“111 Centre on Biological Computing and Artificial Intelligence” , Dalian University (DLU)

Cognitive Systems Engineering

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Computational platforms for CogSysEng

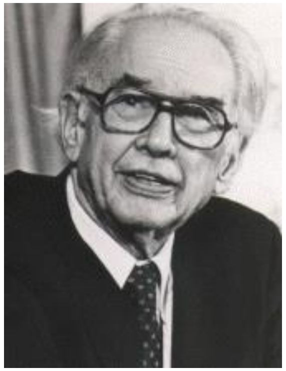
- The computer architecture of John von Neumann separates data and programmes (kept in the memory unit) from the computation (ALU); uses *bits*. First machine ABC by Atanassov and Berry.

- A Neuromorphic architecture integrates the data, the programme and the computation in a SNN structure, similar to how the brain works; uses *spikes* (bits at times).

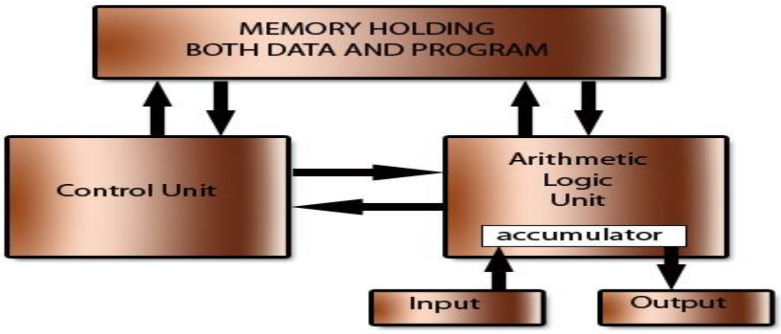
- A quantum computer uses *q-bits* (bits in a superposition) .

A SNN application system can be implemented using either of:

- von Neumann architecture;
- Neuromorphic architecture;
- Neuromorphic/Memristor architecture;
- Quantum computers



The Von Neumann or Stored Program architecture



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N. Sengupta et al, (2018), From von Neumann architecture and Atanasoffs ABC to Neuromorphic Computation and Kasabov’s NeuCube: Principles and Implementations, Chapter 1 in: Advances in Computational intelligence, Jotzov et al (eds) Springer 2018.

Lecture 15. Quantum computation

Quantum information principles: superposition; entanglement, interference, parallelism (M.Planck, A.Einstein, Niels Bohr, W.Heisenberg, John von Neumann, **E. Rutherford**)

- *Quantum bits (qu-bits)*

$$|\alpha|^2 + |\beta|^2 = 1$$

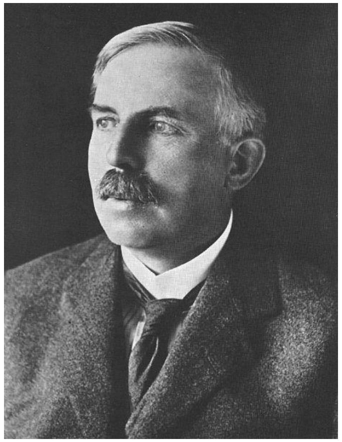
$$|\Psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

- *Quantum vectors (qu-vectors)*

$$\left[\begin{array}{c|c|c|c} \alpha_1 & \alpha_2 & \cdots & \alpha_m \\ \beta_1 & \beta_2 & \cdots & \beta_m \end{array}\right]$$

- *Quantum gates*

$$\begin{bmatrix} \alpha_i^j(t+1) \\ \beta_i^j(t+1) \end{bmatrix} = \begin{bmatrix} \cos(\Delta\theta) & -\sin(\Delta\theta) \\ \sin(\Delta\theta) & \cos(\Delta\theta) \end{bmatrix} \begin{bmatrix} \alpha_i^j(t) \\ \beta_i^j(t) \end{bmatrix}$$



Ernest Rutherford (1871-1937)

- **Applications:**
  - Specific algorithms with polynomial time complexity for NP-complete problems (e.g. factorising large numbers, Shor, 1997; cryptography)
  - Search algorithms (Grover, 1996), O($N^{1/2}$) vs O(N) complexity)
  - Quantum associative memories

