Solving real-world problems with fewer qubits, GIST presents a new and unique quantum approach

- Feynman path integration presents an effective quantum approach to real-world problems... Secures efficient quantum computing capabilities for complex optimization problems while minimizing qubit usage
- It will bring about great changes across all industries, including autonomous driving, pharmaceuticals, finance, and logistics... Published in the international academic journal ‘IEEE Transactions on Intelligent Transportation Systems’

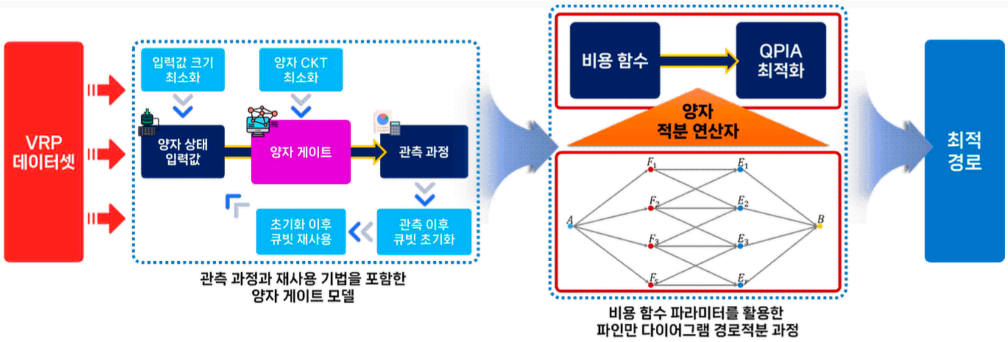
▲ (From the left) Jun Suk Kim, a doctoral student in the School of Electrical Engineering and Computer Science of the AI Graduate School, and Professor Chang Wook Ahn of the AI Graduate School. Example of vehicle route optimization problem and example of quantum circuit diagram and simulator execution results for the proposed quantum approach.

Professor Chang Wook Ahn's research team, who developed Korea's first artificial intelligence (AI) composer 'EvoM', proposed a new approach to solving real-world problems using quantum theory, which is in the spotlight as one of the three game-changing technologies for future industries.

The Gwangju Institute of Science and Technology (GIST, President Kichul Lim) announced that Professor Chang Wook Ahn's research team at the AI Graduate School has developed a quantum algorithm that efficiently solves the Vehicle Routing Problem* using the Feynman Path Integral* method, which explains quantum mechanical phenomena.

* Feynman path integration method: In order to calculate the movement path of a particle in quantum mechanics, all possible paths a particle can take from the start point to the end point are considered and the probability amplitude for each path is calculated to find the most likely path.

* vehicle routing problem: It is a problem of finding a route to deliver products to customers in the optimal order at minimum cost using multiple vehicles. It plays an important role in various industries such as actual logistics, transportation, and delivery services.



▲ Structure of the proposed vehicle path optimization technique using the quantum path integration method: The path integration method used with the quantum approximation method utilizes the Schrödinger wave equation of quantum computing with only limited qubits to gradually amplify the probability amplitude distribution for the optimal vehicle path.

Quantum mechanics is a field of physics that explains the most basic properties of matter and energy. Despite high expectations for its potential, quantum computing*, which uses these principles to process information, requires error correction, etc. to reach the commercialization stage. There are many difficulties in developing practical algorithms because many technical problems must be solved.

In order to maximize the potential performance of quantum computing, it is necessary to develop pure quantum algorithms with unique operating principles resulting from quantum characteristics. However, most research is attempting an approach that replicates existing computing algorithms on quantum computers, so not only is it difficult to obtain so-called actual quantum gain*, but the number of qubits (quantum bits) required to solve a problem is generally not proportional to the size of the problem.

For example, IBM developed the world's first quantum process with over 1,100 qubits earlier this year, but even this unique process is only capable of solving the vehicle routing problem consisting of about 30 cities.

* quantum computing: Using quantum properties of irregularity, probability, overlap, and entanglement, complex problems can be solved much faster than conventional computers, and the basic unit is a qubit.

* quantum gain: An advantage that occurs when quantum technology provides superior performance over existing technology. It generally refers to the ability of a quantum computer to solve a specific problem much faster than a conventional computer.

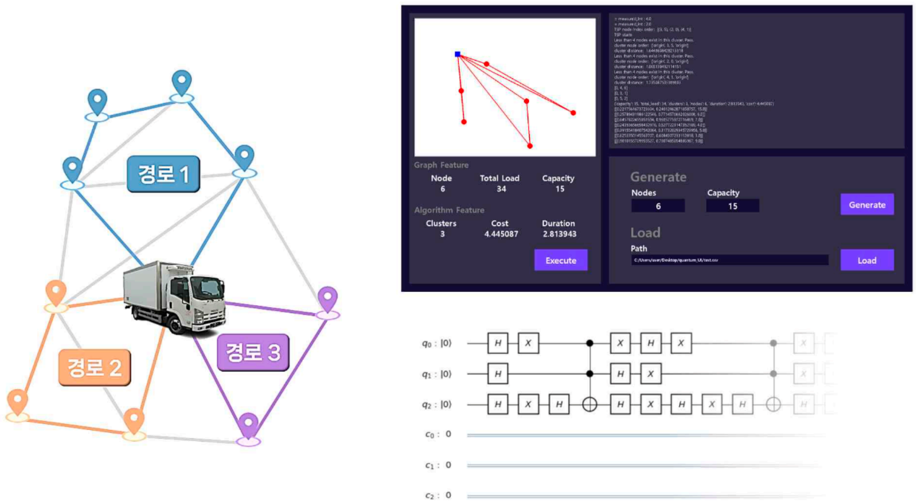
The research team developed a new and original Quantum Path Integral Approach for optimizing vehicle path problems by combining the principles of quantum computation with the Feynman path integral method handled in existing quantum mechanics.

This method consists of referring to the quantum system expressed as Schrödinger's wave function* and using it to calculate the probability amplitude distribution of quantum states representing each optimization path.

* Schrödinger wave function: In quantum mechanics, it is a mathematical function that describes the state of a material particle (e.g. electron, atom) or system, indicating the probability that a specific particle or system will be in a certain state at a specific location. Through a collection of amplitudes, physical properties such as the position and state of motion of particles can be predicted.

The research team conducted a variety of experiments using the proposed approach on complex problems in the real world and vehicle routing problems that share their properties, and confirmed that the proposed approach could successfully find an optimized path, making it possible to use the proposed approach in various ways in the real world. It has been proven that it can be applied practically to the problem.

In particular, it was confirmed that efficient quantum ability to find a solution can be secured while exponentially reducing the qubit usage required to solve the vehicle route optimization problem with N cities from the existing N2 to N.



▲ Simulator and circuit structure for the proposed approach: An example of a vehicle path optimization problem, a quantum circuit diagram for the proposed approach, and the execution results of the simulator are displayed.

Professor Chang Wook Ahn said, "The significance of this research outcome is that it suggests a quantum approach to solving various problems in the real world using a small number of qubits. The realization of practical quantum gains will bring about major changes across all industries, including autonomous driving, pharmaceuticals, finance, and logistics, which are closely related to our daily lives, and is also expected to greatly contribute to advancing the era of quantum computing."

This study was conducted with support from the Institute for Information and Communications Technology Planning and Evaluation (IITP) Artificial Intelligence Graduate School Project, and the research results were recently published in IEEE Transactions on Intelligent Transportation Systems, an international academic journal ranked among the top 2.5% in the transportation systems field.

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