Will we ever understand it?

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Overview

Programming Language for Quantum Computing

History

- 1966 – Knill – basic pseudocode for QP
- 1998 – Omer – rich procedural language – QCL
- 2000 – Sanders, Zuliani – qQCL
- 2001 – Omer, Bettelli – extension of the language C++.
- mostly all languages – imperative languages
  - no control throught compilation
  - global variables

Quantum Flow Chart Language

Quantum Flow Chart Language

- Peter Selinger – Towards a Quantum Programming Language
- all pictures are from P. Selinger, Towards a Quantum Programming Language, in Math. Struct. in Comp. Science 14(4):527-586, 2004
- so far – languages and proposals depend on HW
- QFC – not limitate by HW
- quantum data classic control
  - Shor algorithm
  - Quantum fourier transformation
- functional language
  - operation transform input set to output set
  - no global variables

Quantum Flow Chart Language

- static language
  - no changes throught run
  - syntactical errors – throught compilation
  - no clonning theorem – throught compilation
- variables
  - quantum
    - unitary operations
    - measurement
  - classic
- close world

Quantum Flow Chart Language

- loops
- procedures
- recursion
- structured data
- extension – blocks

Quantum Flow Chart Language

- algorithms contain
  - initialization
  - unitary operations
  - measurement
  - classic read of results

A Brief Introduction to Algebra

A Brief Introduction to Algebra

- vectors
- basis vector
- norm of the vector
- matrix, adjoint of matrix
- trace of matrix
- horizont and vertical concatenation
- unitary matrix $A A^\dagger = E$, $A = S A S^\dagger$
- Hermitian matrix $A = A^\dagger$
- tensor product

A Brief Introduction to Quantum Theory

A Brief Introduction to Quantum Theory

- bits ($b = 1,\ b = 0$)
- quantum bits – Qbits ($b = \alpha\,|0\rangle + \beta\,|1\rangle$)
- entangled pairs
- indexing convention – lexicographic
- unitary transformations – not gate, Hadamard gate..
- measurement
  - observe Qbits and convert them into classical bits

Measurement

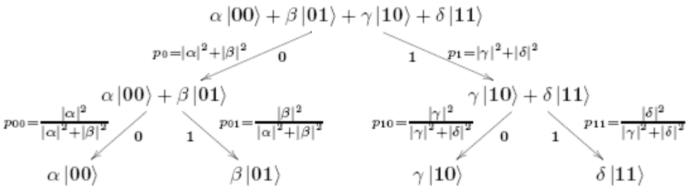

Figure: Schema of measurement

Density Matrices

- positive hermitian matrix which satisfies $tr(A) \leq 1$
- pure quantum state – $u\,u^*$
- mixed quantum state
- no observable difference between mixed states which have the same density matrix
- unitary operations – extend to density matrix $S\,u\,u^*\,S^\dagger$
- measurement – trace density matrix $=$ probability of occurence

