Quantum Computing in Finance: The Intesa Sanpaolo Experience

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The review of this article was arranged by Department Editor Shari LS Worthington.

IEEE DOI 10.1109/EMR.2024.3373796

Abstract*— *Quantum computing (QC) promises to revolutionize the computing domain with its ability to outperform classical computing in various applications. This article explores the potential of QC and its impact on the financial industry, among other domains. It focuses on the Quantum Competence Center at Intesa Sanpaolo, the largest bank in Italy. The Quantum Competence Center aims at leveraging quantum technologies to drive innovation and enhance banking and financial services. This article discusses the establishment of this corporate entity, its objectives, collaborations with academic institutions and quantum providers, workforce development initiatives, future perspectives, and the challenge of integrating QC into the bank's operational workflow.

Key words: Banking and financial services, collaborations, financial industry, innovation, Intesa Sanpaolo (ISP), operational workflow, Quantum Competence Center (QCC), quantum computing (QC), quantum technologies, quantum workforce, workforce development.

I. INTRODUCTION

QUANTUM computing (QC) is foreseen to be the next big step in the evolution of the computing domain. This new computational paradigm is rooted in the laws of quantum mechanics, defining computing devices that are theoretically able to outperform any other classical computer in performing certain applications in finance [1], [2], [3], chemistry [4], biomechanics [5], machine learning [6], [7], networks [8], [9], and many other domains.

In a classical computer, the basic unit of information is the *bit*, which can take 0 or 1 binary values. Instead, in a quantum computer, we handle *qubits*. A qubit is a two-level quantum mechanical system, which can exist in a *superposition* of states, i.e., a linear combination of the two basis states, $|0\rangle$ or $|1\rangle$. A generic qubit state $|\Psi\rangle$ is then defined as

$$|\Psi\rangle = \alpha\,|0\rangle + \beta\,|1\rangle\,. \tag{1}$$

This generic state can also be identified as the vector $|\psi\rangle$ in Figure 1. α and β coefficients are complex numbers that represent the *probability amplitude* of the two basis states. These probability amplitudes are complex numbers constrained by the equation

$$|\alpha|^2 + |\beta|^2 = 1. \tag{2}$$

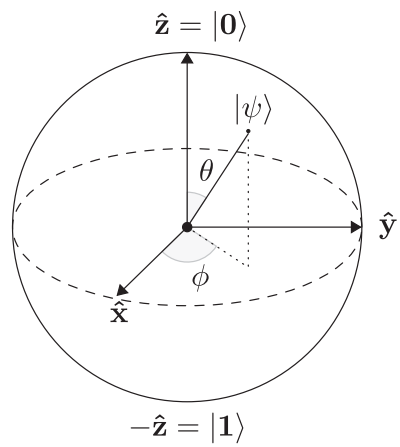

Figure 1. Bloch sphere that visualizes the generic state of a qubit.

This *superposition* characteristic enables quantum computers to perform calculations at an unprecedented speed and tackle complex problems that are practically impossible for classical computers to solve efficiently.

Among the interesting tasks within the financial domain, we find the following:

- credit scoring;
- fraud detection;
- option pricing;
- investment recommendation;
- dynamic portfolio optimization.

The potential breakthroughs that QC can offer in these domains have ignited intense research and development efforts, making it a highly anticipated and promising frontier in the computing world. This article is part of a series of articles in this journal with insights on QC management topics [10], [11], [12] and about managing a quantum team in a large bank [13].

II. Intesa Sanpaolo

Intesa Sanpaolo (ISP) is the largest bank by total assets managed in Italy, and one of the largest financial institutions in Europe [14].

With its headquarters in Turin and Milan, Italy, it operates a vast network of branches and subsidiaries both domestically and internationally.

ISP provides a wide range of banking and financial services to individuals, businesses, and institutional clients. These services include retail banking, private banking, corporate banking, investment banking, asset management, insurance, and wealth management. The bank serves millions of customers across Italy and has a significant presence in Central and Eastern Europe as well [15].

The bank is structured in several different departments working in synergy together covering all activities, which contribute to achieving the company mission, each with a high degree of autonomy. There are also specialized competence centers within the company, which are leading its progress in several domains.

The greatest part of these centers of excellence belongs to the Chief Data, AI, Innovation, and Technology Officer (CDAITO) Department.

