



## Teaching Guide

| Identifying Data         |  |        |                      |           | 2023/24 |
|--------------------------|--|--------|----------------------|-----------|---------|
| Subject (*)              | Programming and Implementation of Quantum Algorithms   |        | Code                 | 614551007 |         |
| Study programme          | Máster Universitario en Ciencia e Tecnoloxías de Información Cuántica  |        |                      |           |         |
| Descriptors              |  |        |                      |           |         |
| Cycle                    | Period   | Year   | Type                 | Credits   |         |
| Official Master's Degree | 1st four-month period  | First  | Optional             | 3         |         |
| Language                 | SpanishGalician  |        |                      |           |         |
| Teaching method          | Face-to-face   |        |                      |           |         |
| Prerequisites            |  |        |                      |           |         |
| Department               | Enxeñaría de Computadores  |        |                      |           |         |
| Coordinador              | Andrade Canosa, Diego  | E-mail | diego.andrade@udc.es |           |         |
| Lecturers                | Andrade Canosa, Diego  | E-mail | diego.andrade@udc.es |           |         |
| Web                      | <a href="https://quantummastergalicia.es">https://quantummastergalicia.es</a>  |        |                      |           |         |
| General description      | <p>O propósito dos computadores cuánticos é aproveitar as propiedades cuánticas dos qubits e poder executar algoritmos cuánticos que utilizan a superposición e o entrelazamiento para ofrecer unha capacidade de procesamento moito maior que os algoritmos clásicos. É importante indicar que o verdadeiro cambio de paradigma non consiste en facer o mesmo que fan as computadoras dixitais ou clásicas, senón que os algoritmos cuánticos permiten realizar certas operacións dunha maneira totalmente diferente que en moitos casos resulta ser máis eficiente, é dicir, en moito menos tempo ou utilizando moitos menos recursos computacionais. Esta materia presenta unha serie de algoritmos cuánticos que proporcionan vantaxes computacionais sobre os mellores algoritmos clásicos equivalentes. Aínda que algún destes algoritmos non teñen unha aplicación práctica directa ou a súa implementación é inviable nos computadores cuánticos actuais, son un claro exemplo das posibilidades que a computación cuántica ofrece para tratar problemas irresolubles clasicamente.</p> <p>Este curso está deseñado para que os estudantes aprendan no laboratorio aspectos relevantes da programación cuántica de algoritmos vistos anteriormente</p> |        |                      |           |         |

## Study programme competences

| Code | Study programme competences  |
|------|--|
| A3   | CON_03 Know the physical bases that allow information to be coded and processed. Understanding of the new rules that Quantum Mechanics imposes for its processing.   |
| A4   | CON_04 Have knowledge of quantum computing, algorithms, circuits, their programming in different languages and accessible platforms.   |
| B1   | HD01 Analyze and break down a complex concept, examine each part and see how they fit together   |
| B2   | HD02 Classify and identify types or groups, showing how each category is different from the others   |
| B3   | HD03 Compare and contrast and point out similarities and differences between two or more topics or concepts  |
| B6   | HD11 Prepare accurately the relevant questions for a specific problem.   |
| B8   | HD13 Improvise solutions in an innovative way to solve a problem.  |
| B12  | HD23 Communicate using the expected norms for the chosen medium.   |
| B13  | HD24 Actively participate in face-to-face activities in the classroom.   |
| B14  | HD31 Assign resources and responsibilities so that all members of a team can work optimally  |
| B16  | HD33 Set goals for the group to analyze the situation, decide what outcome is desired and clearly set an achievable goal.  |
| C1   | C1. Adequate oral and written expression in the official languages.  |
| C2   | C2. Mastering oral and written expression in a foreign language.   |
| C3   | C3. Using ICT in working contexts and lifelong learning.   |
| C4   | C4. Acting as a respectful citizen according to democratic cultures and human rights and with a gender perspective.  |
| C5   | C5. Understanding the importance of entrepreneurial culture and the useful means for enterprising people.  |
| C6   | C6. Acquiring skills for healthy lifestyles, and healthy habits and routines.  |
| C7   | C7. Developing the ability to work in interdisciplinary or transdisciplinary teams in order to offer proposals that can contribute to a sustainable environmental, economic, political and social development. |



|    |  |
|----|--|
| C8 | C8. Valuing the importance of research, innovation and technological development for the socioeconomic and cultural progress of society. |
|----|--|

| Learning outcomes  |                             |   |  |
|--|-----------------------------|---|--|
| Learning outcomes  | Study programme competences |   |  |
| Coñecer as bases físicas que permiten codificar e procesar información. Comprensión das novas regras que impón a Mecánica Cuántica para o seu procesado. | AJ3<br>AJ4                  | BJ1<br>BJ2<br>BJ3<br>BJ6<br>BJ8<br>BJ12<br>BJ13<br>BJ14<br>BJ16 | CJ1<br>CJ2<br>CJ3<br>CJ4<br>CJ5<br>CJ6<br>CJ7<br>CJ8 |
| Ter coñecementos de computación cuántica, algoritmia, circuitos, a súa programación en diferentes linguaxes e plataformas accesibles.                    | AJ3<br>AJ4                  | BJ1<br>BJ2<br>BJ3   | CJ1<br>CJ2<br>CJ3<br>CJ4<br>CJ5<br>CJ6<br>CJ7<br>CJ8 |

