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Simulation of a neuromuscular control using a quantum computer: Estimating Muscular Activation Patterns with D-Wave Technology

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Quantum computing is emerging as a groundbreaking approach for solving complex optimization problems, offering new opportunities in fields requiring both computational efficiency and innovative solution discovery. Quantum annealing, a specialized quantum computing paradigm, leverages quantum adiabatic theorem to efficiently find the global minimum of a problem's cost function, making it a promising tool for tackling combinatorial optimization tasks. In this presentation, we demonstrate the application of the D-Wave quantum annealer to a biomechanical optimization problem: estimating muscular activation patterns.
The problem involves a biomechanical system with one degree of freedom (DOFs) and three muscles actuators(i.e. a simplified elbow joint).Because of muscle redundancy (more
muscles than DOFs),there are virtually infinite sets of activations that enable any given motion. To select the optimal activation set, a cost function—minimizing the sum of square activations—is typically employed, reflecting the body's natural tendency to reduce metabolic cost. During the annealing process, the system occasionally settles into energy levels different from the ground state, representing suboptimal solutions. These alternative solutions are particularly valuable as they often correspond to muscular activation patterns observed in individuals with musculoskeletal disorders or pathologies. Such patterns are challenging to compute using classical methods but are naturally revealed through quantum annealing, providing critical insights into pathological conditions.
Using quantum annealing, we leverage its capacity to explore vast solution spaces simultaneously, enabling the identification of both optimal and suboptimal solutions in a single computation. Preliminary calculations performed on a quantum annealing simulator show promising results, demonstrating the feasibility of this approach and its potential for uncovering insights that are difficult to achieve with classical techniques. Moving forward, we plan to perform the annealing computations directly on the D-Wave quantum computer. This work highlights the advantages of quantum computing in biomechanical research, paving the way for more advanced applications in understanding muscular behaviour and related pathologies.
This work is conducted as part of the ICSC project in collaboration with the University of Bologna which provided the necessary biomechanical data.

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