Machine Learning to Quantum Machine Learning

Extended Abstract

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# 1 Introduction

Machine Learning (ML) is a subset of computer science that uses algorithms to detect patterns in the data and to fit a statistical model. The model aims to make accurate predictions based on new data. [1] Quantum Machine Learning (QML) expands what is capable of classical computers by exploiting phenomena that are observed in quantum physics, such as superposition and entanglement.

# 2 The Qubit

The qubit is to quantum computing is what the bit is to classical computing.

The qubit differs from the classical bit, which is constrained to the states of 0 or 1; a qubit can be simultaneously in states 0 *and* 1 in a state known as super position. [2] Quantum computing heavily relies on linear algebra and matrix transformations to describe the transformation of information. Qubits’ states are represented as vectors where and .

These vectors are represented in Dirac notation where a vertex .

A circle with lines and arrows

Description automatically generatedA super-positioned qubit is represented with . This particular state is represented as a linear combination of the foundational states and ; , where and are complex numbers whose squares' magnitudes represent the probabilities of the qubit being observed in the respective states. This mathematical formula underpins the qubit's capability to embody quantum superposition, illustrating the departure from classical bits that are confined to the definitive states of 0 or 1.

Figure 1: The Bloch Sphere 3D representation of a qubits’ possible states.

# 3 The Quantum Advantage

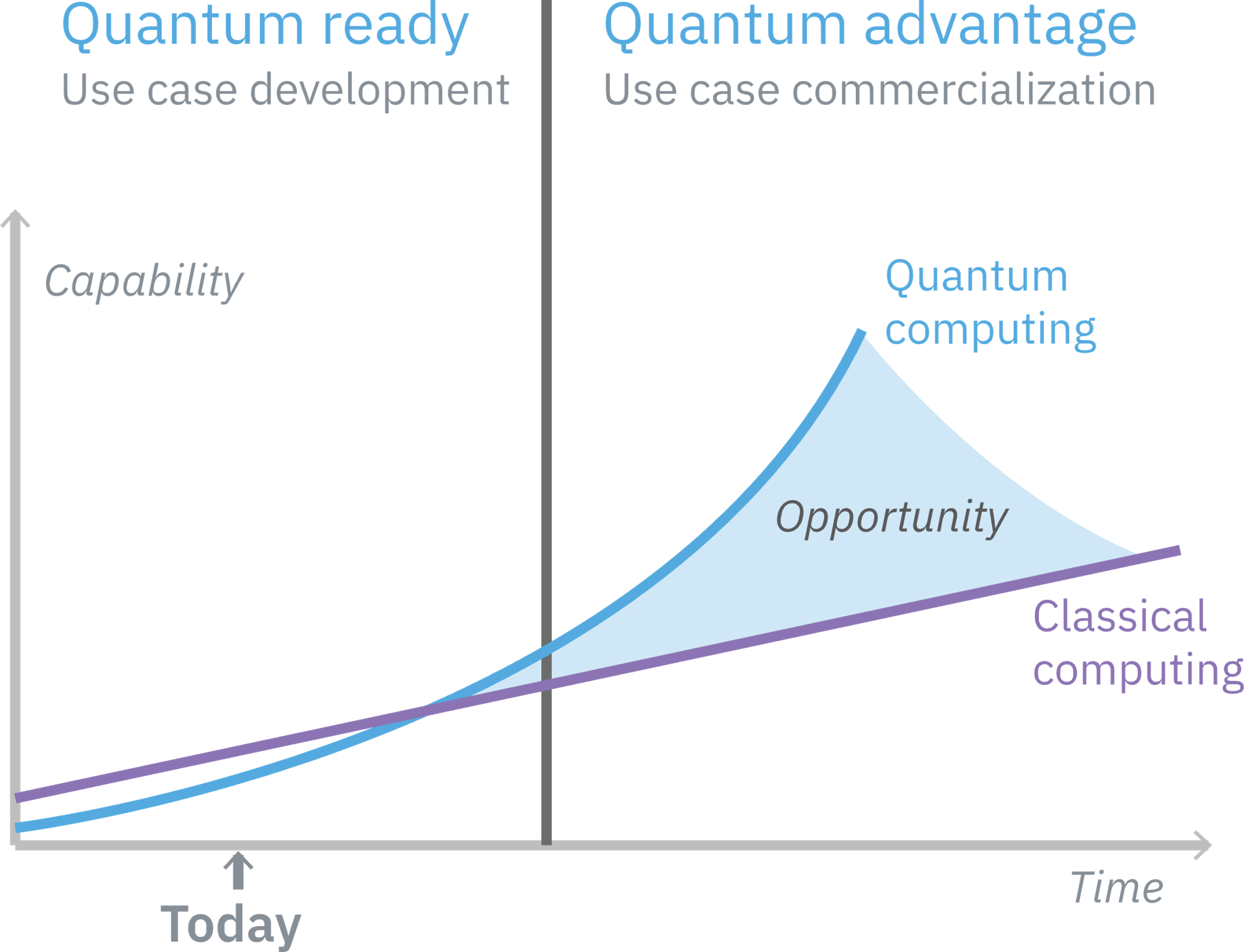
[](https://www.ibm.com/thought-leadership/institute-business-value/public/static/images/Quantum-Report/Figure3.svg)The core advantage of quantum computing lies in its ability to process information in ways that classical systems cannot match, offering exponential speed-ups for certain types of problems. For example, quantum algorithms have been demonstrated to outperform classical counterparts in oracle-based problems, showing that a significant quantum advantage emerges even in existing noisy systems. [3]Furthermore, quantum technology can revolutionize how we learn from experiments, as shown in a study where quantum machines learned from exponentially fewer experiments than required by conventional means, leading to dramatic reductions in the number of necessary experiments. [4] Quantum machine learning also benefits from the ability to process atypical patterns produced by quantum systems, offering potential speed-ups in learning tasks [5]. Additionally, the use of quantum-enhanced feature spaces in machine learning can provide advantages in solving classification problems where classical feature spaces become computationally prohibitive [6]. These advancements underscore the transformative potential of quantum computing and quantum machine learning across various fields, from drug discovery to optimization problems, by leveraging quantum mechanics' unique properties.

Figure 2 Source: [IBM](https://www.ibm.com/thought-leadership/institute-business-value/public/static/images/Quantum-Report/Figure3.svg)

# 4 The QML Model

# 5 Feature Importance

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# Bibliography

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| [1] | A. Burkov, The hundred-page machine learning book, 2019. |
| [2] | J. D. Martín-Guerrero and L. Lamata, “Quantum Machine Learning: A tutorial,” *Neurocomputing,* 2022. |