CDAITO is committed to strengthening the relationship with business departments, making the development and adoption of technologies such as cloud computing and AI more effective, flexible, and integrated.

Figure 2. QCC objectives.

In particular, the Quantum Competence Center (QCC) has been established within the Group Technology Area inside CDAITO.

III. ISP Quantum Competence Center

The QCC was established in July 2020, and its responsibility was assigned to M.Sc. Davide Corbelletto.

Davide, a mathematician, and QC enthusiast, joined ISP in 2016 as a Data Technology Specialist. First, he oversaw the architecture design of data and applications to support areas, such as financial data warehousing, risk management, compliance and internal audit, and accounting and regulatory warning systems.

In 2019, Davide was invited by the company D-Wave to the *Qubits Europe* conference. He knew about quantum mechanics from his time at university. He started studying QC and participating in related events. He understood very early that QC could have a broad impact on the financial domain. Although the 2020 COVID-19 pandemic slowed down the initiative, he was able to bring the management on board to pursue this endeavor.

With this bottom-up approach, Davide soon started the recruiting process. Now, the team is made up of five people, but future prospects entail a steep increase in numbers. He employed colleagues highly skilled in both Data science and software engineering to work on these emerging topics. In fact, such competencies are the most fitting to quickly build the required quantum workforce. Beyond Davide, two collaborators have a software engineering background, and the other two have a data science background. Three of them were already employed inside the company while another one was specifically hired.

On the whole, the team provides five full-time equivalent (FTE) per year.

The QCC has five objectives (as in Figure 2), which are as follows:

1) leading, supervising, and enabling all the experimentations on QC that are starting in the group;
2) training the future quantum software engineer workforce and popularizing the topic, for example, recording and broadcasting seminars or organizing lectures;
3) advising all ISP employees who must deal with quantum technology, such as those in the Cybersecurity, Innovation, or Venture Capitalists Department;
4) collaborating with universities and promoting academic research to establish beneficial synergies;
5) defining the guideline for progressive and consistent adoption of this cutting-edge technology.

IV. QCCs Journey So Far

QCC is hosting and being part of many events and initiatives. These events offer invaluable networking and collaboration opportunities, allowing ISP to be early integrated into the quantum ecosystem, and to form partnerships with QC companies and researchers. By engaging in such events, ISP can guide research in directions beneficial to the finance industry. Moreover, these events may potentially serve as a platform for talent acquisition, helping to identify and recruit experts in the field, and can spotlight promising startups and technologies worthy of investment. Furthermore, these events provide insights into the current state and future potential of QC, equipping employees with valuable skills that can be applied in-house. Finally, active participation in the QC field can establish ISP as a thought leader, enhancing its public image and demonstrating a commitment to innovation and future technologies.

Starting in 2021, QCC undertook significant initiatives, each playing an important role in shaping the bank's early QC journey. The importance of these activities lies not only in their technical achievements but also in their strategic value. For instance, the collaboration with QC firms and academic institutions accelerated ISPs understanding and application of quantum technologies in finance. These partnerships have been instrumental in developing solutions tailored to financial services and positioning ISP for the internal and external public as a leading institution embracing new technology, thus embodying the QCCs goal of driving innovation through quantum technology.

Early relationships with hardware providers are crucial for securing priority access to QC resources. As demand for these technologies increases, those with established partnerships are more likely to have preferred access to limited hardware, ensuring continuity and efficiency in their QC initiatives. In a future landscape where quantum hardware may become scarce, early partnerships can mitigate the risk of being outpaced by competitors.

Some of the initial achievements are listed as follows.

