Semiclassical Qubits

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Abstract. The semiclassical approximation of quantum computing and quasi-qubits (s-bits) have been obtained by us as a result of our work over the past few years. This work can be conventionally divided into two parts. The first part, let's call it the programming model, contains a computer model of quasi-qubits and quantum computing. The second part, let's call it the microelectronic model, describes the microelectronic realization of qubits in the semiclassical approximation (quasi-qubits) and exists in the form of block diagrams, which are supposed to be easy to manufacture. How did we get the semiclassical approximation? The difficulty in solving such a problem was that microparticles in quantum mechanics are described in an infinite-dimensional Hilbert space. Classical models are much poorer in the number of variables; therefore, it is impossible to describe quantum mechanical objects by classical methods due to the small number of available parameters.

1. Introduction. Physics of Non-Inertial Reference Frames

Our way is to supplement the description of the classical model with nonlocal variables, which refine the behavior of qubits in the semiclassical approximation [1,2]. Dwelling on additional nonlocal variables in more detail, we note that they represent a decreasing series and therefore we can set any accuracy of modeling qubits in the semiclassical approximation based on the technical capabilities of the classical computer or microelectronic elements [3] used in the work for the second way of implementing this problem.

Changing the number of nonlocal variables depending on the required computational accuracy and based on our technical capabilities, we get a different computation speed. Note that it is rather difficult to distinguish the semiclassical approximation of qubits (quasi-qubits) from qubits, as well as their comparative speed of calculations, since for example, such differences described in Bell's theorem were experimentally obtained by A. Aspect, who received the Nobel Prize for these results. The maximum values of Bell's observable in these two cases differed by a factor of 1.4 and were difficult to detect due to the instability of the behavior of quantum objects, the states of which can change under any random small influences.

The main goal of this work was to create working semiclassical qubits, which at the first stage can replace a quantum computer with a computational speed comparable to that of a quantum computer. Why do we need a semiclassical implementation of quantum computing and quantum cryptographic processes? To search for problems that can be solved using qubits. In solving a whole class of problems, the use of qubits will not give any advantages over classical methods. Finding problems that give a temporary gain when using qubits is now the most important task. The classical methods known today do not allow satisfactory modeling of quantum computing and quantum cryptographic processes due to the insufficient number of variables in computer experiments. Incomplete understanding of the work of qubits in a quantum computer prevents hopes for their widespread application in practice, with the exception of a limited range of problems. The semiclassical realization of qubits in a quantum computer is necessary to construct the quantum algorithms needed for this. The semiclassical implementation allows us to take the next step towards understanding quantum calculations by working with the available classical elemental base, despite the existing limited resources available to us.

The proposed semiclassical implementation allows a more complete description of the operation of
qubits through the use of additional non-local variables. Difficulties in understanding quantum processes are known to be associated with a small number of variables in the classical model compared to the quantum one. Supplementing the classical model with new variables in the form of nonlocal variables makes it possible to create a semiclassical implementation and understand the structure of qubits and their connections. Ultimately, this leads to an increase in the accuracy and speed of information processing and transmission, to the development of a promising element base for quantum computers and quantum-cryptographic communication systems.

Applying the WKB method to approximate qubits, you can get a semiclassical model with an accuracy that we can set ourselves based on our technical capabilities. As nonlocal variables complementing the description of qubits, we used the time derivatives of the generalized coordinates \( q(t) \) i.e., \( q^{(k)}(t) \), where \( k \) is the order of the derivative. In our case, these variables are non-local, that's why.

Modern physics is the physics of predominantly inertial reference systems. At the same time, it is impossible to find a non-inertial frame of reference in reality, because there are always small random fields and forces. Therefore, one can agree with the existence of inertial reference frames only in theory, extending the postulates of classical mechanics to the case of non-inertial reference frames. Such physics is the physics of non-inertial frames of reference. To do this, we introduce a coordinate transformation in such reference systems.

Conversion of coordinates of a point particle between two Non-Inertial Reference Frames [3] provided \( \tau \) is a time interval for averaging, shall be expressed as

\[
Q = q(t) + \dot{q}(t)\tau + \Delta q(t),
\]

\[
\Delta q(t) = \sum_{k=2}^{N} (-1)^k \frac{1}{k!} \tau^k q^{(k)}(t),
\]

And same holds for momentum

\[
P = p(t) + \dot{p}(t)\tau + \Delta p(t),
\]

\[
\Delta p(t) = \sum_{k=2}^{N} (-1)^k \frac{1}{k!} \tau^k p^{(k)}(t)
\]

\[
Q = q(t) > \frac{1}{2} [q(t + \tau) + q(t - \tau)].
\]

Here, \( \Delta q(t) \) and \( \Delta p(t) \) are remainder terms of the Taylor expansion. The remainder terms \( \Delta q(t) \) and \( \Delta p(t) \) in Non-Inertial Reference Frame may be interpreted as uncertainties of coordinate and momentum of a point particle in this reference frame. In quantum mechanics, uncertainties of coordinate and momentum of a micro particle obey the rule

\[
\Delta q(t)\Delta p(t) \geq \hbar/2.
\]

In Non-Inertial Physics can be introduced an General Uncertainty Relation, as there always exist random small fields and forces influencing either the very system to be described or an observer, that is

\[
\left[ \sum_{k=2}^{N} (-1)^k \frac{1}{k!} \tau^k q^{(k)}(t) \right] \left[ \sum_{k=2}^{N} (-1)^k \frac{1}{k!} \tau^k p^{(k)}(t) \right] \geq \hbar/2
\]

inertial one. In this case instability states of observing objects can be describe by Quantum Theory with high-order derivatives \( \psi(t) = |q, \dot{q}, \ddot{q}, \dddot{q}, ..., q^{(n)}\rangle = |Q(t)\rangle \). Note that here the time derivatives of the generalized coordinates \( q \) play the role of non-local variables, since they do not change from one point to another point in a non-inertial reference frame for a body of any mass.

