Opinions Libres

le blog d'Olivier Ezratty

Publications

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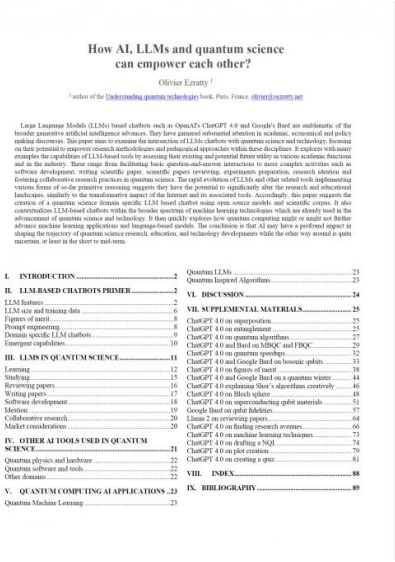
- L'essai **AI, LLMs and quantum science can empower each other?** (24 pages avec 70 pages d'annexes, un index et une bibliographie, janvier 2024) qui décrit notamment le rôle existant et potentiel des chatbots à base de grands modèles de langage pour accompagner les enseignants, étudiants, chercheurs et professionnels des sciences et technologies quantiques.



How AI, LLMs and quantum science can empower each other?

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Large Language Models (LLMs) based chatbots such as OpenAI's ChatGPT 4.0 and Google's Bard are emblematic of the broader generative artificial intelligence advances. They have garnered substantial attention in academic, economical and policy making discourses. This paper aims to examine the intersection of LLMs chatbots with quantum science and technology, focusing on their potential to empower research methodologies and pedagogical approaches within these disciplines. It explores with many examples the capabilities of LLM-based tools by assessing their existing and potential future utility in various academic functions and in the industry. These range from facilitating basic question-and-answer interactions to more complex activities such as software development, writing scientific paper, scientific papers reviewing, experiments preparation, research ideation and fostering collaborative research practices in quantum science. The rapid evolution of LLMs and other related tools implementing various forms of so-far primitive reasoning suggests they have the potential to significantly alter the research and educational landscapes, similarly to the transformative impact of the Internet and its associated tools. Accordingly, this paper suggests the creation of a quantum science domain specific LLM based chatbot using open source models and scientific corpus. It also contextualizes LLM-based chatbots within the broader spectrum of machine learning technologies which are already used in the advancement of quantum science and technology. It then quickly explores how quantum computing might or might not further advance machine learning applications and language-based models. The conclusion is that AI may have a profound impact in shaping the trajectory of quantum science research, education, and technology developments while the other way around is quite uncertain, at least in the short to mid-term.

2

I. INTRODUCTION

This paper looks at the intersection of machine learning and quantum science, with a focus on large language models chatbots. It investigates the various ways quantum scientists can benefit from these new tools and urges them to learn how to make the best use of them. It describes the existing as well as future use cases for LLMs with the observation that they have a significant potential to alter research methodologies and pedagogical approaches in quantum science with academics, researchers and within the industry. It also explores the various other ways machine learning techniques and quantum technologies can help each other.

Part II describes how LLMs fit into the generative AI landscape, the key features of LLM-based chatbots, their size and their training data sources, their figures of merit, and how to make best use of them with prompt engineering. It assesses their reasoning capabilities and shows how it will grow with the addition of various symbolic AI tools, on the road to so called "artificial general intelligence". This part also describes how to create domain specific LLM chatbots using LLM fine tuning and retrieval-augmented generation (RAG) with documents databases. It suggests the launch of a quantum science domain LLM based chatbot using open source language models.

Part III showcases how LLM chatbots can be used in the context of quantum science by researchers, teachers, students, and industry professionals. It covers the process of learning and studying quantum science and technologies, reviewing, and writing scientific and other papers, doing classical and quantum software development, conducting research ideation and collaborative research.

Part IV inventories the use cases of other types of machine learning-based tools in quantum science with research and technology developments in quantum physics and hardware, quantum software and tools and other domains like quantum sensing and quantum communications and cryptography.

