Quantumlike Computation and "Thinking" Based on Classical Oscillations

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ABSTRACT

Classical systems containing decision-making elements can possess quantumlike properties, most importantly interference of probabilities of different decisions. We demonstrate this theoretically using a set of linear numbered oscillators combined with decision-making and other devices. This algorithmically indeterministic system, although classical, can be described in terms of quantumlike unitary transformations, complex wave functions, and non-commuting operators; the decision-making device plays a role similar to the measuring apparatus in quantum mechanics. The system can be used to construct quantum-like bits and logical gates for quantumlike calculations.

Keywords: quantumlike properties, quantumlike computation, thinking, classical oscillations

1 DISCUSSION

Here we show what kinds of quantumlike properties can be present in a "thinking system" containing only classical elements. This classical system makes a yes/no decision whenever it is presented with: (a) A problem that can be formulated mathematically and has a unique solution obtainable in a reasonable time (i.e., the time does not grow exponentially with the number of bits involved in the calculation). In this case the system works first as a classical computer, solving the problem, and then makes the corresponding unique, deterministic decision. (b) A problem that can be formulated mathematically but is either not solvable in a reasonable period of time, or not solvable in principle. In this case the system introduces a probability distribution of possible decisions, and makes a yes/no decision randomly (a probabilistic decision). We will be concerned with case (b).

The first quantumlike property of the system to be noted is indeterminism. In the context of quantum systems having discrete spectra, indeterminism can be construed as the impossibility in principle of finding a computable function to help us predict the result of every single measurement (from an infinite set of results of measurements) by using information about previous measurements and subsequent changes of physical conditions inside or outside the system. In the context of our classical thinking system, indeterminism is the impossibility in principle of the system getting a computable function or algorithm prescribing every single yes/no decision (from an infinite set of decisions) by using information about previous decisions and subsequent changes of physical conditions. So there is an analog between quantum sets of possible results of measurements—which are represented by the eigenstates of the corresponding Hilbert space, and a set of possible decisions of the thinking system. Both the set of possible decisions and the set of quantum eigenstates are mathematical, and in this sense "non-physical" objects. By contrast, all physical components of our thinking system behave purely classically, as they must.

One of the simplest algorithmically unsolvable problems that can be posed to any thinking system is to decide what is the correct direction—along a given axis (yes), or the opposite (no)—when a yes/no decision about another axis has already been made and a change of the orientation of the second axis relative to the first one has been given.[1] (There are important additional assumptions we will skip here.) Of course, there are no restrictions on having an algorithm for all decisions in the case of a finite number of angles between orientations of two axes. However, there does not exist a logically consistent algorithm for the entire infinite set of possible angles between axes, even when they lie in the same plane. (An analogous problem arises in 1/2-spin measurements.[2]) Thus, when a thinking system faces a correct direction problem and expects the axes in question to be oriented arbitrarily, it cannot behave predictably because it cannot in principle have the needed general prescription (i.e., algorithm). Of course, the correct direction problem is algorithmically unsolvable only if the angles expected by the thinking system can be defined with sufficient precision. When they cannot, nonprobabilistic yes/no decisions are impossible again, but for a completely different reason: lack of knowledge, not lack of an algorithm. Probabilities must be introduced in both situations. However, probabilities due to lack of algorithms and those due to lack of knowledge behave differently with respect to sequential chains of events (decisions, in this case). In the algorithmic case, quantumlike interference of probabilities can influence such decisions, and under some conditions even Bell's inequalities can be violated. This crucial difference provides the possibility of experimentally investigating the nature of the seemingly unpredictable decisions often made by naturally occurring thinking systems.

Further probing of the decision$\leftrightarrow$quantum measurement similarity central to the quantumlike properties of thinking systems shows that such properties can appear not merely due to the nature of problems needed to be solved—as in the case described earlier—but mostly due to the nature of the structure of the system [3]. Consider a system of identical, numbered, linear oscillators, combined with a decision-making device making random choices of numbers (or, we can say, of the oscillators having these numbers). For a given set of numbered oscillators, the probability of the choice of a number k is proportional to the energy of the oscillator #k, and the energy is proportional to the square $|c_k|^2$ of the complex amplitude, c_k, of this oscillator. Coordinate q_k of the oscillator #k, k=0,1,...,N, oscillates as $q_k = A[c_k \exp(i\omega t) + c_k^* \exp(-i\omega t)]$. The quantumlike normalization condition, $\sum |c_k|^2 = 1$, is possible in the absence of perturbations, when the oscillators' energies are conserved. Quantum qubits are reproduced here by pairs of oscillators, $k = 0,1$. Adiabatically slow perturbations acting during time $(t' - t)$, can perform different unitary transformations of the quantumlike complex amplitudes, $c_k'(t') = u_{kl}(t' - t)c_l(t)$. These transformations can be considered as rotations of vectors in a Hilbert space of "number-states," $|\psi\rangle = \sum c_k |k\rangle$, quite similar to the number-state rotations in quantum systems used for quantum computing. These vectors are superpositions of the number-eigenvectors, representing numbered oscillators. Each unitary transformation is a part of a quantumlike computation. All quantumlike non-commuting operators—logic gates—needed for such computations can be reproduced in this system. Obviously, quantum properties of indeterminism (of decisions) and interference of probabilities of decisions are also reproduced.

Without going into further detail here, we should point out one defect of this system in comparison with quantum computers. Since number-states represent numbered oscillators in this system, multiplication of any two number-eigenstates, #m and #n, needs physical operations on the copies of the oscillators #m and #n. Similar multiplications in quantum mechanics are performed very efficiently by Nature on mathematical, "non-physical" objects in Hilbert space. But in the case of mathematical problems lacking efficient classical algorithms, our system calculations involve exponential growth of the number of oscillators' copies as a function of the number of bits. That means that the efficiency of the computing is the same as that of classical computing, even if the algorithms used are quantum. This defect, however, can be circumvented. Instead of exponentially many multiplications of states requiring the corresponding operations on oscillators, our system can multiply algebraically a relatively small number of pure mathematical objects—quantumlike operators required by the corresponding efficient quantum algorithm. How many of the needed operators can be multiplied this way? In quantum algorithms, the final state should always be some irreducible superposition having only a limited, not exponentially large, number of number eigenstates. Otherwise, quantum computing for problems without efficient classical algorithms would be useless. In our system, in the ideal case, the pure algebraic multiplication of operators can be continued until the state-superposition reaches this irreducible stage. This thesis has yet to be proved; the author has only checked it in the case of factorization of some integers by using the famous Shor quantum algorithm.

2 CONCLUSION

Our conclusion, which is unaffected by the defect discussed above, is that a thinking system built up from oscillators as described in [3] may have the ability to think in a quantumlike way, that is, creating and executing not only classical algorithms but also quantum algorithms applicable to the quantumlike part of the system.

REFERENCES

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