2. Ostrogradsky Formalism and Wentzel–Kramers–Brillouin (WKB) approximation for Qubits

Classical Euler-Lagrange equations in Ostrogradsky formulation [5] accounting for random small influences in the form of higher derivatives will take on the form

\[
\delta S = \delta \left\{ L_r(q, \dot{q}, \ddot{q}, ..., \dot{q}^{(n)}..., 0) dt = \int \sum_{n=0}^{N} (-1)^n \frac{d^n}{dt^n} \frac{d\mathcal{L}}{d(q^{(n)})} \delta q^{(n)} dt = 0
\]
or
\[
\frac{\partial L}{\partial q} - \frac{d}{dt} \frac{\partial L}{\partial \dot{q}} + \frac{d^2}{dt^2} \frac{\partial L}{\partial \dot{q}^2} + \frac{d^3}{dt^3} \frac{\partial L}{\partial \dot{q}^3} + \ldots + (-1)^n \frac{d^n}{dt^n} \frac{\partial L}{\partial \dot{q}^n} + \ldots = 0.
\]

This equation with instability [6] of high-order derivatives coordinates on time can be rewritten as [7,8]
\[
F - ma + \tau \ddot{a} - \frac{1}{2!} \tau^2 m a^{(2)} + \ldots + (-1)^n \frac{1}{n!} \tau^n m a^{(n)} + \ldots = 0
\]
\[
\dot{a}(t_0) = 0, \quad a(t_0) = 0, \ldots, a^{(n)}(t_0) = 0, \ldots
\]
\[
\tau \text{ being the time interval, and } a \text{ – acceleration, } t_0 \text{ is the moment of the time of stability trajectory.}
\]

The second Newton’s law is a second-derivative differential equation describing stability dynamics \( F - ma = 0 \).

In mathematical physics WKB theory is a method for approximating the solution of a differential equation whose highest derivative is multiplied by a small parameter. Applying this method for formula (3), we obtain the solution with terms \( S_n(t) \) in the expansion in \( \delta \to 0 \)
\[
\sum_{n=0}^{\infty} (-1)^n m_n(t) \frac{d^n}{dt^n} q = 0
\]
\[
q(t) \sim \exp \left[ \frac{1}{\delta} \sum_{n=0}^{\infty} \delta^n S_n(t) \right].
\]

3. Algorithm for semiclassical Qubits (s-bits)

Using a random number generator, the random process \( \varphi(t) \) with \( \langle \varphi(t) \rangle = 0 \) has been given the random phase on the angle \( 0=2\pi \). The algorithm of a random s-bits [8] is
\[
f(t, \theta) = \text{sign}(\varphi(t) + \theta)
\]
a being \( \theta \) means measurement angle. Then \( f(\theta) = 0 \) and \( f(\theta \pm \pi) = -f(\theta) \), means \( f(\theta \pm \pi) \) and \( f(\theta) \) are anticorrelated. Here we note that \( f(\theta) \) and \( f(\theta \pm \pi/2) \) are non-correlated s-bits.

It is very important that if, for example, the first s-bit is used for the process of s-bits initialization as signal s-bit, and during the computation process on the second s-bit the changes, then we must also change the state of the signal s-bit. Then the calculations on the second s-bit will affect the calculations of the others of the s-bits.

The implemented program of semiclassical computer with s-bits is posted on the website https://theorphys.org/.

4. Conclusion

Additional terms in the form of higher derivatives have non-local character, which enables their employment for description the non-locality of quantum mechanics. Random and instability variables in the form of high-order derivatives coordinates on the time can describe the effect of quantum correlations and non-locality of quantum states in Non-Inertial Reference Frames.

References
[1] Kamalov T F 2011 Quantum Computers and Computing 11 p 52 (Preprint arXiv: 1011.4256)
[2] Rybakov Y P, Kamalov T F 2016 Int. J. of Theor. Phys. 55 9 4075
[3] Garcia Zavala Y M et al 2011 CIENCIA ergo sum 18 2 p 171
[4] Kamalov T F 2020 J. Phys.: Conf. Ser. 1557(1) 012003
[5] Ostrogradsky M V 1850 Mem. Acad. St. Peterburg 6 4 p 385
[6] Woodard R P 2007 Lecture Notes in Physics 720 403 (Preprint arXiv:astro-ph/0601672)
[7] Kamalov T F 2020 Symmetry 12 1 p 63
[8] Kamalov T F, Rybakov Y P 2006 Quantum Computers and Computing 6 1 p 125