Part V covers the potential use cases of quantum computing in machine learning applications including large language models. It also shows how quantum inspired algorithms can help reduce the computing and energetic footprint of classical machine learning solutions.

Part VII supplemental materials contain a wealth of prompts and results covering various fields of quantum science, including learning, summarizing the state of the art, listing figures of merits for technologies like single photon sources and detectors, circulators, traveling wave parametric amplifiers, analyzing a paper, producing a position paper, and creating a quiz.

Part IX contains an extensive bibliography for readers willing to dig into the way LLMs and their tools operate.

The intended audience of this paper is students, researchers and professionals in the broad quantum science and technology ecosystem who have a limited knowledge and understanding of machine learning and particularly, large language models chatbots. A preliminary understanding of machine learning and neural network basics is however a plus here[2].

II. LLM-BASED CHATBOTS PRIMER

Generative AI refers to a subset of artificial intelligence algorithms and technologies that create new content of various formats (texts, images, 3D models or even humans, videos, music, software code, molecules, etc.), based on the patterns and information learned from large datasets, and with existing content of the same type (e.g., for responding to a text question by a text answer) or of different types (e.g., creating some image or video based on a text specification). This differs from other machine learning models that are focused on labelling, clustering, or interpreting data and making various predictions not in relation with media content creation (e.g., forecasting sales and inventory, or planning a robot movement)[3].

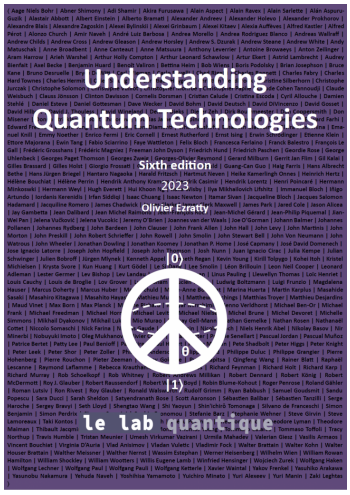
Generative AI tools make use of deep learning neural networks models that are trained on vast amounts of data, allowing them to implicitly understand patterns and structures within the training data. Once trained, these models generate new content extrapolated from existing content. Three well-known generative AI tools are large language models based on transformers like OpenAI GPT (Generative Pre-trained Transformer), which generates human-like text in chatbots, GANs (Generative Adversarial Networks) and VAE (Variational Autoencoders), which create realistic images, videos, and mimic under various constraints (using a given style, changing its format, filling voids, adding bokeh to a picture background, etc.), with applications in verticals like healthcare[4] and artistic creation. These models can produce content not explicitly programmed in the model but by understanding the data they were trained on[5].

Generative AI applications include the transformation of existing content (improving image resolution, converting them from monochrome to color, making people younger or older, creating new music) or the generation of content using content of different types (creating a text description of an image, creating an image based on its description, creating videos and sound of a person based on a text script, turning a sketch into a picture or even a 3D model, etc.). We will differentiate here the generative AI algorithms and models from the products which are using it.

LLM features

As of January 2024, the most popular generalist large language models-based chatbots were ChatGPT 4.0 ($20/month subscription[6 7]), Google Bard (free[8]) and Llama2 from Meta (free). Other such tools include Claude 2 from Anthropic but its regular access is limited to US and UK users. These tools use language models based on the transformer neural network model, which was invented in 2017 by a Google AI team[9]. To clarify the LLM terminology, ChatGPT 4.0 is a chatbot product that is using a language model, GPT-4, and other software tools and generative AI models like DALL-E which generates images based on their text description. Google Bard is based on the PaLM2 language model, and soon its Gemini successor.

- L'ebook **Understanding Quantum Technologies**, sixième édition, publiée en septembre 2024, 1366 pages. Toujours en anglais et sans version française. Une version simplifiée de 24 pages est aussi disponible.



- L'essai **Where are we heading with NISQ?** (50 pages, publié en mai 2023) qui fait le point des ordinateurs quantiques à qubits bruités, leurs applications et leur devenir.

Where are we heading with NISQ?

