Preface

"Perhaps the quantum computer will change our everyday lives in this century in the same radical way as the classical computer did in the last century."
— excerpt from press release, Nobel Prize in Physics 2012.

Quantum computers promise dramatic advantages over current computers. Governments and industries around the globe are now investing large amounts of money with the expectation of building practical quantum computers. Recent rapid physical experimental progress has made people widely expect that large-scalable and functional quantum computer *hardware* will be built within 10–20 years. However, to realize the super-power of quantum computing, quantum hardware is obviously not enough, and quantum *software* must also play a key role. The software development techniques used today cannot be applied to quantum computers. Essential differences between the nature of the classical world and that of the quantum world mean that new technologies are required to program quantum computers.

Research on quantum programming started as early as 1996, and rich results have been presented at various conferences or reported in various journals in the last 20 years. On the other hand, quantum programming is still a premature subject, with its knowledge base being highly fragmentary and disconnected. This book is intended to provide a systematic and detailed exposition of the subject of quantum programming.

Since quantum programming is still an area under development, the book does not focus on specific quantum programming languages or techniques, which I believe will undergo major changes in the future. Instead, the emphasis is placed on the foundational concepts, methods and mathematical tools that can be widely used for various languages and techniques. Starting from a basic knowledge of quantum mechanics and quantum computation, the book carefully introduces various quantum program constructs and a chain of quantum programming models that can effectively exploit the unique power of quantum computers. Furthermore, semantics, logics, and verification and analysis techniques of quantum programs are systematically discussed.

With the huge investment and rapid progress in quantum computing technology, I believe that within 10 years more and more researchers will enter the exciting field of quantum programming. They will need a reference book as the starting point of their research. Also, a course on quantum programming will be taught at more and more universities. Teachers and students will need a textbook. So, I decided to write this book with the two-fold aim:

(i) providing a basis for further research in the area; and
(ii) serving as a textbook for a graduate or advanced undergraduate level course.

Quantum programming is a highly interdisciplinary subject. A newcomer and, in particular, a student is usually frustrated with the requisite knowledge from many different subjects. I have tried to keep the book as self-contained as possible, with details being explicitly presented so that it is accessible to the programming languages community.

Writing this book gave me an opportunity to systemize my views on quantum programming. On the other hand, topics included in this book were selected and the materials were organized according to my own understanding of this subject, and several important topics were omitted in the main body of the book due to my limited knowledge about them. As a remedy, some brief discussions about these topics are provided in the prospects chapter at the end of the book.