Hypothetic Paraparticles and How They Can Potentially Speed Up Computations

Sebastian Balderrama, Daniel Marin, and Vladik Kreinovich
Department of Computer Science, University of Texas at El Paso
500 W. University, El Paso, TX 79968, USA
sbalderrama3@miners.utep.edu, djmarin1@miners.utep.edu, vladik@utep.edu

Hypothetic paraparticles and their possible use in computing. Usually, elementary particles have a single stable state, i.e., the state with the smallest possible energy. However, recently, researchers raised the possibility of having particle that have two different minimum-energy states; these particles are called *paraparticles* [1,2]. This feature makes paraparticles a perfect tools for storing one bit of information – if we use only one elementary particle to store a bit (instead of several molecules), that will make computers drastically smaller and thus, faster.

Can we speed up computations even further? We do not know the exact equations describing the paraparticle's energy, it can be any analytical function. In such situations, to get a first approximation to the particle's description, it is reasonable to restrict the general Taylor expansion of the energy function to the first few terms – as long as that allow to explain the basic behavior of the particle.

For many physical systems – such a pendulum – such a first approximation comes from consider quadratic terms. To find the minimum-energy state, we can differentiate the energy function with respect to all unknowns and equate all the resulting derivatives to 0. Differentiating a quadratic function leads to a linear expression, so we get a system of linear equations. Such systems either have a unique solution, or the whole linear space of solutions – but they cannot have just two solutions. So, to describe paraparticles, we need to go beyond quadratic terms.

The next after quadratic are cubic terms. However, a cubic polynomial cannot have a global minimum: in some directions, it reaches infinity and thus, in opposite directions, it tends to $-\infty$. Thus, to describe paraparticles, we need to also take into account the next order terms – i.e., consider 4th order polynomials.

An interesting feature of 4th order polynomials is that for then, finding a global minimum is NP-hard (see below). So, in general, finding the minimum-energy state of a paraparticle is probably an NP-hard problem. A particle, left to itself, reaches its minimum-energy state – and usually does it fast. So by observing hypothetic paraparticles, we may be able to find, in short time, solutions to an NP-hard problem. By definition, NP-hardness means that we can reduce any problem from the class NP to this problem in feasible time. Thus, paraparticles may lead to feasible algorithms may lead to a feasible way of solving all the problems from the class NP – i.e., in effect, to solution of all the problems in mathematics, physics, and engineering!

How to prove that minimizing 4th order polynomials is NP-hard. We can prove this by reducing, to this problem, the known NP-hard subset sum problem: we have a list of natural numbers $s_1, \ldots, s_n$ and a natural number s, and we need to find a subset $S \subseteq \{1, \ldots, n\}$ over which the sum of s_i's is equal to s. This is equivalent to finding $x_i \in \{0, 1\}$ for which $\sum_i x_i \cdot s_i = s$. For each instance of this problem, let us form the following 4th order polynomial: $\sum_i (x_i \cdot (1 - x_i))^2 + (\sum_i x_i \cdot s_i - s)^2$. This polynomial is always non-negative, and its minimum is equal to 0 if and only if all the terms in the sum are 0s. In particular, this means that $x_i \cdot (1 - x_i) = 0$ (so either $x_i = 0$ or $1 - x_i = 0$, i.e., $x_i = 1$) and $\sum_i x_i \cdot s_i = s$. So, if we could minimize this polynomial, we would be able to solve the subset sum problem. This reduction proves that the above minimization problem is also NP-hard.