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In 2017, John Preskill defined Noisy Intermediate Scale Quantum (NISQ) computers as an intermediate step on the road to large scale error corrected fault-tolerant quantum computers (FTQC). The NISQ regime corresponds to noisy qubit quantum computers with the potential to solve actual problems of some commercial value faster than conventional supercomputers, or consuming less energy. Now, over five years on, it is a good time to review the situation. While rapid progress is being made with quantum hardware and algorithms, and many recent experimental demonstrations using fewer than 50 qubits, no one has yet successfully implemented a use case matching the original definition of the NISQ regime. This paper investigates the space, fidelity and time resources of various NISQ algorithms and highlights several contradictions between NISQ requirements and actual as well as future quantum hardware capabilities. Crucially, either two-qubit gate errors are still around the 0.1%-1% range (with superconducting qubits) or their number capping under 50 (with trapped ion qubits), which limits experiments to rather small algorithms instances that can easily be classically emulated. It then covers various techniques which could help like qubit fidelities improvements, various brands of quantum error mitigation methods, analog-digital hybridization, using specific qubit types like multimode photons as well as quantum annealers and analog quantum computers (sic: quantum simulators or programmable Hamiltonian emulators) which seem closer to delivering useful applications although they have their own mid to longer-term scalability challenges. Given all the constraints of these various solutions, it seems possible to expect some practical use cases for NISQ systems, but with a very narrow window before various scaling issues show up. Turning to the future, a scenario can be envisioned where NISQ will not necessarily be an intermediate step on the road to FTQC. Instead, the two may develop along different paths, due to their different requirements. NISQ requires a laudred or so qubits with gate fidelities well above 99.99% to outperform conventional supercomputers in speed or in energy efficiency, while FTQC accepts lesser gate fidelities, around 99.9%, but requires millions of qubits and very long range entanglement capabilities. This leaves open a key question on the trade-offs that may be necessary to make between qubit scale and qubit fidelities in future quantum computers designs.

CONTENTS

I. INTRODUCTION

The NISQ era was first defined by John Preskill in his keynote address at the first Q2B conference from QC Ware in California in December 2017 and laid out in a paper published in Quantum in 2018[1]. He then said that "*Quantum computers with 50-100 qubits may be able to perform tasks which surpass the capabilities of today's classical digital computers, but noise in quantum gates will limit the size of quantum circuits that can be executed reliably […]. I made up a word: NISQ. This stands for Noisy Intermediate-Scale Quantum. Here "intermediate scale" refers to the size of quantum computers which will be available in the next few years, with a number of qubits ranging from 50 to a few hundred […]. With these noisy devices we don't expect to be able to execute a circuit that contains many more than about 1000 gates*". We have a definition for hardware with over 50 qubits to obtain some potential space related quantum advantage vs classical computers and shallow algorithms that are tolerant to the noise generated during qubit initialization, qubit gates and qubit measurement.

John Preskill added that, generally speaking and beyond NISQ, "*Arguably, though, quantum technology might be preferred even if classical supercomputers run faster, if for example the quantum hardware has lower cost and lower power consumption*". This last part has not been much investigated so far. Most scientific papers published on NISQ algorithms are dealing with some form of computational advantage but not with other kinds of advantages that are more economical in nature, and particularly pertaining to their energetic footprint. Indeed, work must be done to find situations where NISQ systems may someday generate similar results than best-in-class supercomputers or HPC's algorithms, not necessarily faster but, with a lower energy consumption.

NISQ algorithms classes

The best known quantum algorithms suitable for NISQ systems belong to the broad variational quantum algorithms (VQA) class[2]. Given existing and near future qubit gate fidelities, these algorithms quantum circuits should have a shallow depth, meaning a small number of qubit gate cycles, preferably under 10. This class includes VQE (variational quantum eigensolver[3] [4]), for quantum physics simulations, QAOA (quantum approximate optimization algorithm[5]) for various optimizations tasks, VQLS (variational quantum linear solvers[6]) to solve linear equations and QML (quantum machine learning) for various machine learning and deep learning use cases.

