Physics Department Senior Design Project Proposal

Project Mentor: Prof. Mark Coffey, 303-273-3818, mcoffey@mines.edu
(Name, phone, email)

Project Title Decomposition of Three Quantum Bit Logic Gates

Project Type: [ ] Team; Number of students__1-2___ [ ] Honors

Objective
(What is the science and/or engineering in this project?)
To obtain at least necessary conditions for the decomposition of three-qubit (quantum bit) quantum logic gates in terms of small numbers of controlled-NOT (CNOT) logic gates. Secondarily, to understand and apply concepts of matrix decomposition, tensor products, controlled logic operations, and entanglement. Honors option available for this project.

Prior Background
(What is the history of your involvement with this topic, including previous student projects?)
Previously the feasibility and evolution time of reaching the CNOT logic gate from two-qubit model Hamiltonians was investigated. A related student project lead to a joint publication that is listed below. In addition, the operator Schmidt decomposition for two-qubit operator has been specifically analyzed, also resulting in a recent joint publication. This type of project provides an introduction to the subject of quantum computing, including specifically the representation of qubits and the circuit model of computation. For three qubits the full problem is an open research topic, since the equivalent of a magic basis of quantum states is not available.

Student Expectations
(What do you anticipate the student(s) will be able to accomplish during the academic year?)
Gain an understanding of qubits, quantum logic gates, especially including the CNOT and C^2NOT gates, and elementary quantum circuits. Apply concepts of matrix decompositions, the properties of tensor products, and controlled logic operations. Obtain necessary conditions for the desired logic gate decompositions. Develop a number of explicit examples of three-qubit gate decompositions. Both analytic and symbolic computing analyses are anticipated. The regular completion of theoretical and/or computational exercises is expected.

Supervision Plan
(Who will be directly interacting with the student(s), you, a post-doc, grad students, or others?)
I will initially directly work with the student(s), and there will likely be meetings where another research student(s) will join the discussion.

Resources
(What equipment, algorithms, and facilities are available, and what will be assembled as part of the project?)
Student computer labs suffice for computing facilities. Mathematica suffices for symbolic computing software. A quantum computing textbook will be provided, as well as research papers.

Technical References
(Identify a few key starting points for the student(s); journal citations, prior reports, instruction manuals, etc.)

This topic is closely related to research Problem 4.4 in the standard textbook Quantum Computation and Quantum Information by M. A. Nielsen and I. L. Chuang (Cambridge, 2000).

V. V. Shende, S. S. Bullock, and I. L. Markov, Phys. Rev. A 70, 012310 (2004).
G. Vidal and C. M. Dawson, Phys. Rev. A 69, 0103101 (2004).
M. W. Coffey and G. G. Colburn, J. Phys. A 40, 9463 (2007).
M. W. Coffey and R. Deiotte, Quant. Info. Proc. (2008).