QUANTUM COMPUTING: THE BEST ALLY FOR LAST MILE OPTIMISATION

REPLY Reply [MTA, STAR: REY, ISIN: IT0005282865] specialises in the design and implementation of solutions based on new communication channels and digital media. As a network of highly specialised companies, Reply defines and develops business models enabled by the new models of AI, big data, cloud computing, digital media and the internet of things. Reply delivers consulting, system integration and digital services to organisations across the telecom and media; industry and services; banking and insurance; and public sectors.

www.reply.com

The progressive growth in the rate of complexity in logistics has added several constraints to be taken into consideration in the route optimization perspective. To make a delivery involves considering parameters like the distance between each pair of customers, the territorial distribution of the warehouses, the capacity of the courier's vehicle fleet, the delivery time slots that need to be respected, any unforeseen last-minute events, and still others.

What is the optimal last-mile delivery path to guarantee a high service level to the end user, while at the same time improving the efficiency of logistic processes?

THE LOGISTICS DILEMMA

From a mathematical point of view, the classic route optimisation problem was originally formulated in the 19th century by the Irish mathematician W. R. Hamilton and by the British mathematician Thomas Kirkman and is known as the **TSP - Travelling Salesman Problem**: given a set of destinations and of the related distances, it is necessary to find the minimum path that makes it possible, starting from one point, to visit all the other points, passing through them once and only once.

Within the scope of the **complexity theory**, in terms of **NP-hardness** (**non-deterministic polynomial-time hardness**) the Travelling Salesman Problem is an **NP-hard** problem. This means that it is practically impossible to find an efficient way of solving the problem in a reasonable amount of time.

The objective of the TSP is therefore to determine the least expensive solution based on the cost of each "possible connection" and the cost of the overall itinerary.

THE LOGIC OF COMPLEXITY

For the logistics of the new millennium, however, the concept of optimal organisation is not limited to the definition of the minimum overall path that vehicles must take to serve everyone they need. Indeed, the problem is increased – and consequently complicated – by an increasing number of often contradictory variables and needs. These include, for example: **traffic, balancing weekly work**, as well as the **environmental impact** which, together with the protection of the **rights of workers in the supply chain**, represent aspects of increasing concern for consumers, even if these may potentially interfere with the latter's **needs** for **flexibility, customisation** and **free** delivery services.

TOWARDS THE VEHICLE ROUTING PROBLEM (VRP) AND BEYOND

Faced with the progressive increase in the rate of complexity, characterised by a growing number of constraints that need to be taken into consideration in order to define the optimal path, the **TSP** concept has greatly evolved. Indeed, a new class of problems has been defined, and can be qualified as a **generalisation** of the Travelling Salesman Problem. This includes the much more complex **VRP - Vehicle Routing Problem**, which takes into consideration an entire fleet of vehicles and not a single "traveller".

Inspired by today's real-life cases, the literature has gone even further, outlining even more **evolved versions of the VRP** which, for example, further complicate the calculation by adding the constraint of delivery windows and/or the multi-warehouse variable (when vehicles depart from several warehouses and do not necessarily return to the starting one).

It should also be remembered that, beyond the purely mathematical definition, we are also talking about dynamic optimisation problems.

The best possible route is, in fact, a result subject to constant change, which requires a continuous recalculation based on the variations introduced by a multiplicity of constraints.

LOGISTICS IN THE POST-COVID ERA

The **last-mile delivery** models were, of course, permanently revolutionised – and further complicated – by the pandemic: if, on the one hand, the health emergency has partially paralysed B2B supply chains, on the other, the restrictions imposed by the global situation have also led to an unprecedented **explosion in online shopping.**

E-commerce has thus become today's primary sales channel. A phenomenon that has led to a growth in volumes and to the redefinition of delivery times (24/7/365) and processes (which must also take into consideration the new requirements regarding social distancing, as well as anti-Covid19 safety and hygiene).

GROWTH IN VOLUMES

REDEFINITION OF DELIVERY TIMES

REDEFINITION OF PROCESSES

This is further complicated by the expansion of **types, ranges and variety of goods to be marketed and sold**, which are increasingly more heterogeneous in nature (ranging from large items such as furniture to perishable items such as groceries).

THE LIMITATIONS OF CONTINUED MANUAL MANAGEMENT

The contingent reality therefore continues to complicate an already complex operational problem such as that of last-mile organisation.

Today, most distribution partners continue to plan their itineraries without the support of an optimisation tool. Indeed, the management of courier routes is often based on the empirical experience of the individuals who, every morning, define the daily travel plan manually.

However, with the increase in variables and in the volumes of deliveries, finding an optimal solution involves an explosion in terms of time and costs. This intrinsic difficulty in solving this type of problem can also emerge with the use of standard algorithms and software relying on metaheuristic methodologies, which are not capable of dealing with the problem and finding a solution in a reasonable or useful amount of time. These solutions are also often associated with **extremely high licensing** and **upgrading costs**.