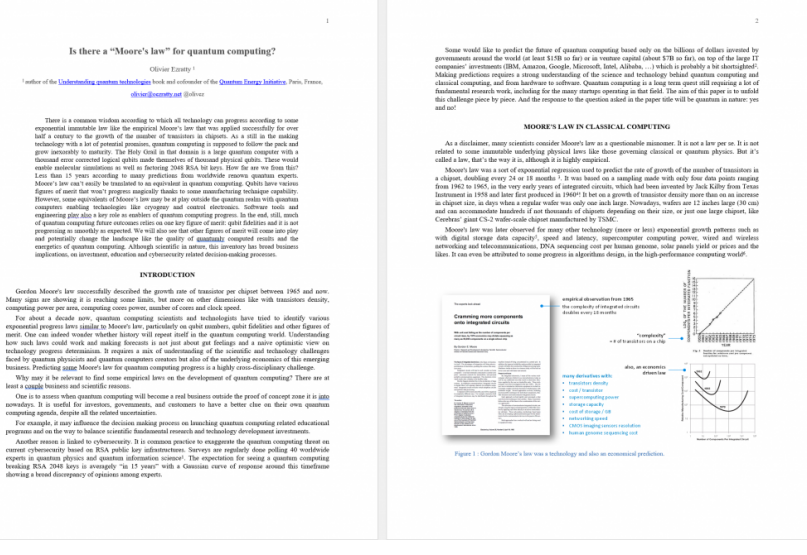
These are most of the time heuristic algorithms that determine near-optimal solutions to various forms of optimization problems. VQE, QAOA and QML being all various breeds of optimization problems to find energy or cost function minima. Variational algorithms are hybrid by design with a very significant part being implemented in a classical computer, a part that is itself a NP-hard class problem that scales exponentially with the input size[7].

Totally outside the NISQ relevant algorithms class are unique and discrete log factoring algorithms (the most known ones coming from Peter Shor in 1994), oracle based search algorithm (like Grover[8] and Simon algorithms), and all algorithms relying on a quantum Fourier transform, including HHL for linear algebra and many partial derivative equations (PDE) solver algorithms. All these algorithms require a fault-tolerant quantum computing (FTQC) architecture, noticeably since, given a number of qubits, typical FTQC gate-based algorithms have a computing depth that grows up on a quasi-polynomial scale with the number of qubits.

In the space and speed domains, a quantum advantage requires at least from 50 to 100 physical qubits. The space and speed domains advantages are however distinct. There are situations where some speedup could be obtained with qubits in the 30-50 range, at least when comparing a QPU with perfect qubits, fast gates and a classical server cluster executing the same code in emulation mode[9], which is usually not the best-in-class equivalent classical solution. Under 18 qubits, it is even recommended to use a local quantum code emulator[10]. It is not only cheaper, but faster and convenient since your computing job is not placed on a potentially long waiting list and you do not have to pay for expensive cloud QPU (quantum processing unit) resources access. A laptop, a single cloud server or server cluster is always cheaper than a quantum computer in that case. As a reference, we propose a taxonomy of various quantum advantages in Figure 29, page 32 in this paper, including space, speed, quality, energetic and cost.

Thus far, most NISQ experiments have been run with fewer than 30 qubits. While they are elegant proofs of concepts, they do not yet demonstrate any speed up over classical computing, meaning they are not yet in the NISQ regime as defined by John Preskill and listed in Figure 1.

- L'essai **Is there a Moore's law for quantum computing?** (32 pages, publié en mars 2023) qui pose la question de l'éventuelle existence d'une loi de Moore pour l'augmentation de la puissance des ordinateurs quantiques. La réponse est normande : cela dépend des indicateurs !



Is there a "Moore's law" for quantum computing?

