

# A type safe quantum programming language for quantum control and indefinite causal orders

**Lab:** LORIA, Nancy, France

**Team:** Inria team Mocqua

**Advisors:** Romain Péchoux (romain.pechoux@loria.fr) and Simon Perdrix (simon.perdrix@loria.fr)

The development of quantum programming languages that include quantum control primitives is one of the most important problems in quantum computing. During program execution, quantum control can allow quantum superpositions that depends on the quantum state and, therefore, provides all the quantum functionality that a programmer may want to access.

A fundamental example of quantum control is the *quantum switch* [1] which inputs two quantum evolutions  $U$  and  $V$ , and a *control* qubit, and consists in applying  $U$  followed by  $V$  or  $V$  followed by  $U$  depending on the state of the control qubit. In particular, when the qubit is in a superposition state,  $U$  and  $V$  are in an indefinite causal order [2]: in one branch of the superposition  $U$  is applied before  $V$ , but after  $V$  in the other branch.

Indefinite causal order is an important subclass of quantum control, which allows some speed up compared to standard classically controlled quantum computing [3,4,5].

The objective of this internship is to develop the syntax and semantics of a programming language with quantum control and to design a type system so that typable programs are precisely the programs that correspond to indefinite causal orders.

As an application, we will consider how well-typed quantum programs can be compiled into quantum circuits.

## References:

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