# An artificial neuron model implemented on the IBM quantum processor



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#### **Coworkers & Acknowledgments**



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\* The views expressed in this work do not reflect the official policy or position of IBM and the IBM-Q Team



# **Artificial neural networks (ANN)**



possible model of brain: feed-forward network of interconnected signal processing elements



Each node mimics the functionality of a single neuron





Rosenblatt, Psychol. Rev. 65, 386 (1958)

# **Applications of ANN**

> single perceptron
 → a linear classifier





➤ Evolution into A.I. → translate text, control vehicles, play games, …



# **Quantum neural network models**

Idea: exploit quantum mechanics to enhance neural network computing capabilities

superposition  $|\psi
angle = a|0
angle + b|1
angle$ 

entanglement

DI PAVIA



Most algorithms are difficult to implement on NISQ (Noisy Intermediate Scale Quantum) devices

Schuld et al., Quant. Inf. Proc. **13**, 2567 (2014) Schuld et al., Phys. Lett. A **7**, 660 (2015) Rebentrost et al., Phys. Rev. A **98**, 042308 (2018) Implementing the perceptron on a digital quantum computer

The key function

$$\sum_{j} i_{j} w_{j}$$

Encoding input and weights



Tacchino et al., arxiv:1811.02266 (2018)



#### Hypergraph states



Rossi et al., New J. Phys. 15, 113022 (2013)

# Implementing the perceptron on a digital quantum computer



Quantum algorithm: a circuit model



Tacchino et al., arxiv:1811.02266 (2018)

#### **Pictorial representation**

in vector space:











## **Potential advantages**



29 x 29 pixels at 10 pixels per inch

e.g. 20 qubits are sufficient to process 1024x1024 pixels (i.e. 1 Mpixel)

 $2^{N}$ -bit input and weight vectors can be encoded in  $\pm 1$  factors in a balanced superposition of the computational basis states of *N* qubits

**Exponential advantage in storage** 





#### **Summary**



Single perceptron efficiently implemented on 5-qubits IBM-Q hardware

If scaled, this allows for an exponential scaling of encoding resources

Further work: multilayer networks, continuously valued input/weight vectors...show quatum advantage