

Workshop: - “**Modélisation Quantique**”

ISC-PIF - Institut des Systèmes Complexes Paris Île-de-France  
113 rue Nationale, 75013, Paris, France

Monday 25-10-2021 at 14h00 (CET)

## **Adapting Logic to Physics**

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Adapting logic to physics addresses interesting questions. Non-classical logics such as fuzzy and many-valued logics seem promising candidates. Quantum information brings up new issues in logic due to the effects of non-commutativity, superposition, entanglement and reversibility.

We propose a quantum-like method in logic, Eigenlogic, where connectives are represented by operators (matrices), logical truth values by their eigenvalues, and logical interpretations by the quantum states.

Using a superposition of logical input states one gets a fuzzy logic representation where logical valuations correspond to quantum probabilities.

Semantics can be modified by using alternative alphabets for truth values, for example the binary  $\{+1, -1\}$  instead of Booleans  $\{0, 1\}$  are better adapted to quantum mechanical spin  $\frac{1}{2}$ . Many-valued logical operators are designed by operator interpolation methods using the Cayley-Hamilton theorem and can be associated with the quantum angular momentum.

Eigenlogic permits to consider syntax (operations) and semantics (values) as dual representations of the same logical operator and are transformed, in the case of Pauli-Weyl logical operators, by the discrete Fourier transform operator.

We outline differences with traditional quantum logic and a correspondence is made between logical universality and entanglement using the logical operator eigenvalue structure. First order logic and computability issues are also considered in Eigenlogic in relation to quantum algorithms and entangling gates.

Applications are proposed in quantum information with a logical formulation of the Bell inequalities, in quantum computing with a new quantum oracle expression and for the emerging concept of quantum robot applied to Braitenberg vehicle AI agents.

Z. Toffano & F. Dubois (2020): Adapting Logic to Physics: The Quantum-Like Eigenlogic Program. *Entropy* 22. Available at <https://www.mdpi.com/1099-4300/22/2/139>

Toffano, Z. Eigenlogic in the Spirit of George Boole. *Logica Universalis*, Birkhäuser-Springer, 14, 175–207 (2020). Available at <https://hal-centralesupelec.archives-ouvertes.fr/hal-02615451>

Z. Toffano & F. Dubois (2018): Quantum eigenlogic observables applied to the study of fuzzy behaviour of Braitenberg vehicle quantum robots. *Kybernetes* 48(10).

Available at <https://hal-centralesupelec.archives-ouvertes.fr/hal-02095400>