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QUANTUM COMPUTING

How Can Portuguese NHS Benefit?

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Quantum computing: How Can Portuguese NHS Benefit?

Computação quântica: como pode o SNS Português beneficiar?

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* - As other papers of the "SPMS vision paper series" this paper is first-authored by a technician/staff of SPMS outlining a promising technology, trend or topic, middle-authored by its hierarchy, and last-authored and edited by the President of the Board of SPMS, where he ends by outlining the SPMS president view of the future for the tech, trend or topic, and the immediate next steps.

Abstract

It often seems that there is nothing to really "discover" in the world of information systems and technology, or that no longer really surprises the end user. However, there is an expanding area that is starting to capture the attention of software developers and, hence, those responsible for planning ahead: Quantum Computing.

The following paper aims to be a first and humble contribution to introduce the concept associated with Quantum Computing, some ongoing work, and how it can, soon, increase value in healthcare information systems. Quantum computing, will have implications for programing as well as information systems architecture, and it harbours the potential to provide professionals and citizens with tools to accelerate decision support with a high level of information security and integrity, advanced collaboration between humans and non-humans, synthetic knowledge creation and quantum AI.

Next steps: 1) SPMS will seek to create a virtual working group with Big Tech Companies, Universities in Portugal and abroad and any relevant SME/Start Up to mature the applicability to Hospital Information Systems and Quantum analytics of Hospital Data Spaces. 2) A smaller partnership circle will be attempted to identify a piloting/ EU fund application or research grand application for concrete exploration of the technology in light of existing national and EU funding as the coming Horizon Europe funds.

1. Introduction

Quantum Computing has been studied since the 1950s and internationally recognized companies have made a significant investment expanding the concept and engaging various business areas that can profit if Quantum Computing based processes could be implemented. Areas such as chemistry, physics or medicine have been easy targets for the development and application of quantum computing technologies to solve problems that currently have no known or easy solution.

The resource constraints that typical computing infrastructures currently have, do not allow them to easily scale and finish calculations to unsolved algorithms and problems. Some machine learning and artificial intelligence systems, even optimized and trained, make nowadays' computers insufficient resources to solve certain problems. Quantum computers thus have the role of accelerating the training process of these systems.

In the following chapters, the concept of Quantum Computation will be detailed, in how it can be applied and what to expect from this new paradigm in healthcare. A possible approach to the applicability of these concepts in the development of Health information systems will be presented, namely in the field of intelligence, decision support, security or integrity of information, always as a complement of the role of the clinical teams in the treatment of the patient.

2. What is quantum computing?

Quantum Computing is the science that studies the possible applicability of theories, principles and properties of Quantum Mechanics in Computer Science. With this definition, development in this area is aimed at quantum computers.

The type of computer used in classical and sequential computing and programming perfectly delineates the processing of data storage, physically dividing it into what we know as processor and memory, linking them together by communication components. This architecture limits devices in power, speed and data processing capabilities, leading to areas such as Artificial Intelligence or Problem Solving and Simulation being heavily penalized for lack of processing power. This limitation led some scientists and some companies to invest in research efforts in the area of Quantum Mechanics, in order to find solution for the creation of machines with higher processing capacity and speed.

The common digital computing uses binary digits to code for the data whereas quantum computing uses quantum bits or qubits (Saffman, 2016). A qubit is a quantum version of the classical binary bits that can represent a zero, a one, or any linear combination of states (called superpositions) of those two qubit states (Nielsen, Chuang, & Grover, 2002). Therefore, qubits allow computer bits to operate in three states compared to two states in the classical computing. This allows quantum computers to work thousands of times faster than regular computers. For example, a conventional analysis of a dataset with n points would require 2n processing units whereas it would require just n quantum bits using a quantum computer. Quantum computers use quantum mechanical phenomena like superposition and quantum entanglement to perform computations (Raychev, 2015).

To better understand the concept of concurrent processing, we can apply it in a practical case of everyday life: the difference is as simple as having a factory and assembly of components in series or having a factory that applies all phases of the assembly process simultaneously.

