Quantum Computer

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Abstract

If the idea of the possibility to realize quantum computers is based on the conclusions drawn from Bell experiments, then we are seriously mistaken. This is because entanglement in Bell experiments is not what it looks like and because of that, probabilities represented by the Bloch sphere, occurring in Bell experiments, are wrongly ascribed to qubits.

Introduction

Quantum computers are supposed to function based on the idea that probabilities represented by the Bloch sphere apply to qubits. A qubit is an elementary particle that is supposed to be in a superposition of states of a property, for instance spin. The probabilities of the Bloch sphere, however, do not apply to qubits. I 'll tell you why. To understand the functioning of qubits we have to descend to the lowest fundaments of quantum physics. There we find the Bohr-Einstein debate.

The Bohr-Einstein debate

The debate is about the question whether the Quantum Theory is complete or not. To me it doesn't matter so much whether it is complete or not, as long as it is correct and I have no reason to doubt that. From another point of view the debate is about the meaning of the words: 'superposition' and 'entanglement'. Superposition and entanglement deal with the state of a property of elementary particles. Superposition can mean that a particle can be in different states at the same time (Bohr) or it can mean that a particle is at every moment in one definite, but unknown, state (Einstein). Entanglement can mean interaction between the states of one or more particles (Bohr) or it can mean that entangled particles have opposite properties (because of conservation laws, Einstein). It makes a difference if entanglement is applied to one particle or to a number of particles. One particle is of course entangled with itself but instantaneous interaction between two particles at a distance is not comprehensible whereas opposite properties of particles of an entangled pair in respect of each other is very well comprehensible. To superposition it makes no difference if applied to one particle or to a large number. Superposition for a large number of particles can mean that each particle is in a random, unknown, definite state, which is only naturel, or it can mean that each particle is in different states at the same time, which makes no sense.

Mathematics is not decisive about the convictions of Bohr and Einstein. Mathematics can be interpreted such that both notions hold, up to a certain point. That point is the quantum computer. To find out whether a quantum computer can function or not we have to find out who's notions correspond to reality: Bohr's or Einstein's. They cannot both be true, they cannot both correspond to reality. The decision can only be made by experiments. Fortunately Bell experiments do so.

Bell experiments

Bell experiments were designed (by Bohm) to decide who was right and who was wrong in the Bohr-Einstein debate. In Bell experiments spin of large numbers of pairs of entangled particles is measured. The results in Bell experiments are probabilities for pairs of entangled particles to yield combinations of equal spin outcomes or combinations of opposite spin outcomes when their spin is measured. Quantum Theory predicted certain probabilities. Bell calculated probabilities that were different from those predicted by Quantum Mechanics (QM). It was believed that when experiments would show QM's probabilities, that then Bohr would be right and Einstein would be wrong. This is because Bell stated that QM's probabilities could not be explained by 'hidden variables' (Bell's Theorem) and thus, according to Bell, to explain QM's probabilities, something like entanglement must exist, meaning entanglement according to Bohr's notion (some non-local effect). When the experiments finally could be performed, they did show QM's probabilities and so Einstein was declared to be wrong. QM's probabilities could not be explained physically, but Quantum Theory predicted them, so who cared? Bohr's entanglement was widely accepted.

However, a recently discovered principle (the Principle of Perspective, [1]) showed that Bell's probabilities were not applicable to the experiments. The Principle of Perspective is about the comparison of results of detections of an object. It says that results of detections of an object from different directions may not be compared as if the results were obtained from detections from one direction. The Principle of Perspective says that when an object at one moment is detected from different directions, that then the comparison of the results of the detections is meaningless unless the detections are made equivalent. To make the detections equivalent it is enough to take into account all rotations from the detectors in respect of the object and in respect of each other.

Application of the principle shows why experiments yield QM's probabilities [1], and thus that Bell's probabilities do not apply. This makes Bell's Theorem invalid and the meaning of 'entanglement' questionable. However, the principle only explains the results of the experiments assuming Einstein's notions of 'entanglement' and 'superposition'. Otherwise the results of the experiments make no sense: without the principle they couldn't be explained physically. Without the principle the results only are predicted by QM, but that is not an explanation. So the application of the principle, combined with physically comprehensible notions of entanglement and superposition, explains the results in Bell experiments. This means that not Einstein was wrong, but Bohr, and that Einstein was right. What does this mean for qubits and quantum computers?

The Bloch sphere

Quantum computers operate with qubits. A qubit is an elementary particle that is supposed to be in a superposition of states of a certain property, for instance: spin. Since it is still widely believed that Bohr's notions are valid, superposition of states of a qubit means that the state of the qubit is indefinite (until measurement) and that it obeys the laws of Quantum Mechanics. The laws of QM are not physical laws but they are a set of mathematical rules from which the interpretation is not clear. Because a qubit is obvious entangled with itself, it is believed that QM's probabilities that apply to entangled particles, also apply to qubits. These probabilities have been exposed by Bell experiments and they apply to pairs of entangled particles. However, these probabilities only can be explained assuming Einstein's notions of superposition and entanglement. As is stated earlier Bohr's and Einstein's notions cannot both be true. Since Einstein's notions are valid for Bell experiments, it is unlikely that suddenly Bohr's notion of superposition applies to qubits. This makes the application of QM's probabilities to qubits questionable.

