Environmental noise in quantum computation and the promises of quantum search

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Quantum computation uses systems of quantum particles to tap into theoretical promises of immense speed-up, even compared to the fastest conventional supercomputers. By constructing so-called quantum bits out of these particles, which unlike the digital bits used to represent ones and zeroes in your home computer, may exist in what is referred to as a superposition, which is to say the bit is "off" (0) and "on" (1) simultaneously. Although these quantum systems may be constructed out of a number of different quantum particles (such as the spin of an electron or orientation of a photon), they are invariably subject to environmental noise, from which unwanted errors with regard to the quantum states of the system inevitably follow.

We set out to investigate the impact of environmental noise on an important search algorithm within quantum computation, Grover's algorithm. This quantum algorithm purports to solve the problem of searching for some desired object in an unordered set of objects, analogous to finding a needle in a haystack. In theory, Grover's algorithm should decrease the number of steps needed to find this object from n to the square root of n, where n is the number of objects in our set (to find a needle in a haystack, we could look through every straw in the stack before finding the needle).

We performed experimental simulations of an IBM quantum computer with and without noise to measure the its impact on the output of the algorithm. Our results indicate that Grover's algorithm is gravely impacted by noise; even at five qubits, the noise is at a point where it renders the results unusable. If the effects of noise on the algorithm could be mitigated, Grover's algorithm could have numerous practical applications; for example, it could have dire consequences for cryptography, speeding up brute-force search by a considerable factor. On a brighter note, it could also speed up database lookup and constraint satisfaction solving problems fundamental to vaccine and drug development.