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Sequential realization of Quantum Instruments

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In adaptive quantum circuits classical results of mid-circuit measurements determine the upcoming gates. This allows POVMs, quantum channels or more generally quantum instruments to be implemented sequentially, so that fewer qubits need to be used at each of the N measurement steps. In this talk, we mathematically describe these problems via adaptive sequence of instruments (ASI) and show how any instrument can be decomposed into it. Number of steps N and number of ancillary qubits n_A needed for actual implementation are crucial parameters of any such ASI. We show an achievable lower bound on the product $N \cdot n_A$ and we determine in which situations this tradeoff is likely to be optimal. Contrary to common intuition we show that for quantum instruments which transform n to $m (> n)$ qubits, there exist N -step ASI implementing them just with $(m-n)$ ancillary qubits, which are remeasured $(N-1)$ times and finally used as output qubits.