Quantum Flow Charts

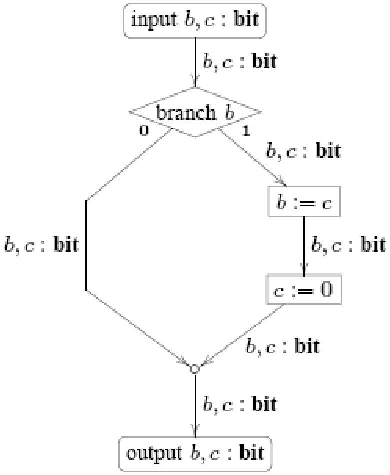

Figure: Flow chart

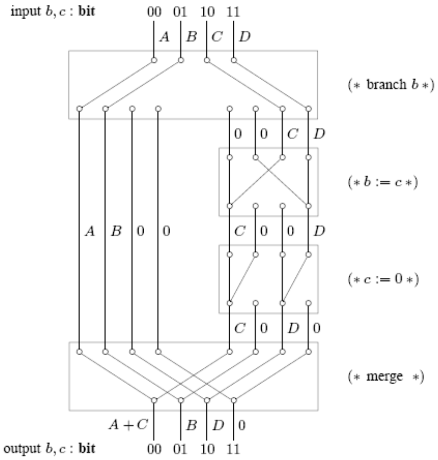

Figure: Probability in Flow chart

Rules for Flow chart

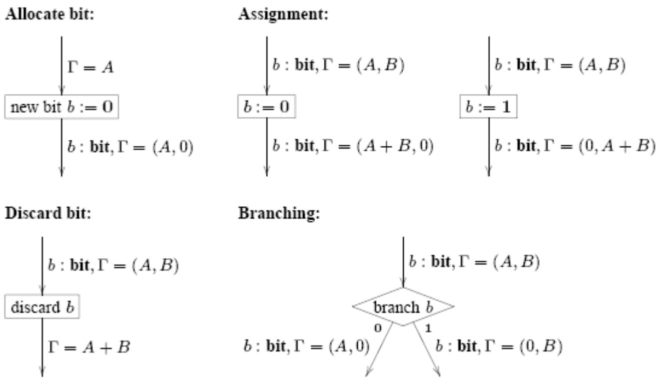

Figure: Rules for Flow chart

Rules for Flow chart

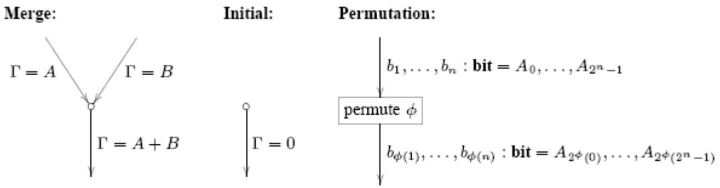

Figure: Rules for Flow chart

Quantum Flow Charts

- from control flow diagram combined with data flow diagram
- introduce probability
- introduce Qbits
- unitary operations $(q* = S)$ – linear function
- measurement – branch
- density matrix – Qbits
- tupe matrix – bits
- cycles, procedures, recursion

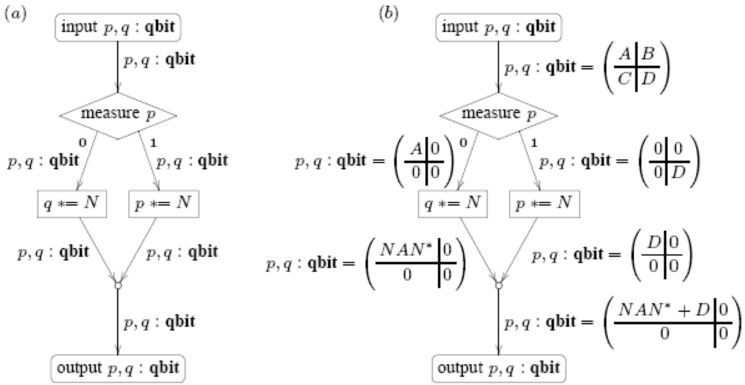

Figure: Quantum Flow chart

Rules for Quantum Flow chart

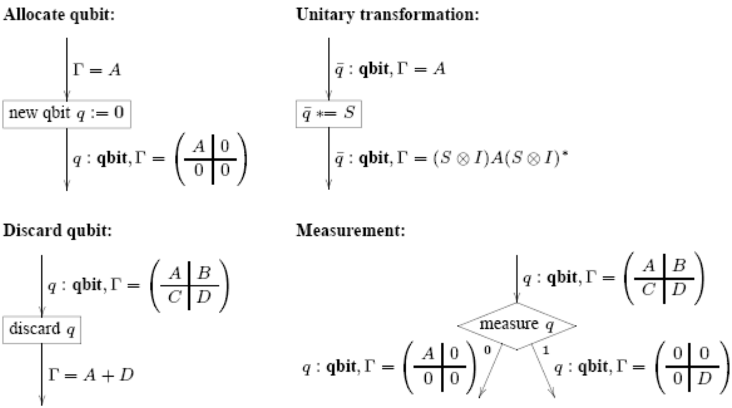

Figure: Rules for Quantum Flow chart

Rules for Quantum Flow chart

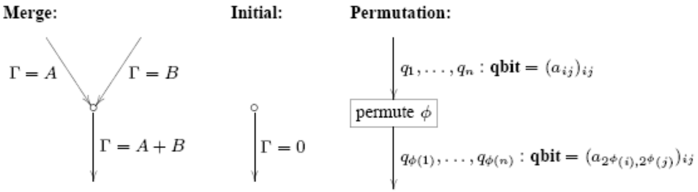

Figure: Rules for Quantum Flow chart

Cycles

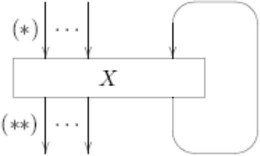

Figure: Cycles

Procedures

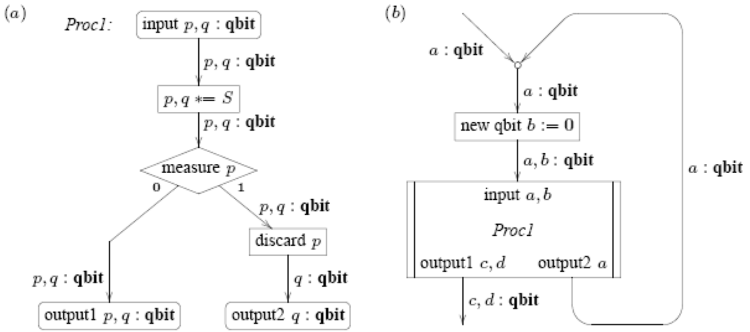

Figure: Procedures

Quantum Fourier Transformation

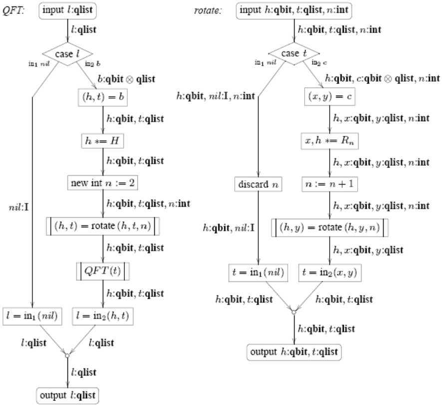

Figure: Quantum Fourier Transformation