Single photon decision-maker solves multi-armed bandit problem

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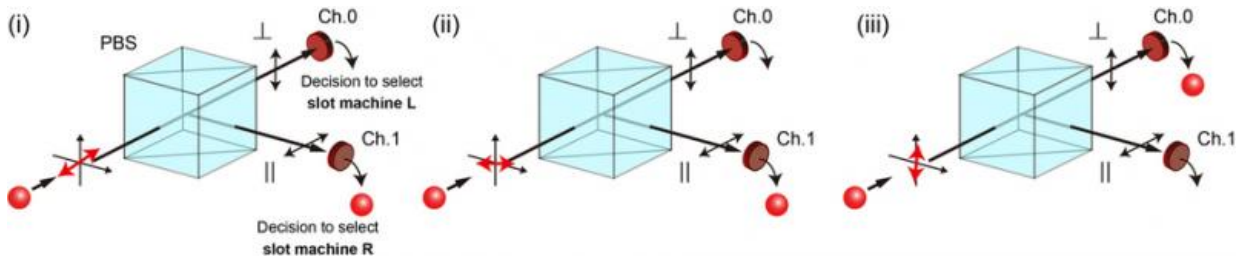

Principle of single-photon decision maker: single photon and polarization. (i) Light polarized 45° with respect to the horizontal axis is incident on a polarizing beam splitter (PBS). The single photon travels down to one of the output channels (Ch.0 or Ch.1) with a probability of 0.5 for each channel. However, the probability of a single photon to travel down one of the channels is unity; thus, the selected channel is immediately associated with a decision. (ii) Nearly horizontally polarized light is highly likely to be detected in Ch.1, leading to the decision of selecting slot machine R. (iii) Nearly vertically polarized light is highly likely to be detected in Ch.0, leading to the decision of selecting slot machine L. Credit: *Scientific Reports* 5, Article number: 13253 (2015) doi:10.1038/srep13253

(Phys.org)—A combined team of researchers from France and Japan has created a decision-making device that is based on basic properties of quantum mechanics. In their paper published in *Scientific Reports* (and uploaded to the *arXiv* preprint server), the team describes the idea behind their device and how it works.

There is a classic decision-making problem that is known as the exploration-exploitation dilemma—it is typically described by suggesting a scenario where a gambler faced with a floor full of slot machines must decide which offers the best payout on a regular basis. In real life, the solution involves feeding all of the machines coins until a discernible pattern emerges. Computer algorithms have been developed to run essentially the same process. Now, however, that approach appears to be ready for an update, as the researchers with this new effort have come up with a way to run the same sort of algorithm without using any kind of computer. Instead, they use a laser, a photon detector and feedback device. The idea is based on the fact that quantum mechanics laws are probabilistic in nature.

The device is based on prior research that has shown that if photons are fired from a proton gun at a 45 degree angle, they will each have an equal chance of being vertically or horizontally polarized when they strike a detector—thus a stream will have equal numbers of both. But, if the filter on the gun is changed slightly, to say fire at 44 or 46 degree angles, that increase the odds of the associated polarization. The team used that fact by adding a feedback loop to the system—data sent back representing a "win" on a slot machine caused the filter to move in one direction, while a loss moved it in the other. Over time, the preponderance of wins (indicating a learning process) from one virtual machine would drive the device towards indicating it was the winning choice.

The researchers report that their decision-making device was able to very quickly determine which among a group of virtual slot machines afforded the best payout—all without a computer or program. This is significant because the exploration-exploitation dilemma crops up in a wide variety of real world applications, from business decision making, to oil exploration, to gaming and of course gambling.

More information: Single-photon decision maker, *Scientific Reports* 5, Article number: 13253 (2015) DOI: 10.1038/srep13253 . On *Arxiv*: arxiv.org/abs/1509.00638

Abstract

Decision making is critical in our daily lives and for society in general and is finding evermore practical applications in information and communication technologies. Herein, we demonstrate experimentally that single photons can be used to make decisions in uncertain, dynamically changing environments. Using a nitrogen-vacancy in a nanodiamond as a single-photon source, we demonstrate the decision-making capability by solving the multi-armed bandit problem. This capability is directly and immediately associated with single-photon detection in the proposed architecture, leading to adequate and adaptive autonomous decision making. This study makes it possible to create systems that benefit from the quantum nature of light to perform practical and vital intelligent functions.