Ideal Projective Measurements Have Infinite Resource Costs

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We show that it is impossible to perform ideal projective measurements on quantum systems using finite resources. We identify three fundamental features of ideal projective measurements and show that when limited by finite resources only one of these features can be salvaged. Our framework is general enough to accommodate any system and measuring device (pointer) models, but for illustration we use an explicit model of an N-particle pointer. For a pointer that perfectly reproduces the statistics of the system, we provide tight analytic expressions for the energy cost of performing the measurement. This cost may be broken down into two parts. First, the cost of preparing the pointer in a suitable state, and second, the cost of a global interaction between the system and pointer in order to correlate them. Our results show that even under the assumption that the interaction can be controlled perfectly, achieving perfect correlation is infinitely expensive. Our results are phrased as fundamental bounds in terms of the dimensions of the systems.