| Contents  |  |
|---|--|
| Topic   | Sub-topic  |
| 1- Introducción aos algoritmos cuánticos "clásicos";          | .  |
| 2- Paralelismo cuántico                                       | .  |
| 3- Oráculos cuánticos   | .  |
| 4- Algoritmos cuánticos "clásicos";                           | a. Algoritmos de Deutsch e Deutsch-Jozsa<br>b. Algoritmo de Bernstein-Vazirani<br>c. Algoritmo de periodicidade de Simon |
| 5- Algoritmo de procura de Grover: amplificación de amplitude | .  |
| 6- Transformada Cuántica de Fourier                           | .  |
| 7- Algoritmo Cuántico de Estimación de Fase                   | .  |
| 8- Algoritmo de factorización de Shor                         | .  |

| Planning              |   |                      |                               |             |
|-----------------------|---|----------------------|-------------------------------|-------------|
| Methodologies / tests | Competencies  | Ordinary class hours | Student?s personal work hours | Total hours |
| Laboratory practice   | A3 A4 B1 B2 B3 B6<br>B8 B12 B13 B14 B16<br>C1 C2 C3 C4 C5 C6<br>C7 C8 | 10                   | 30                            | 40          |
| Supervised projects   | A3 A4 B1 B2 B3 C1<br>C2 C3 C4 C5 C6 C7<br>C8                          | 3                    | 6                             | 9           |
| Practical test:       | B1 B2   | 3                    | 0                             | 3           |



|   |  |   |    |    |
|---|--|---|----|----|
| Objective test  | A3 A4 B1 B2 B3 C1<br>C2 C3 C4 C5 C6 C7<br>C8 | 3 | 0  | 3  |
| Guest lecture / keynote speech  | A3 A4  | 5 | 15 | 20 |
| Personalized attention  |  | 0 |    | 0  |
| (*)The information in the planning table is for guidance only and does not take into account the heterogeneity of the students. |  |   |    |    |

| Methodologies                  |   |
|--------------------------------|---|
| Methodologies                  | Description   |
| Laboratory practice            | Resolución dos exercicios e problemas propostos, posta en común de dúbidas. Darase protagonismo ao alumnado para que presente os seus resultados.                                       |
| Supervised projects            | Nelas atenderase de forma personalizada ao alumnado para proporcionarlle orientación e resolver as súas dúbidas   |
| Practical test:                | Proba de carácter práctico realizada na aula  |
| Objective test                 | Proba de carácter obxectivo realizada na aula   |
| Guest lecture / keynote speech | Nelas explicaranse os contidos programados e responderanse as dúbidas que xurdan. Proporanse exercicios e problemas que os estudantes deberán resolver no seu tempo de traballo propio. |

| Personalized attention |  |
|------------------------|--|
| Methodologies          | Description  |
| Laboratory practice    | O alumnado recibirá aseoamento durante a realización das súas prácticas de laboratorio por parte do profesorado. |

| Assessment      |  |  |               |
|-----------------|--|--|---------------|
| Methodologies   | Competencies                                 | Description  | Qualification |
| Practical test: | B1 B2  | Asistencia e participación ás clases expositivas e interactivas, entrega de exercicios e problemas resoltos, exposición voluntaria de resultados | 60            |
| Objective test  | A3 A4 B1 B2 B3 C1<br>C2 C3 C4 C5 C6 C7<br>C8 | Exames e/ou tests parciais e/ou finais   | 40            |

| Assessment comments |
|---------------------|
|                     |

| Sources of information |  |
|------------------------|--|
| <b>Basic</b>           | Básica:- Notas de Clase- Varios autores, Qiskit textbook: Quantum protocols and quantum algorithms, Disponible online en: <a href="https://qiskit.org/learn/course/quantum-protocols-and-quantum-algorithms/">https://qiskit.org/learn/course/quantum-protocols-and-quantum-algorithms/</a>  |
| <b>Complementary</b>   | - Thomas G. Wong. Introduction to Classical and Quantum Computing, capítulo 7, Rooted Grove, 2022- Noson S. Yanofsky e Mirco A. Mannucci. Quantum computing for computer scientists, capítulo 6, Cambridge University Press, 2008.- M.A. Nielsen and I.L. Chuang: Quantum Computation and Quantum Information, capítulos 4-6, Cambridge, 2010. |

| Recommendations   |  |
|---|--|
| <b>Subjects that it is recommended to have taken before</b>     |  |
| Quantum Computing Tools/614551006                               |  |
| <b>Subjects that are recommended to be taken simultaneously</b> |  |
| Practical Applications of Quantum Computing/614551010           |  |
| <b>Subjects that continue the syllabus</b>                      |  |
| Quantum Computing and Machine Learning/614551008                |  |
| Quantum Computing and High Performance Computing/614551009      |  |
| <b>Other comments</b>   |  |



(\*)The teaching guide is the document in which the URV publishes the information about all its courses. It is a public document and cannot be modified. Only in exceptional cases can it be revised by the competent agent or duly revised so that it is in line with current legislation.