- Back in 2021, QCC started to experiment with two QC platforms: 1) DWave Quantum Annealers and 2) IBM Universal Quantum Computer. Engaging with D-Wave—through its European partner Data Reply—and IBM, both leaders in different QC paradigms, enabled QCC to broaden its technological horizons. D-Wave specializes in quantum annealing, a technique well-suited for optimization problems, while IBMs universal quantum computers offer a more general approach to quantum computation. By experimenting with both, QCC could compare their capabilities, leading to a more nuanced understanding of how different QC technologies can be tailored to specific financial applications. Collaborating with these vendors goes beyond mere technology usage; it is about building relationships that foster innovation. These collaborations can lead to joint research efforts, shared knowledge, and early access to new quantum technologies and advancements. This proactive engagement positions QCC not only as a user of quantum technologies but also as a contributor to the evolving QC ecosystem. By experimenting with both D-Wave and IBM hardware, QCC prepares for a future where different quantum technologies coexist and complement each other. This diversification ensures that QCC remains adaptable and capable of leveraging the most suitable quantum solutions as they evolve. In the same year, it also assisted the foundation of the Quantum Technologies Observatory promoted by Politecnico di Milano, of which it is currently a partner. Being a partner in the Quantum Technologies Observatory (now Quantum Computing and Communications Observatory) opens doors to a rich talent pool of researchers, students, and educators. This association not only aids in talent acquisition but also fosters an environment of innovation where fresh ideas and perspectives from both the academic and the industrial world can be integrated into experimental applications in a number of fields, such as finance, energy, or defense.
- 2022 was a year full of announcements:

– The investment performed by NEVA, the ISP Venture Capital division, in the Israeli start-up Classiq [16]. Classiq is a company specializing in the development of quantum software, primarily focusing on creating a platform that simplifies and accelerates the process of designing quantum algorithms. Their technology enables users, even those with limited QC expertise, to build complex quantum algorithms more efficiently. This is significant in the emerging field of QC, where developing algorithms can be challenging due to the complex nature of quantum mechanics. This investment reflects ISPs commitment to being at the forefront of technological innovation. By investing in Classiq, a startup at the cutting edge of QC, NEVA is not only supporting groundbreaking developments in the field but is also positioning the bank to directly benefit from these advancements. This is also an endorsement for QCC representing that the bank is interested in QC.
– The launch of the *PoliQI* initiative, the first metropolitan photonic quantum-proof network realized in collaboration with Politecnico di Milano, Lombardia Region, and the Italian Army that will enable secure communication between the financial, the institutional, and the military districts in the city [17]. By participating in the creation of the first metropolitan quantum-proof fiber-based network, ISP positions itself as a pioneer in adopting quantum-resilient infrastructure. This initiative demonstrates the bank's foresight in preparing for a future where QC could challenge traditional encryption methods. The collaboration with Politecnico di Milano, Lombardia Region, and the Italian Army underlines ISPs commitment to partnering with key institutional stakeholders. Such collaborations not only enhance the project's credibility but also ensure that the network is designed to meet the varied needs of all participating entities.
– ISP attendance to the National Center of Research in HPC, Big Data, and Quantum Computing financed by the EU Recovery Fund [18]: attending a center financed by the EU Recovery Fund aligns ISP with the broader technological strategies and objectives of the European Union. These collaborations can lead to valuable exchanges of ideas, joint projects, and insights into new technologies that can significantly benefit the bank's operations and services. In this collaboration, ISP is studying two use cases. The first one is about fraud detection, a special and very important form of anomaly detection that is used to prevent financial crimes. The second one is credit scoring, a way to assess if a borrower is eligible to receive credit. The classical solutions to both problems show some issues due to the fact we usually must deal with unbalanced datasets for the former, and it is difficult to choose meaningful input features for the latter. Moreover, we are talking of two problems with a very broad impact on society from a financial inclusion point of view: while the first ensures protection to people involved in transactions, the second addresses the need for a more transparent process related to credit admission.

- ISP supports the creation of the postgraduate Quantum Computing and Communication Master promoted by Politecnico di Torino, where five ISP employees attended the first edition during 2022–2023 and three more will attend starting December 2023 [19]. By supporting this master's program and having its employees attend, ISP is actively investing in developing specialized in-house expertise in QC and communication. This initiative ensures that the bank has a knowledgeable team capable of understanding and leveraging quantum technologies in its operations.

