class of problems that cannot be solved with standard computers because the possible solutions increases exponentially with the number of variables. This network of quantum systems can be adapted and scaled up by expanding the number of OPOs or scaled down and miniaturized. The machine can be implemented with simple programming to solve a wide range of NP optimization problems in fields such as logistics, drug discovery, finance or circuit design.

Stage of Research
The inventors have built a prototype machine and used it to find solutions for thousands of scenarios with up to 100-variables. They have demonstrated experimental results with more than 99.6% success for one-dimensional problems using a 16-bit coherent Ising machine.

Applications

- **Quantum computing** - blended optical and electronic hardware system designed to solve combinatorial optimization problems in polynomial time, with end user applications in areas such as:
    - logistics and scheduling
    - drug discovery
    - finance
    - integrated circuit design
    - manufacturing

Advantages

- **Efficient, scalable computation:**
    - simple programming makes this design easy to realize at a larger scale
    - number of sites can be increased with time division multiplexing
    - possible to miniaturize
- **Simple hardware implementation:**
    - off-the-shelf lasers, crystals and optical elements
    - no single-photon sources or detectors
- **Room temperature operation**

Publications

- Mcmahon, P. L., A. Marandi, Y. Haribara, R. Hamerly, C. Langrock, S. Tamate, T. Inagaki, H. Takesue, S. Utsunomiya, K. Aihara, R. L. Byer, M. M. Fejer, H. Mabuchi, and Y. Yamamoto.(2016)A Fully-programmable 100-spin Coherent Ising Machine with All-to-all Connections. *Science*.
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- Stanford researchers create new special-purpose computer that may someday save us billions, *Stanford Report* Oct. 20, 2016.
- Computation using a network of optical parametric oscillators (Published PCT Application WO2015006494A1)

Patents

- Published Application: WO2015006494
- Published Application: 20160162798
- Issued: 9,830,555 (USA)

Innovators

- Alireza Marandi
- Yoshihisa Yamamoto
- Robert Byer
- Zhe Wang
- Shoko Utsunomiya

Licensing Contact

Luis Mejia

Senior Licensing Manager, Physical Sciences

Email