3. How to apply? Is it feasible?

Currently, we do not have the maturity or the resources available to easily accelerate the application of Quantum Computing in existing solutions. However, several companies are investing heavily in this area, boosting the creation of entirely quantum computers, which will change the market paradigm of these devices, whether home, business or corporate.

Well-applied, Quantum Computing will solve several problems that currently force us to break them down into smaller problems whose resolution we can control and ensure.

Cloud vendors like IBM, Google and Microsoft are pushing to be frontline vendors in this early phase, by facilitating research, experiments or even more structured application of quantum computing. IBM Q Experience ™ provides full stack quantum software framework to accelerate experimentations and states as "the most widely used and accessible quantum cloud platform". Google ™, in its turn, claims to have achieved computer supremacy with a recently published study in Nature, in which their processor took 200 seconds to sample one instance of a quantum circuit a million times – compared with an equivalent task for a state-of-the-art classical supercomputer would take approximately 10,000 years (Arute et al., 2019). Microsoft has its Azure Quantum service, in a preview mode, and, as the other vendors, will offer prebuilt frameworks and algorithms to facilitate use and be competitive in this type of business offer. Amazon Web Services, in its turn, is promoting Bracket, similarly with the other vendors.

4. Healthcare use cases

Nowadays, various biomedical and healthcare fields like genomics, mobile biometric sensors, and smartphone apps generate lots of raw and structured data. Therefore, it is recognized that one should know about and assess what can be achieved using this data.

Medical imaging and pathology could be early adopters: CT scans can be analysed to quickly identify anomalies. This process can take a fraction of the time that it takes nowadays. Also, precision medicine can be accelerated. Personalized chemotherapy protocols can be calculated faster, and with more customization and granularity, with quantum computing's enhanced data processing abilities.
The analysis of big data can provide further insights in terms of procedural, technical, medical and other types of improvements in healthcare.

The collective big data analysis of Electronic Health Records, Electronic Medical Records and other medical data is continuously helping to build better clinical decision support systems, risk assessment and prognostic tools.

5. Application in the Electronic Medical Records software

Healthcare information systems, as in many other areas today, have difficulties in taking full advantage of Artificial Intelligence due to lack of capacity and speed of processing. The role of quantum computing in this area will be critical and crucial.

By providing Health Information Systems with clinical decision support tools, we can generate and increase value to these systems, ensuring greater security and speed and quality while providing care.

With the machine learning branch of Artificial Intelligence and the learning capacity with which we have an information system, we will make it an indispensable working tool for improving the treatment and monitoring of users, but also for security at all levels. However, without processing capacity, we will not have excellent results like health deserves and needs.

Common goals of an EMR include reducing cost of analytics, developing effective Clinical Decision Support (CDS) systems, providing platforms for better treatment strategies, and identifying and preventing clinical risk that can be determined using big data. Also, it's crucial to promote security of data transferred and stored in the system, in terms of cryptography.

This combination of data can result in a better outlook, determination, and treatment of various diseases, but also in capacity and resource planning, that ultimately can limit the access to the healthcare services. Quantum computing can also promote a better personalized medicine framework.
Supercomputers and quantum computers can help in extracting meaningful information from big data, in dramatically reduced time periods and with smaller datasets.

The interoperability of different signal processing technologies in research and practicing medical professionals' fields is growing. Thus, developing a detailed model of a human body by combining physiological data and "-omics" techniques can be the next big target (Dash, Shakyawar, Sharma, & Kaushik, 2019). This can be of big interest for the diagnostic and treatment.

6. One step at the time – going practical

There are different opportunities in each step of this extensive process to introduce this kind of technology into our processes.

High volume of heterogenous (and most of the time unstructured) data puts a challenge to the NHS. Efforts are needed in sitting together data scientists, healthcare professionals, health informatics and bioinformatics to promote effective use cases. The connection with academia is also important to fulfil this objective.

Furthermore, new strategies and technologies should be developed to understand the nature (structured, semi-structured, unstructured), complexity (dimensions and attributes) and volume of the data to derive meaningful information.

The birth and integration of big data within the past few years has brought substantial advancements in the health care sector ranging from medical data management to drug discovery programs for complex human diseases including cancer and neurodegenerative disorders.