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There is a common wisdom according to which all technology can progress according to some exponential immutable law like the empirical Moore's law that was applied successfully for over half a century to the growth of the number of transistors in chipsets. As a still in the making technology with a lot of potential promises, quantum computing is supposed to follow the pack and grow inexorably to maturity. The Holy Grail in that domain is a large quantum computer with a thousand error corrected logical qubits made themselves of thousand physical qubits. These would enable molecular simulations as well as factoring 2048 RSA bit keys. How far are we from this? Less than 15 years according to many predictions from worldwide renown quantum experts. Moore's law can't easily be translated to an equivalent in quantum computing. Qubits have various figures of merit that won't progress magically thanks to some manufacturing technique capability. However, some equivalents of Moore's law may be at play outside the quantum realm with quantum computers enabling technologies like cryogeny and control electronics. Software tools and engineering play also a key role as enablers of quantum computing progress. In the end, still, much of quantum computing future outcomes relies on our key figure of merit: qubit fidelities and it is not progressing so smoothly as expected. We will also see that other figures of merit will come into play and potentially change the landscape like the quality of quantum computed results and the energetics of quantum computing. Although scientific in nature, this inventory has broad business implications, on investment, education and cybersecurity related decision-making processes.

INTRODUCTION

Gordon Moore's law successfully described the growth rate of transistor per chipset between 1965 and now. Many signs are showing it is reaching some limits, but more on other dimensions like with transistors density, computing power per area, computing costs power, number of cores and clock speed.

For about a decade now, quantum computing scientists and technologists have tried to identify various exponential progress laws similar to Moore's law, particularly on qubit numbers, qubit fidelities and other figures of merit. One can indeed wonder whether history will repeat itself in the quantum computing world. Understanding how such laws could work and making forecasts is not just about gut feelings and a naive optimistic view on technology progress determinism. It requires a mix of understanding of the scientific and technology challenges faced by quantum physicists and quantum computers creators but also of the underlying economics of this emerging business. Predicting some Moore's law for quantum computing progress is a highly cross-disciplinary challenge.

Why may it be relevant to find some empirical laws on the development of quantum computing? There are at least a couple business and scientific reasons.

One is to assess when quantum computing will become a real business outside the proof of concept zone it is into nowadays. It is useful for investors, governments, and customers to have a better clue on their own quantum computing agenda, despite all the related uncertainties.

For example, it may influence the decision making process on launching quantum computing related educational programs and on the way to balance scientific fundamental research and technology development investments.

Another reason is linked to cybersecurity. It is common practice to exaggerate the quantum computing threat on current cybersecurity based on RSA public key infrastructures. Surveys are regularly done polling 40 worldwide experts in quantum physics and quantum information science[2]. The expectation for seeing a quantum computing breaking RSA 2048 keys is averagely "in 15 years" with a Gaussian curve of response around this timeframe showing a broad discrepancy of opinions among experts.

MOORE'S LAW IN CLASSICAL COMPUTING

As a disclaimer, many scientists consider Moore's law as a questionable misnomer. It is not a law per se. It is not related to some immutable underlying physical laws like those governing classical or quantum physics. But it's called a law, that's the way it is, although it is highly empirical.

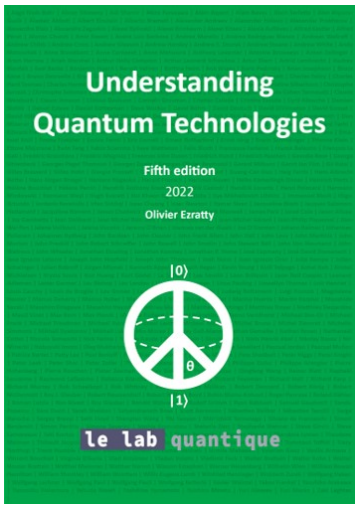
Moore's law was a sort of exponential regression used to predict the rate of growth of the number of transistors in a chipset, doubling every 24 or 18 months [3]. It was based on a sampling made with only four data points ranging from 1962 to 1965, in the very early years of integrated circuits, which had been invented by Jack Kilby from Texas Instrument in 1958 and later first produced in 1960[4] It bet on a growth of transistor density more than on an increase in chipset size, in days when a regular wafer was only one inch large. Nowadays, wafers are 12 inches large (30 cm) and can accommodate hundreds if not thousands of chipsets depending on their size, or just one large chipset, like Cerebras' giant CS-2 wafer-scale chipset manufactured by TSMC.

