
# Quantum Programming Training Session

April 28, 2025 (14:40 – 18:20)

## Pre-requisites

- Algebra
    - Vectors are one-dimensional arrays of numbers which, in quantum computing, are used to represent the state of a quantum system. A linear combination is formed by adding scalar multiples of vectors, which represents quantum superposition. The span of a set of vectors defines all possible linear combinations. Matrices are two-dimensional arrays which transform one vector into another. We use matrices to represent gates in quantum computing. Matrix multiplication is used to perform a sequence of gates one after another. Eigenvalues give the outcome of measurement of a quantum system, upon which the system collapses to the associated eigenvector.
    - Vectors: https://www.youtube.com/watch?v=fNk_zzaMoSs&list=PLZHQObOWTQDPD3MizzM2xVFitgF8hE_ab (10min)
    - Linear combinations, span and matrices: https://www.youtube.com/watch?v=k7RM-ot2NWY&list=PLZHQObOWTQDPD3MizzM2xVFitgF8hE_ab&index=2 (10min)
    - Linear transformations and matrices: https://www.youtube.com/watch?v=kYB8IZa5AuE&list=PLZHQObOWTQDPD3MizzM2xVFitgF8hE_ab&index=3 (11min)
    - Matrix multiplication: https://www.youtube.com/watch?v=XkY2DOUCWMU&list=PLZHQObOWTQDPD3MizzM2xVFitgF8hE_ab&index=4 (10min)

- Eigenvectors and eigenvalues: https://www.youtube.com/watch?v=PFDu9oVAE-g&list=PLZHQObOWTQDPD3MizzM2xVFitgF8hE_ab&index=14 (17min)

- Complex numbers
  - Complex numbers extend the real number system by introducing the imaginary unit, which is the square root of –1. The Argand diagram provides a geometric representation of complex numbers on a plane, with the real part plotted on the x-axis and the imaginary part on the y-axis.
  - Complex numbers overview https://math.libretexts.org/Bookshelves/Differential_Equations/Introduction_to_Partial_Differential_Equations_(Herman)/08%3A_Complex_Representations_of_Functions/8.02%3A_Complex_Numbers (~15min)
  - Imaginary numbers https://www.youtube.com/watch?v=hqr1DtXXHpY&list=PLHJcI57De8cp_iiPlKUDhNOexGCQYkxL3 (5min)
  - Complex numbers https://www.youtube.com/watch?v=bmsapLZM2Uo&list=PLHJcI57De8cp_iiPlKUDhNOexGCQYkxL3&index=2 (4min)
  - Argand diagram https://www.youtube.com/watch?v=V7mECV0M1ys&list=PLHJcI57De8cp_iiPlKUDhNOexGCQYkxL3&index=5 (3min)
- Linear gradient (2D), Optimisation related
  - The gradient is the slope of a function, and the steepest negative gradient is used to guide optimisation algorithms such as gradient descent.
  - http://www.cedar.buffalo.edu/~srihari/CSE676/4.2%20Gradient-based%20Optimization.pdf (page 1-15, ~15min)
- Qubits, Gates, circuits
  - A qubit is the fundamental unit of quantum information, capable of existing in superpositions of 0 and 1, represented by a two-dimensional vector. Quantum gates manipulate qubits through unitary transformations. Circuits are formed by putting together a sequence of gates and measurements.
  - https://ichec.github.io/ct4106/lecture-03/from-bits-to-qubits.html (~20min)
- Hamiltonian – introduction
  - The Hamiltonian of a system describes its total energy and governs the evolution of quantum states through the Schrödinger equation.
  - https://www.youtube.com/watch?v=BusR0WQ_Gxo (1min)
  - http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/hamil.html#c1 (~2min)
  - https://github.com/ICHEC/QTrain/blob/main/docs/hamiltonian.md (~5min)

    - http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/Scheq.html#c1 (~10min)
- Classical SVM
    - Support Vector Machines (MIT): https://www.youtube.com/watch?v=_PwhiWxHK8o