FROM GOOD APPROXIMATION TO OPTIMISATION

Today, being able to count on **computational speed** and **algorithmic flexibility** capable of managing complex logistic processes has become a key requirement for operators in the sector.

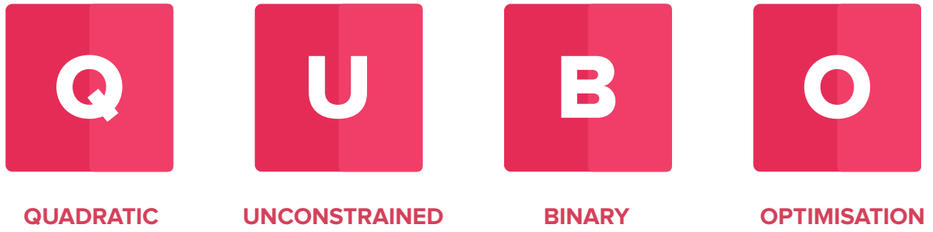
In this context, **Quantum Computing** can provide decisive support: the technology enables operators to overcome the limits of a good approximation, for a modelling capability that is increasingly close to the complexity of today's reality, as well as closing the gap towards the real-time optimisation of delivery routes

In fact, guaranteeing the best solution does not only mean reaching a certain set of points in a city at the lowest cost, but also getting rid of inefficiencies and collecting or internalising all the different needs of end customers, of logistics service providers and of e-commerce operators of the third millennium.

QUANTUM-INSPIRED ALGORITHMS: THE FUTURE PROSPECTS OF LOGISTICS

In addition to its consolidated experience in the logistics field, collaborating with major **e-commerce** operators and beyond, Reply has launched an inter-functional, international team focused on Quantum Computing. Among its various areas of research, the team has been taking a close look at the **Logistics 4.0 context**.

The Reply team examined how to best exploit the potential and specific characteristics offered by this technology, defining appropriate models and inserting them into a **Quantum Inspired Algorithm** designed to facilitate last mile optimisation: the **QUBO**.



The QUBO (Quadratic Unconstrained Binary Optimisation) model has been designed to describe quadratic and binary variable combinatorial optimisation problems, and therefore to be able to solve them efficiently through the quantum capability. The **flexibility and power** of this model allow it to manage a high rate of complexity while maintaining its speed, regardless of the number of constraints introduced, such as the need to manage various delivery times and windows, costs (per km, hour, journey, CO2, etc.), changes to the shipments and deliveries, fixed or variable size of the fleet, etc.

Thanks to this approach, the optimised, unified and continuous management of an increasing number of variables becomes possible and, above all, these variables can be dealt with **over time, regardless of their complexity**.

REPLY'S EXPERIMENTATION

Once the minimisation function was defined, the Reply team tested the optimisation performance through **D-Wave's python library, Qbsolv**, using anonymised data from various customers. Various simulations were carried out to compare the different solutions, Quantum Computing vs. non-Quantum Computing, which clearly confirmed the **superior performance of the quantum approach** compared to the traditional one.

The literature continues to advance our understanding of this technology daily, with new studies on Quantum Computing and its various forms. However, there are still very few real use cases to be found where these concepts can be put into practice.

In this sense, the positive results of Reply's studies and experimentation are encouraging, laying the foundations for the improvement of the algorithms used, in order to complicate the models and make them more similar to real customer cases.

To offer customers a commercial solution capable of automating and optimising the last mile with increasing efficiency, while ensuring quality and safety, the Reply team is working on defining a Quantum-Inspired algorithm **prototype capable of running on traditional GPUs** and thus addressing the key accessibility aspects associated with quantum hardware, in terms of costs.

REPLY'S QUANTUM OPTIMISATION FOR OPERATIONAL LOGISTICS

Reply is not only capable of adopting and using Quantum Computing technology, but also of integrating it into a structured application context. A key example is **Lea Reply**, the microservices architecture designed and developed by Reply to support operational logistics.

A highly flexible and **customisable cloud solution** designed to make it possible to satisfy both the needs of e-commerce and those of the logistics operator. A platform conceived and developed in an **Industry 4.0** logic (IoT, blockchain, AI, control towers and autonomous devices such as Automated Guided Vehicle and drones), whose modules also include a quantum optimisation component.

Thanks to the extensive experience gained in the logistics and Quantum Computing sector, Reply is able to support companies in adopting Quantum-Inspired solutions, with the many important advantages that these can generate in the short, medium and long term: from the savings generated by the optimisation of processes, to the **progressive simplification of the supply chain** enabled by technology, the improved reputation due to the higher quality and efficiency of the services offered and, finally, the reduced environmental impact.