Also, 2023 seems to have started in a promising way, and indeed:

– In March, QCC released its first peer-reviewed journal paper, written in collaboration with IBM and Politecnico di Torino [3]. This article proposed a variant of the CRA quantum algorithm addressing the limitations of other implementations by enhancing risk models to consider multiple systemic risk factors, allowing flexibility in input data, and testing through classical simulation and the use of quantum processing units (QPU). While it increases circuit complexity, this variant offers a more realistic software solution and holds promise for the financial sector as quantum technology advances.
– In April, the *Quantum Anti-Fraud Squad*, specifically made up for the occasion by the ISP/QCC, joined the *Quantum Hackathon* contest launched by the *International Centre for Theoretical Physics* and Quantinuum, Ltd., mentoring a group of students involved in the competition [20]. This event served not only as an excellent venue to test the mentoring capabilities of the group but also as an opportunity to connect and network with potential collaborators, also with companies organizing or sponsoring the event. The main takeaway from this event though was that if you want to reach some sort of result, also aside from winning the competition, you need to work at the same time on two sides in parallel: 1) the functional/domain expert mentorship and 2) the technical mentorship. Thus, to actually work on real use-case

applications, mentors for the groups in a hackathon should be at least two: one with business knowledge who can identify what would be a real advantage that quantum technologies can bring to the sector, and the other with technological knowledge on how to achieve it.
– Since June, ISP has been actively supporting the activities of the newly established *QubiTo* student team working on QC at Politecnico di Torino.

Moreover, ISP is working with Politecnico di Torino and LINKS Foundation to understand what processes inside the entire spectrum of operations could benefit from a quantum approach, developing Proofs-of-Concept (PoCs) for those use-cases, which may have a higher impact in the long run, when quantum computers will be powerful enough to gain a significant advantage over classical algorithms. As a result of the QCC activity, some scholarly publications have appeared [2], [3], [21], [22]. These PoCs are centered around areas where QC is projected to offer significant advantages over classical algorithms. Such areas can be credit risk analysis [2], [3], derivative pricing, risk modeling, portfolio optimization, natural language processing, or fraud detection [1]. By focusing on high-impact areas, ISP aims to leverage quantum technologies to revolutionize key aspects of its operations. These PoCs are not only about testing the capabilities of QC but also about shaping ISPs future strategies. The learnings from these projects are guiding how ISP approaches the integration of quantum technologies into their broader operational framework, particularly in preparing for a future where QC becomes mainstream. The scholarly publications resulting from these PoCs contribute to the growing body of knowledge in QC applications in finance. They not only highlight ISPs pioneering work in this field but also provide valuable insights for the broader financial and academic communities interested in the practical applications of quantum technologies.

In September 2023, at IEEE Quantum Week, this collaboration presented a second peer-reviewed paper about quantum machine learning [22] and participated in the Workshop on Quantum in Consumer Technology.

V. Challenges and Future Perspectives

ISP is committed to employing quantum algorithms and technology in every field that is relevant to financial services, from credit risk analysis to fraud detection and from portfolio optimization to financial recommendation systems. The interest also involves cybersecurity, both in the sense of developing a more robust communication channel for information exchange and in studying possible alternatives to public key encryption protocols, which are not necessarily quantum such as postquantum cryptography.

In the financial domain, there are many possible applications of quantum that could have a potential advantage over classical counterparts. QC allows the use of another type of math that can be exploited to solve problems that may not be classically intractable but in which there can still be some advantage to be gained. This advantage can be defined either in the speed domain, reaching the same outcome faster, or in the precision domain, reaching a finer solution granularity that was not previously possible.

QCC is building experience in this field while playing a role in the Italian and European development of the quantum ecosystem.

After knocking on doors to obtain projects and money, in 2023, QCC finally had its first internal client, the Innovation and Processes Department. The main challenge remains to be confirmed again as a strategic pillar of the next industrial plan, not starting from scratch when QC devices would be offered on the market as a regular service by many providers.

Given the number of activities being brought forward, the gained achievements so far, and the optimistic expectations for QC market evolution, it is expected that QCC will do nothing else than continue growing.

VI. Final Remarks for Nonbanking Managers

For managers outside the banking industry, the lessons from ISPs experience are manifold.

In the first place, it illustrates the adoption of a QC strategy inside a large corporation, and a path to building the internal QC workforce while interacting with partners, academia, and government. QC is a technology under development that is expected to have important implications for a wide number of sectors in the year to come.

The QCCs journey illustrates the importance of strategic partnerships with providers, governmental agencies, and academia, continuous learning, and being at the forefront of technological innovation. These principles are universally applicable, regardless of the industry. The QCCs approach to problem solving and innovation through emerging technologies can serve as a model for managers seeking to navigate their organizations through the complexities of the digital age.

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