Moore's law was later observed for many other technology (more or less) exponential growth patterns such as with digital storage data capacity[5], speed and latency, supercomputer computing power, wired and wireless networking and telecommunications, DNA sequencing cost per human genome, solar panels yield or prices and the likes. It can even be attributed to some progress in algorithms design, in the high-performance computing world[6].

Figure 1 : Gordon Moore's law was a technology and also an economical prediction.

- L'ebook **Understanding Quantum Technologies**, cinquième édition, publiée en septembre 2022, 1128

pages. C’est la mise à jour de la quatrième édition, toujours en anglais et sans version française. Une version simplifiée de 24 pages est aussi **disponible**.



- L’essai **Mitigating the quantum hype** (24 pages, février 2022) qui fait le point sur la “hype” du calcul quantique et sur les moyens d’en limiter les effets négatifs.


Mitigating the quantum hype

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We are in the midst of quantum hype with some excessive claims of quantum computing potential, many vendors’ and even some research organizations’ exaggerations, and a funding frenzy for very low technology readiness level startups. Governments are contributing to this hype with their large quantum initiatives and their technology sovereignty aspirations. Technology hypes are not bad per se since they create emulation, drive innovations and also contribute to attracting new talents. It works as scientists and vendors deliver progress and innovation on a continuous basis after a so-called peak of expectations. It fails with exaggerated overpromises and underdeliverons that last too long. It can cut short research and innovation funding in the mid to long term. After looking at the shape and form of technology and science hype and driving some lessons from past technology hypes, we investigate the current quantum hype and its specifics. We find that, although there is some significant uncertainty on the potential to create real scalable quantum computers, the scientific and vendor fields are relatively sane and solid compared to other technology hypes. The vendors hype has some profound and potentially positive impact on the organization of fundamental research. Also, quantum technologies comprise other fields like quantum telecommunications and quantum sensing with a higher technology readiness level, which are less prone to hype. We then make some proposals to mitigate the potential negative effects of the current quantum hype including recommendations on scientific communication to strengthen the trust in quantum science, vendor behavior improvements, benchmarking methodologies, public education and putting in place a responsible research and innovation approach.

INTRODUCTION

Artificial intelligence specialists who have been through its last “winter” in the late 1980s and early 1990s keep saying that quantum computing, if not quantum technologies on a broader scale, are bound for the same fate: a drastic cut in public research spendings and innovation funding. Their assumption is based on observing quantum technology vendors and even researchers overhype, on a series of oversold and unkept promises in quantum computing and on the perceived slow improvement pace of the domain.

The quantum race launched by many governments, particularly with the USA, China, and other developed countries in between is also artificially fueling this trend, fed by “technology sovereignty” concerns. The recent large funding rounds of leading startups like IonQ, PsiQuantum and Rigetti contributed to entertain this overhyper perception. Some go as far - way too far - with arguing that quantum computing is a scam created by scientists who found a way to get funding for their research ventures.

Trying to stage a balanced view, this paper describes the shape and form of this quantum hype and what are its similarities and differences with other digital era hypes like symbolic artificial intelligence, 3D television, consumer 3D printing, virtual and augmented reality, Blockchain and crypto-currencies as well as with other science related hypes. It proposes some insights and code of conduct for the quantum ecosystem that would avoid the pitfalls of the current quantum hype while keeping the benefits of a vibrant scientific and technology ecosystem. It also builds on and complements earlier work by science philosophers in the field of quantum ethics and responsible innovation[2].

Quantum fundamental research has been active since 1900 with Planck’s fundamental discovery of the energy quanta. Since then, the only sluggish period was World War II when American and German scientists like Enrico Fermi and Werner Heisenberg were mobilized on nuclear physics[3]. It enabled the creation of the first nuclear bombs and their unfortunate usage. It was one the several cases where innovation was not synonymous with progress, creating a philosophical chasm between science and society. This “crisis of science” still resonates with scientists.

