Online tool aids quantum computing research

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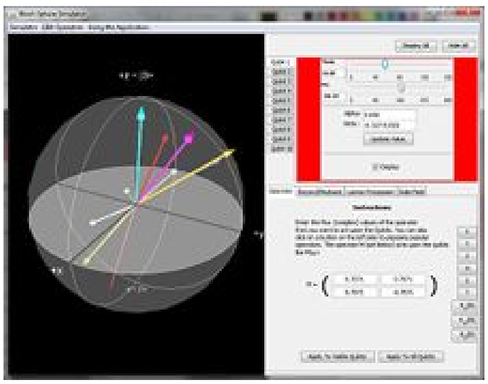

The Bloch Sphere Simulator is available online for use by students and researchers.

(PhysOrg.com) -- Quantum computing holds great promise, but will require informed specialists who can explore its full potential. Through a book, an interdisciplinary class and now a brand new online tool, University of Cincinnati Professor Marc Cahay is preparing students for this emerging field.

“It is too early to tell if quantum computing will ever be commonplace,” said Marc Cahay, professor of electrical & computer engineering at the University of Cincinnati. Through a first-year graduate level class, “Introduction to Quantum Computing,” Cahay is inspiring students to prepare for this emerging field. He has expanded his efforts through a book and a new online tool.

“As a theoretical construct, quantum computing has been booming for the last 15 years,” he said. “From a practical standpoint however, the study of quantum computers is still in its infancy.”

At this stage, the area of quantum computing has its fair share of advocates and nay-sayers, but Cahay said the basic ingredients of quantum computing can be mastered with mathematical tools available to students in a wide variety of disciplines as they reach senior level studies.

“The field of quantum computing allows a very fresh and practical approach to an introduction to the basic concepts of quantum mechanics,” Cahay said. “These concepts are becoming of increasing important as we progress deeper into the nanomillenium where breakthroughs in nanoscience and nanotechnology are daily events.”

The big boost to the field came from the prediction in the mid-1990s that quantum computers could solve very practical problems much more efficiently than their classical counterparts, he said. For instance, the advent of practical quantum computers would create havoc in the field of cryptography in which most data encryption codes for secure data transmission relies on the difficulty of factoring large numbers on classical computers. Quantum computing also promises to open up revolutionary search algorithms and could provide a path to sustain the exploding information on the World Wide Web with nearly daily leaps in the quantity of available online data.

“The benefits of quantum computing seem therefore to be too rewarding to pass up,’ Cahay said.

To understand quantum computing, students must thoroughly understand specialized concepts, beginning with the qubit. The power of the quantum computer is based on using these “qubits,” or “quantum bits.”

To better visualize the concept of a qubit and the action of quantum gates or operations acting on it, Cahay and several students have developed over several years the Bloch Sphere Simulator. The Bloch Sphere Simulator converts the equations into a visual representation, allowing students to see a visual representation of how the mathematics plays out in the theoretical world of quantum mechanics.

“Most quantum computing algorithms require the multiplication of a large number of complex matrices,” Cahay said. “I can visualize the operations up to a point, but even with all my 20 year experience in the field, I find it difficult beyond a certain stage.”

Quantum computers do not process classical binary bits – zero and one – but instead process quantum bits which are coherent superpositions of both zero and one, he said. Standard computer bits are electrical switches that are either on (one) or off (zero). A qubit is far more powerful than a classical bit. A qubit may represent zero or one but also a superposition of these states, in other words anything in between zero and one. A quantum computer derives its immense power from this superposition, he said, especially when the concept is extended to a system of multiple qubits and the latter are allowed to entangle.

“A physical way of implementing a qubit is through the spin of a single electron,” Cahay said. “In semiconductors, this has been realized by trapping a single electron or a few electrons in a nanostructure called quantum dot. The study and manipulation of these qubits has led to field of spintronics which could pave the way to the practical implementation of a quantum computer. “

Cahay has been working to spread his excitement about quantum computing and spintronics since 2003. Working with colleagues in engineering, computer science, and physics, Cahay coordinated the creation of an introductory class in quantum computing, first offered in

2004. The class has been offered every year since and has attracted students from a very diversified background. Since then, in collaboration with Supriyo Bandyopadhyay of Virginia Commonwealth University, Cahay has co-authored Introduction to Spintronics, the first textbook on the topic, published in 2008. This textbook has been described as an "accessible, organized, and progressive presentation" of the field.

The Bloch Sphere Simulator is an outgrowth of the class and the book. Cahay said he frequently drew diagrams in class and finally suggested student project to covert the drawings into an animation package. After several iterations, the projects eventually led to the development of a user-friendly tool which was the recent master's thesis of Stephen Shary.

Shary considerably increased the functionality of the software as well as the user interface. The end product was used in class for the first time in the winter of 2011 and has proved to be a very valuable tool for students to master the basic concepts of quantum computing.

"A student can use this software at home," Cahay said. "Typically, I will ask a student to work out the problem mathematically, but then to check his/her answers using the Bloch Sphere animation package."

The simulator is available online for quantum computing faculty and students around the globe. Shary has incorporated a tracking system into the simulator which reveals hundreds of hits every month from all over the world.

"The more people will use the simulator, the more we will be able to improve its capabilities," Cahay said, "to make it not only an educational but also a valuable tool for researchers around the world."

Provided by University of Cincinnati