Qualification of the potential of Quantum Computing on Operational Research issues within La Poste

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1 Introduction: Context

La Poste is the main distributor of mail and parcels in France and the leading European mail operator. In recent years, with the development of Internet exchanges and e-commerce, La Poste mail market have undergone major changes. The volume of letters sent is falling steadily and rapidly (approximately 8 billion addressed items of mail), while the volume of parcels is increasing significantly each year (500 million parcels delivered each year to more than 20 million distribution points).

The optimization of production processes mainly revolves around two key aspects of mail and parcel logistics networks: the optimization of mechanical mail sorting and the optimization of transport and delivery.

However, with the decline in mail and the major transformations of the mail product range in 2023 and the integration of new services into the transport and delivery logistics chain, La Poste must optimize (as frequently as possible) the itineraries of hundreds of trucks (11,000 daily connections) and the organization of the activity of tens of thousands of agents (more than 70,000 mail delivery postmen and almost 10,000 parcel delivery postmen)..

Hence, La Poste must have skills oriented towards high-performance computing like quantum computing, which is currently the emerging technology. A collaboration with the LIRMM and the LIMOS is being set up around a thesis subject to study this opportunity.

2 The Challenges

In addition to analyzing both the current state of quantum computing and its potential for development in the coming years, the principal challenge is to understand which decision problems will or will not be adapted to quantum computing architectures, what gains but also what limits to expect. To this end, three high-potential themes have already been highlighted internally:

- Reverse logistics of empty containers in parallel with the traditional routing of parcels and mail.
- The optimization required for the design of national mail and parcel transport networks in scenarios of changing mail stream volumes.
- Dynamic adjustment of the postman's round according to the prediction of the service rate, the external conditions (congestion, delay) as well as the chosen delivery perimeter,

The industrial challenges of the academic collaboration are to explore the applications of quantum computing [1], [2] to the combinatorial optimization problems presented above, and to identify the possible contributions of quantum algorithms to the solution of these problems or others arising from industrial problems within La Poste. This should allow to:

- Forming convictions about the potential of quantum computing: what uses, in what timeframe, what types of machines and what algorithms [3].
- Cross-reference this estimate with manufacturers' performance improvement predictions to assess the key milestones ahead.
- To be able, from this insight, to determine the practical milestones for solving these problems on an industrial scale, and on which quantum architectures.
- To prepare La Poste for the paradigm shift introduced by quantum technologies and the revolution they will bring to the world of industry.

3 The scientific roadmap

Today, research work on quantum algorithms in combinatorial optimization is very limited, especially on the industrial applications part, because machines cannot yet solve real-size instances. However, it is important to work on the scientific aspects, at the risk of endangering the applicability of the algorithms. The following scientific issues are therefore mainly guided by industrial issues/

- Design/adapt one or more quantum algorithms for solving a combinatorial problem/set of problems with the same structure [4], in order to allow a generalization of the results. The aim will be to implement these algorithms and test them on machines and/or quantum simulators, adapting the size and constraints if necessary;.
- On a problem, demonstrate theoretically the quantum advantage of an algorithm over classical solutions, and empirically if quantum machines allow it before the end of the thesis.
- Design/adapt classical algorithms inspired by quantum algorithms.

References

[1] M.A. Nielsen and I.L. Chuang (2010), "Quantum Computation and Quantum Information.", *Cambridge University Presse*

[2] O. Ezratty (2020), "Comprendre l'informatique quantique", *blog « Opinions Libres » (http://www.oezratty.net)* ISSN 2680-0527

[3] J. Preskill (2018), "Quantum Computing in the NISQ era and beyond", *arXiv :1801.00862v3 [quant-ph]*

[4] F. Glover, G. Kochenberger and Yu Du (2019), "Quantum Bridge Analytics I : A Tutorial on Formulating and Using QUBO Models," *arXiv :1811.11538v6 [cs.DS]*

[5] E. Bourreau G. Fkeury, Ph. Lacomme (2022), "Introduction à l'informatique quajtique", *edition Eyrolles*

[5] E. Farhi and J. Goldstone (2014), "A Quantum Approximate Optimization Algorithm", *36*

[6] Lov K. Grover (1996), "A fast quantum mechanical algorithm for database search", *arXiv : quant-ph/9605043*

[7] W. P. Baritompa et al (2005), "Grover's Algorithm Applied to Global Optimization, SIAM" *Journal on Optimization* **15(4)***:*1170-1184