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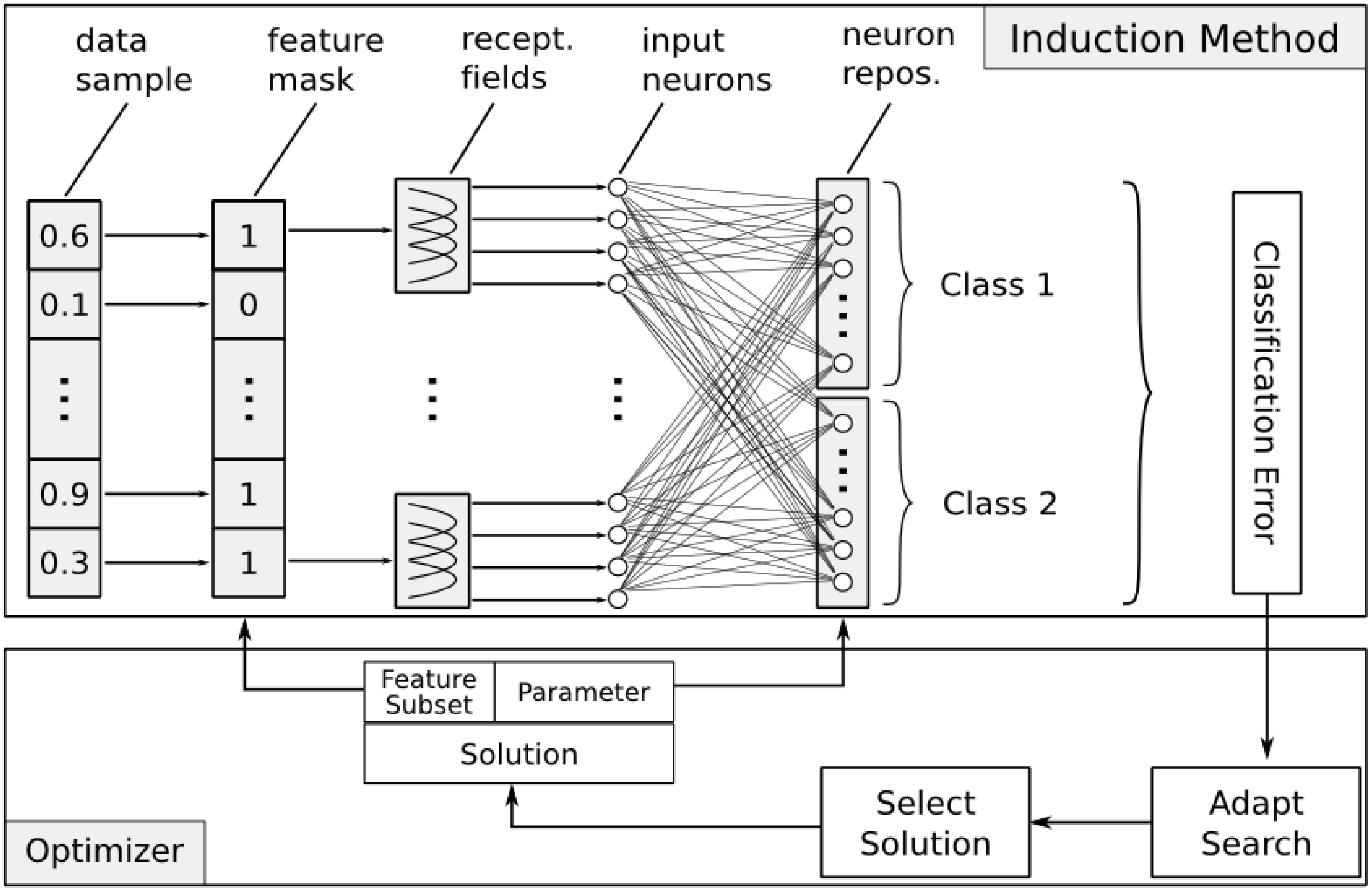
- A most interesting feature of quantum physics is the principle of *superposition*. The machinery of classical physics allows constructions of new mixed states (which correspond to a probability distributions of pure states), and so does also quantum physics. Quantum physics allows also the construction of new pure states as superpositions of existing ones (for exact definitions of the terminology used here, we refer to [15-18]).
- All information in the physical world is anyway represented by some physical system, and therefore also the nature of the information is affected by the nature of the physical world. It turns out that the information represented by quantum physical systems, *quantum information* differs from its classical counterpart in many notable parts, for example, it turns out that quantum information cannot be cloned arbitrarily [15]. As classical computing can be described as manipulating classical information, quantum computing is, in the same spirit, manipulation of quantum information. It is possible that the properties of quantum information help in resolving some computational tasks essentially more efficiently than classical information allows. In fact this was suggested already in [16], but a most interesting example was given in a very remarkable discovery where Peter Shor [17] demonstrated that quantum computers would allow efficient integer factorization, a task assumed impossible for classical information processing. For a presentation of notable quantum algorithms, we refer to [18]. It is worth emphasizing here that the efficiency of quantum computing comes from ingenious use of superposition principle, not from the high “clock frequency” of quantum computers.

Quantum-inspired evolutionary algorithms for optimisation of eSNN

(Kasabov, 2007-2008; S.Schliebs, M.Defoin-Platel and N.Kasabov, 2008; Haza Nuzly, 2010))



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