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A quantum perceptron gate and a classical Toffoli gate with microwave-driven trapped ions

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Direct implementation of multi-qubit gates with three or more qubits circumvents decomposition into two-qubit operations, effectively reducing the required depth of quantum circuits. Using the inherent all-to-all coupling in a trapped ion quantum computer, we experimentally realize classical Toffoli and perceptron gates with three microwave-driven hyperfine qubits using 171Yb+ ions. The classical Toffoli gate can be used to efficiently implement arithmetic operations, such as a half-adder. The perceptron gate, when nested with other perceptrons, can be used as universal approximator. Both, the perceptron and Toffoli gates are implemented by a continuous microwave driving field, while the qubits' coherence is protected by pulsed dynamical decoupling. In case of the perceptron, a dressing field applied to the target qubit is adiabatically ramped down. We report the implementation of a two-layer neural network using successive perceptron gates. For the Toffoli gate, the target qubit is controlled by two control qubits and a top hat microwave pulse. 171Yb+ ions are stored in a linear Paul trap exposed to a permanent magnetic field gradient. Using MAgnetic Gradient Induced Coupling (MAGIC), all-to-all coupling in the qubit register is achieved while the qubits can be individually addressed by microwave radiation.

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