QM's probabilities can be represented by the Bloch sphere [2]. The probabilities of the Bloch sphere come in pairs. They apply to opposite states and add up to 1. The probabilities occurring in Bell experiments satisfy perfectly to the probabilities of the Bloch sphere: at certain settings of the detectors a pair of entangled particles has a certain probability (a QM probability) to show a combination of equal outcomes and a complementary to 1 probability to show a combination of opposite outcomes. So the QM probabilities from Bell experiments fit on the Bloch sphere. The explanation for these probabilities (applying the Principle of Perspective, [1]) show that these probabilities totally are defined by the settings of the detectors. They are independent from the spin directions of an individual pair. A pair of entangled particles is measured by two detectors and the combination of settings of the two detectors define the probability for a combination of equal outcomes or a combination of opposite outcomes. How the probabilities are defined by the settings is explained in [1]. To measure one particle (a qubit) only one detector is needed, so by what is the probability defined to show spin 'up' or spin 'down' of the qubit? Indeed a qubit has a probability to show spin 'up' and a complementary to 1 probability to show spin 'down'. But those probabilities do not necessarily have to be QM's probabilities (represented by the Bloch sphere). Since the settings of the detectors define the probabilities in Bell experiments and qubits are measured by only one detector it is not likely that qubits show QM's probabilities. Moreover, we have found that Einstein's notion of superposition is valid in Bell experiments meaning that it probably also is valid for qubits. This would mean that a qubit is in a definite (random?) state and doesn't obey 'quantum laws'. So, although qubits are entangled with themselves, it is very unlikely that the probabilities represented by the Bloch sphere, which are definitely QM probabilities, apply to qubits.

It is stated that the spin of qubits can be manipulated precisely [2]. It may be. But at the end of a calculation by a quantum computer qubits have to be measured to know the outcome. Now there are three possibilities. First: the spin of a qubit is unknown and random. Then the probability to show a certain spin is ½, which is only one probability of the Bloch sphere. Second: the spin of a qubit is known. Then the probability to show a certain spin is 1 or 0. These only are two probabilities of the Bloch sphere. Third: the qubit yet obeys enigmatic quantum rules. Then the probability to show a certain spin may be one of the probabilities of the Bloch sphere. Since a qubit is not a pair of entangled particles and the Bloch sphere represents probabilities that are defined by the angle between the settings of detectors in Bell experiments, and so are valid for pairs of entangled particles and not for qubits, the third possibility is very unlikely. Moreover, the qubit has to be in a state corresponding to Bohr's notion of superposition and we showed that that kind of superposition is not valid (and it is not comprehensible).

Experiments appear to confirm Quantum Theory, including Bohr's notion of superposition and entanglement. But Quantum Theory is a statistical theory that applies to large numbers. Experiments work with large numbers of particles so they do confirm Quantum Theory. Statistical theories, however, are not valid for individual particles. At the level of individual particles (or pairs) Einstein's notion of superposition and entanglement is valid, not Bohr's. That is showed in [1].

Since in Bell experiments the probabilities (represented by the Bloch sphere) apply to outcomes for pairs of entangled particles and since they are defined by the settings of the detectors in Bell experiments, and since quantum computers are supposed to operate with Bloch's probabilities, I don't believe quantum computers will ever function. Unless……. quantum computers operate as inverse Bell experiments, meaning that qubits correspond to pairs of entangled particles in a way that they can operate with the probabilities of the Bloch sphere. It is stated that spin of a qubit can be manipulated precisely, pointing to a point on the Bloch sphere [2]. This might be possible by a detection-like operation to manipulate the qubit. But in this way it is not the qubit that Is in superposition, but it is the detector having a dual function: manipulate the qubits as well as measure them. Outcomes, obtained this way, are not meaningful.

In descriptions on the operation of quantum computers it is stated that spin of a qubit can be manipulated precisely to point to a certain point of the Bloch sphere. This is a bit strange: how can spin of a qubit be manipulated precisely while the qubit is in superposition? And “that is not comprehensible” I don’t accept as an answer to the question.

A difference between a classical bit and a quantum bit is that a classical bit shows itself at the end of a calculation. A qubit doesn’t. It has to be detected. But before it is detected it has been manipulated (to perform a calculation) by a detection-like operation to point at a certain point of the Bloch sphere. What then is the meaning of its final detection? It is like setting your watch at seven minutes past twelve and then say: “look, it is seven past twelve”.

The point is: spin of a qubit is either known (manipulated in a certain direction), or it is unknown. When it is known the probability for that outcome is 1 or 0. When it is unknown the probability for a certain outcome is ½. This probability is always found in experiments. Qubits cannot be in a state that corresponds to QM’s probabilities for outcomes of measurements of their spin because qubits are measured by one detector and it takes two detectors to obtain QM’s probabilities. The two detectors define QM’s probabilities and this only is the case for combinations of outcomes when pairs of entangled particles are measured, not for outcomes of measurements on qubits. Take in account, in addition, that Einstein’s notion of superposition and entanglement are valid for individual particles (or pairs) and it is clear that qubits cannot be in (Bohr’s) superposition, meaning that they cannot be in a state that corresponds to QM’s probabilities (the probabilities of the Bloch sphere).

Summary

It is stated that spin directions of qubits can be manipulated in a way that they precisely point to a probability of the Bloch sphere. Either that is possible but then qubits are not in a state of superposition, so the probabilities of the Bloch sphere do not apply to qubits, or it is not possible and then qubits cannot function at all.

Conclusions

1. The probabilities of the Bloch sphere do not apply to qubits.
2. A qubit is not in superposition (no more than a cat can be dead and alive at the same time).
3. If a quantum computer can calculate with directions (spin directions of qubits) then the working of a quantum computer is much, much more difficult and the computer is much more susceptible for failure than a classical computer, without the expected benefits of a quantum computer.

Of course I can be wrong in [1], but someone will have to show me.

Reference:

[1] Gerard van der Ham; The Principle of Perspective. https://bell-game-challenge.vercel.app/

[2] Marcel Vonk; Van Getal tot Heelal.