In Portugal, since 2002, there is a national EMR solution that today is known as SClínico Hospitalar that has witnessed advancements in terms of data collection, interoperability and semantics, management and usability. We believe that big data will not replace skilled manpower, subject knowledge experts and intellectuals, but it definitely works as an important support to day-to-day clinical care.

In the coming years, SPMS will have an important role in launching first predictive systems (e.g. derma AI, semi-automatic coding, etc). The clinical prediction in an individual's health state will be based on current or existing data (such as EHR-based and Omics-based). Similarly, it can also be presumed that structured information, obtained from a certain geography, might lead to generation of population health information. Taken together, big data will facilitate healthcare by introducing prediction of epidemics (in relation to population health), providing early warnings of disease conditions, and helping in the discovery of novel biomarkers and intelligent therapeutic intervention strategies for an improved quality of life. As such, SPMS should:

1. Co-create models and define work fields

2. Strengthen the focus on data structuring, capturing (including vital signs and blood test results) and availability

3. Take advantage of the several business intelligence systems, namely SClínico Hospitalar and SIMSNS

4. Study the importance of quantum computing in enhancing security, including cryptography

5. Study and establish partnerships with academia and cloud vendors, that can unleash the potential of this technology with proper cost benefit analysis

Conclusion

7. Conclusion

Quantum computing can provide unprecedented power and speed of processing as well as novel and fundamentally different algorithmic search and data homogenization strategies. Despite an area in discovery and with "hype-risk" associated, and also the fact that we still do not have easy access and knowledge for managing work tools necessary for this field, it is important to start thinking about information systems in this way and with this component provided in the architecture of new solutions, namely in terms of data structure, meaningfulness and intended outcomes.

It is essential to underline the importance of starting to invest in working groups, dedicated to Research and Development in the area of Quantum Computing, with the objective of promoting the adoption of measures and strategies implementation, documenting processes and procedures of adaptation of current information systems to the systems we want for the future. Partnerships with academia, startups and "big vendors" will be needed.

Vision

8. President's Vision on Quantum Computing for healthcare

The move from binary world to multi-dimensional computing may be as unknown as how would we sail across Africa to India, in the XIV century.

We know that healthcare, but especially hospitals, will have large and rich health data spaces, with near to real time data streams from Internet-of-Things (IoTs) connected devices, sensor, wearables and "implantables". We also know, AI algorithms currently under usage and in "hype", relay on rigid binary code, while trying to "think" flexible based on "fuzzy" models, neuronal networks being the most popular, in its various forms and levels of complexity (learning neuronal networks, and networks of networks as exemplars of layered toped complexity). There is, therefore, an opportunity of real, anticipatory, new AI-based models grounded in Quantum Computing. I see that Quantum AI can use real time data from sensors and implantables and provide more predictable and explainable decision-support or guide autonomous robotic action, than current fuzzy and "black-boxed" models based on presenting "a case" to a system trained/educated from exposure to other cases with dissimilar data and information sources.

Hospitals are "Networks of Things" (NoTs) already. Just they are not fully wired, or better, wirelessly-"wired"-up facilities. 5G may play a role, but advanced PANs and LANs will still be needed. Processing in different dimensions is not just a velocity issues as it is a data-path issue. We need to be able to assert different "weights" to the same data elements, and this is only possible if how we fundamentally compute, is not depend of a 0-1 choice.

On the other hand we will need to fully characterize the hospital data space iceberg that is relevant to predict patient outcomes, and support robotic (soft or hard) action.

Hence we need to define the computing tools for a PoC (Proof of Concept), and later for a MVP (Minimum Viable Product) so that some sort of preliminary experimentation can occur. We need to understand what tools industry has been thinking to provide to the tool set we will need to create this new form of house.

As immediate next steps:

1) SPMS will seek to create a virtual working group with Big Tech Companies, Universities in Portugal and abroad and any relevant SME/Start Up to mature the applicability to Hospital Information Systems and Quantum analytics of Hospital Data Spaces.

2) A smaller partnership circle will be attempted to identify a piloting/EU fund application or research grand application for concrete exploration of the technology in light of existing national and EU funding as the coming Horizon Europe funds.

9. Some (limited) References

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