A universal protocol that inverts the evolution of a qubit with a high probability of success

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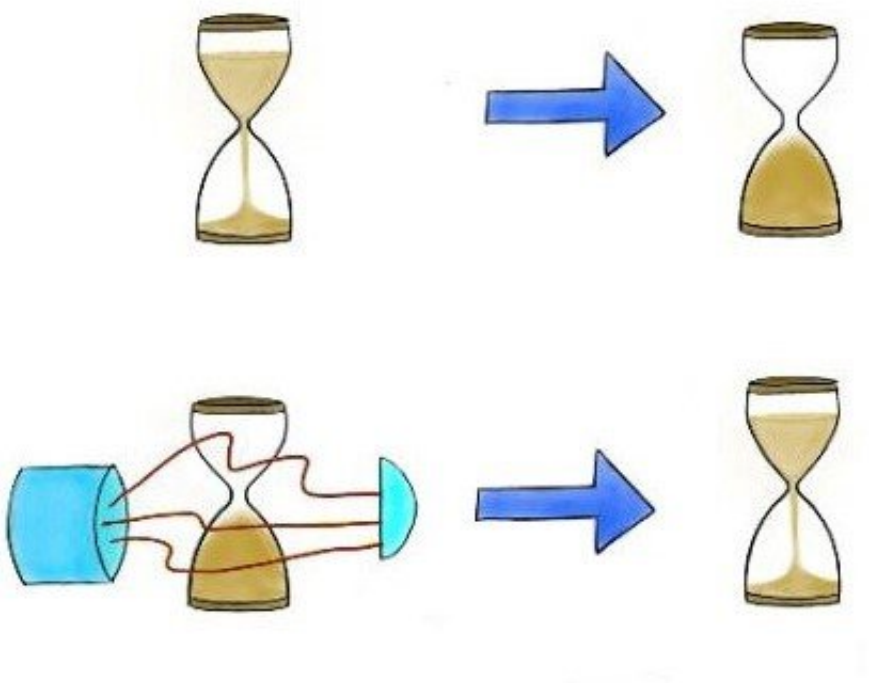

Credit: David Trillo

Researchers at the Institute for Quantum Optics and Quantum Information (IQOQI) in Vienna recently devised a universal mechanism

to invert the evolution of a qubit with a high probability of success. This protocol, outlined in *Physical Review Letters*, can propagate any target qubit back to the state it was in at a specific time in the past.

The introduction of this protocol builds on a previous paper published in 2020, where the same team presented a series of time translating protocols that could be applied in uncontrolled settings. While some of these protocols were promising, in most tested scenarios their probability of success was found to be too small. In their new study, the researchers thus set out to create an alternative protocol with a higher probability of success.

"Our newly developed protocol inverts the unitary evolution of a qubit," David Trillo, one of the researchers who carried out the study together with Benjamin Dive and Miguel Navascués, told Phys.org. "A qubit (or quantum bit) is a two-level quantum system that serves as the quantum equivalent of bits used in quantum computers. Any quantum system has some natural evolution in time that needs to be controlled or at least accounted for when designing physical processes around them (e.g., when building a quantum computer). Our protocol takes a qubit and outputs the same system, but in the state that it would be in if it had evolved backwards in time."

The protocol created by Trillo and his colleagues is universal, which means that it can be applied to any qubit, irrespective of its natural time evolution or what state it is when the protocol is used. Universal protocols are inherently probabilistic, meaning that they cannot succeed all the time, but rather have a certain probability of success.

In initial evaluations, the researchers found that their universal quantum rewinding mechanism has a high probability of success, namely of 1. Essentially, the protocol works by setting a target qubit on a superposition of flight paths and then performing a series of quantum

operations on it.

"Our protocol works for uncontrolled systems, or in other words qubits on which we don't know how to apply particular transformations," Trillo explained. "Its cool new feature is that, whenever it fails, we can correct the failure and drive the system to the desired state. By adaptively performing these corrections, we can make the probability of success as high as we want, at the cost of increasing the running time of the protocol."

The new universal protocol introduced by Trillo and his colleagues allows researchers to rewind any given qubit in an uncontrolled setting with a high probability of success. While protocols that could achieve this in controlled settings already existed, unlocking the ability to propagate individual qubits in uncontrolled environments to a previous state could open new valuable possibilities for research.

"One wonders what other phenomena from the controlled setting we can transfer to an uncontrolled one," Trillo added. "Ideally, we would like to generalize this protocol to higher dimensional systems. This seems to be quite challenging though, as new ideas are needed for this. We are also looking into improving the success probability of the other protocols in the original paper, particularly SWAP protocols."

More information: D. Trillo et al, Universal Quantum Rewinding Protocol with an Arbitrarily High Probability of Success, *Physical Review Letters* (2023). DOI: 10.1103/PhysRevLett.130.110201

protocol-inverts-evolution-qubit.html