The symbolic simulation and manipulation of quantum circuits

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The simulation of quantum computers and quantum information systems on classical computers is an important part of quantum information science. With such simulations, algorithms can be developed and tested, experiments can be validated and insight can be gained about the foundations of quantum information. We have developed an open source software package for simulating quantum computers symbolically using a computer algebra system, SymPy. The symbolic manipulation of gates and circuits has many advantages over the traditional numerical approach where gates and qubits are represented as large matrices and vectors. In this work, we introduce the software, describe its features through examples and outline the advantages of this approach.

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I. INTRODUCTION

II. SYMPY

```
from __future__ import division
from sympy import *
x, y, z, t = symbols('x y z t')
k, m, n = symbols('k m n', integer=True)
f, g, h = symbols('f g h', cls=Function)
```

```
((x+y)**2 * (x+1)).expand()
```

$$x^3 + 2x^2y + x^2 + xy^2 + 2xy + y^2$$

```
solve(Eq(x**3 + 2*x**2 + 4*x + 8, 0), x)
[-2*I, 2*I, -2]
```

```
limit((sin(x)-x)/x**3, x, 0)
```

$$-\frac{1}{6}$$

```
(1/cos(x)).series(x, 0, 6)
```

$$1 + \frac{1}{2}x^2 + \frac{5}{24}x^4 + \mathcal{O}\left(x^6\right)$$

III. SYMBOLIC DIRAC NOTATION

IV. QUBITS

V. GATES

VI. DENSITY OPERATOR

VII. ALGORITHMS AND EXAMPLES

A. Quantum Fourier transform

B. Grover's Algorithm

C. Teleportation

D. Dense coding

E. Heisenberg limited measurement

F. Quantum error correction

[1] L. K. Grover, Am. J. Phys **69**, 769 (2001).