Quantum-to-classical transition may be explained by fuzziness of measurement references

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(Phys.org) —The quantum and classical worlds are clearly very different, but how a physical system transitions between them is much less clear. The most well-known attempt to explain the quantum-to-classical transition is decoherence, which is the idea that interactions with the environment destroy quantum coherence, causing a quantum system to become classical.

But in more recent years, physicists have been investigating alternative explanations based on an observer's limited ability to control the precision of the measurements made on a system. The idea is that a system that appears to exhibit quantum behavior when observed with very precise measurements will appear to behave classically if the measurements are too coarse or fuzzy. In such a scenario, the coarsening of measurements forces the quantum-to-classical transition.

The problem is, fuzziness in measurements does not always result in the quantum-to-classical transition, and physicists aren't sure what exact conditions of the measurement process are necessary to definitively force the quantum-to-classical transition.

In a new study published in *Physical Review Letters*, physicists Hyunseok Jeong and Youngrong Lim at Seoul National University in Seoul, Korea, and M. S. Kim at Imperial College London in the UK, have proposed an explanation.

They explain that a complete measurement process is composed of two parts: one part is to set and control a measurement reference (such as timing or angle), and the other is the final detection. All of the previous studies have focused on coarsening the resolution of the final detection.

Here, the physicists looked at both parts of the measurement process and found that their coarsening leads to completely different outcomes. Their main result is that coarsening the measurement reference always forces the quantum-to-classical transition, while coarsening the final detection does not. This is because increasing the "macroscopicity" of the system, such as by increasing the number of photons in an entangled photon state, can make up for the coarseness of the final detection, but not for the coarseness of the measurement reference.

"Our results reveal a previously unknown yet very critical element in the process of the quantum-to-classical transition," Jeong told *Phys.org*. "In the previous research along this line, researchers have paid attention to coarsening of the measurement resolution (i.e., efficiency of the final detection) to explain the quantum-to-classical transition, but it does not result in the quantum-to-classical transition under certain conditions. On the other hand, coarsening of the measurement references provides a stronger mechanism to explain the quantum-to-classical transition, as far as we could see, without an exception. Our results provide new insights into the quantum-to-classical transition and deepen the understanding of the measurement process by revealing the importance of the observer's ability in controlling the measurement references."

The researchers explain that coarsening and decoherence are complementary explanations of the same problem.

"The approach based on coarsening of measurements enables one to explain a part of the quantum-to-classical transition that cannot be explained by decoherence and vice versa," Jeong said. "They are not

contradictory to each other, nor does one of them replace the other."

The analysis suggests that this finding holds true for a wide range of physical systems, such as optical, atomic, and mechanical, and for systems using various degrees of freedom. In the future, the researchers hope to further investigate the extent of these results.

"We hope to provide a more general and complete picture of the quantum-to-classical transition in our future research," Jeong said. "In our published work, we investigated several different types of physical systems in order to support our claim. There exists, however, an interesting open problem to formally prove our claim in a completely general way for arbitrary systems. In general, we will further explore the boundaries between the quantum and classical worlds to understand and clarify when and how quantum systems become classical and vice versa."

More information: Hyunseok Jeong, Youngrong Lim, and M. S. Kim. "Coarsening Measurement References and the Quantum-to-Classical Transition." Physical Review Letters, DOI: 10.1103/PhysRevLett.112.010402
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