Taking statistics to the quantum domain

November 9 2016, by Lisa Zyga

In the quantum change point problem, a quantum source emits particles that are received by a detector. At some unknown point, a change occurs in the state of the particles being emitted. Physicists have found that global measurement methods, which use quantum repeaters, outperform all classical measurement methods for accurately identifying when the change occurred. Credit: Sentis et al. ©2016 American Physical Society

(Phys.org)—The change point problem is a concept in statistics that pops up in a wide variety of real-world situations, from stock markets to protein folding. The idea is to detect the exact point at which a sudden change has occurred, which could indicate, for example, the trigger of a financial crisis or a misfolded protein step.

Now in a new paper published in *Physical Review Letters*, physicists Gael Sentís *et al*. have taken the change point problem to the quantum domain.

"Our work sets an important landmark in quantum information theory by porting a fundamental tool of classical statistical analysis into a fully quantum setup," Sentis, at the University of the Basque Country in Bilbao, Spain, told *Phys.org*.

"With an ever-growing number of promising applications of quantum technologies in all sorts of data processing, building a quantum statistical toolbox capable of dealing with real-world practical issues, of which change point detection is a prominent example, will be crucial. In our paper, we demonstrate the working principles of quantum change point detection and facilitate the grounds for further research on change points in applied scenarios."

Although change point problems can deal with very complex situations, they can also be understood with the simple example of playing a game of Heads or Tails. This game begins with a fair coin, but at some unknown point in the game the coin is switched with a biased one. By statistically analyzing the results of each coin toss from the beginning, it's possible to determine the most likely point at which the coin was switched.

Extending this problem to the quantum realm, the physicists looked at a quantum device that emits particles in a certain state, but at some unknown point the source begins to emit particles in a different state. Here the quantum change point problem can be understood as a problem of quantum state discrimination, since determining when the change in the source occurred is the same as distinguishing among all possible sequences of quantum states of the emitted particles.

Physicists can determine the change point in this situation in two different ways: either by measuring the state of each particle as soon as it arrives at the detector (a "local measurement"), or by waiting until all of the particles have reached the detector and making a measurement at the very end (a "global measurement").

Although the local measurement method sounds appealing because it can potentially detect the change point as soon as it occurs without waiting for all of the particles to be emitted, the researchers found that global measurements outperform even the best local measurement strategies.

The "catch" is that global measurements are more difficult to experimentally realize and require a quantum memory to store the quantum states as they arrive at the detector one by one. The local measurement methods don't require a quantum memory, and instead can be implemented using much simpler devices in sequence. Since global detection requires a quantum memory, the results show that change point detection is another of the many problems for which quantum methods outperform all classical ones.

"We expected that global measurements would help, as coherent quantum operations tend to exploit genuinely quantum resources and generally outperform local operations in many information processing tasks," Sentis said. "However, this is a case-dependent advantage, and sometimes sophisticated and clever local strategies are enough to cover the gap. The fact that here there is a finite performance gap says something fundamental about change point detection in quantum scenarios."

The results have potential applications in any situation that involves analyzing data collected over time. Change point detection is also often used to divide a data sample into subsamples that can then be analyzed individually.

"The ability to accurately detect quantum change points has immediate impact on any process that requires careful control of quantum information," Sentis said. "It can be considered a quality testing device for any information processing task that requires (or produces) a sequence of identical quantum states. Applications may range from probing quantum optical fibers to boundary detection in solid state systems."

In the future, the researchers plan on exploring the many applications of quantum change point detection.

"We plan on extending our theoretical methods to deal with more realistic scenarios," Sentis said. "The possibilities are countless. A few examples of generalizations we are exploring are multiple change points, noisy quantum states, and detection of change points in optical setups."

More information: Gael Sentís *et al*. "Quantum Change Point." *Physical Review Letters*. DOI: 10.1103/PhysRevLett.117.150502
Also at arXiv:1605.01916 [quant-ph]