Conservation of Information

Amr Sabry
School of Informatics and Computing
Indiana University Bloomington

The work of Landauer (1961), Bennett (1973), and Feynman (1982) makes a strong case for the proposition that "information is physical" and hence that computation must necessarily obey a "conservation of information" principle. Conventional models of computation (e.g., Boole's logic, Church's lambda-calculus, and Turing's machine), however, are all based on primitive operations that do not conserve information.

We embrace the principle of "conservation of information" and use it to revisit the foundations of logic and computation. In particular, we develop a pure reversible model of computation that is obtained from the type isomorphisms and categorical structures that underlie models of linear logic and quantum computing and that treats information as a linear resource that can neither be erased nor duplicated. We then establish that conventional models of computation have inadvertently included implicit computational effects which we call "information effects." More precisely, computation in such conventional models can be systematically translated to our pure reversible model in a way that exposes the implicit manipulation of information as computational effects that are evident in the text of the program and that can be tracked by a type system.

Our framework re-asserts that information is a significant computational resource that should, in many situations (e.g., quantitative information-flow security, differential privacy, energy-aware computing, VLSI design, and biochemical models), be exposed to programmers and static analysis tools. At a more foundational level, our model unveils deeper and more elegant symmetries of computation than have previously been reported. In particular, ongoing research which we will briefly discuss has exposed two notions of duality: an additive duality and a multiplicative duality which give rise to negative and fractional types (or propositions) that have have natural computational and logical interpretations.