The industry payback of quantum physics research came with the transistor invention in 1947, the laser in the early 1960s, and many other technology feats (TVs, LEDs, GPS, ...) leading to the “first quantum revolution” based digital era we are enjoying today.

The “second quantum revolution” era deals with controlling individual quantum objects (atoms, electrons, photons) and using superposition and entanglement. The early 1980s were defining moments with Yuri Manin and Richard Feynman expressing their ideas to create respectively gate-based quantum computers and quantum simulators (in 1980 and 1981) and then, with Alain Aspect *et al* underlining their famous 1982 Bell inequalities violation experiment using distant entangled photons[4].

We are now 40 years ahead, and even though quantum science advances have been continuous, usable quantum computers offering a quantum advantage compared with classical computers are not there yet and this can be the source of some impatience[5]. However, three other technologies related to quantum revolution 1 are alive and well: quantum telecommunications, cryptography and sensing. To some extent, the latter is well under-hyped.


2

HYPE ONTOLOGY

Hype is a term referring to over mediatization and inflated, excessive or misleading claims that are applicable to particular products, products categories, technology trends, scientific domains, personalities like artists or politicians, and even speculative financial bubbles and scams[7]. Hype characterizations range from broad societal phenomena to explicit, well thought-out and planned marketing strategies. It can be confused with marketing exaggerations which are among its implementation artefacts. On the other hand, buzz is a quiet way to disseminate promotional content, before it gets amplified by hype.

Hype existed way before the Internet but nowadays can be orchestrated by leveraging social media to amplify their effects[8]. As a marketing strategy, hype can be applied in various fields like in fashion to promote new styles and brands. It can even be based on creating artificial scarcity or fake strong demand. Also, many old Ponzi financial schemes were created with hype development mechanisms.

Science and technology hypes

Scientific and technology hypes do not involve the same stakeholders as fashion, financial and politics hypes. They deal a lot with how the scientific community, the industry and society interact with each other in an unorganized fashion. As we get closer to the commercial world, business and financial values and systems are becoming powerful hype echo chambers.

Technology hypes are not bad per se[9]. It depends on their scale and how self-fulfilling promises are delivered. Hypes drive research, invention and innovation on a global basis[10]. Their main use case is to attract government and private sector funding. They can indirectly help make progress with science and make the field attractive to new talent. And unlike Gene Kranz’s famous quote, failure is an option. No failure would mean that not enough scientific and technology avenues were investigated. The field of quantum technologies is probably exemplifying this phenomenon with a sheer diversity of pursued technology options, and not just with the many quantum computing qubit types that are investigated.

Scientific hype can also happen way before it enters the entrepreneurial and commercial scene, when various positive or beneficial aspects of science are inappropriately exaggerated and sensationalized, with the caveat that evaluation appropriateness relies on value judgements[6]. Hype can show up first in scientific papers’ titles created by research labs communicators[11]. This frequently happens in life science with the past examples of pluripotent stem cells and cancer curing monoclonal antibodies[12]. This can be driven by the way researchers are funded and rewarded in most countries. Technology vendors are indeed not the only ones competing with each other for funding. Science is also a very competitive field, where visibility, recognition, careers as well as public and private funding are at stake.

The hype can then be amplified when science communication and academic publishing is translated in layman’s terms in news media[13]. It can also be a side effect of papers being published on pre-print servers like Arxiv, without being peer reviewed although most scientific papers benefit from some media visibility after they are published in peer-reviewed publications.

Hype emotions and irrationality

Science and technology hype is a field of collision between, on one hand, information streams stoking emotions and irrationality, and on the other hand scientific, technologic and even business rationality. It builds on strong beliefs in science driven progress and on the confusion between laboratory experiments and production-grade solutions. Hype goes way beyond a mere classical build-up of rational expectations and a societal contract on the required investments needed to deliver value[14].

Emotionally, hype drives hope, envy and fear. Hope of solving key problems like with healthcare or climate change. Envy and fear of missing out on becoming wealthy (FOMO) for entrepreneurs and investors, or, for governments, of being overpowered by another country. Lastly, fear of losing competitiveness or missing business opportunities for corporations.

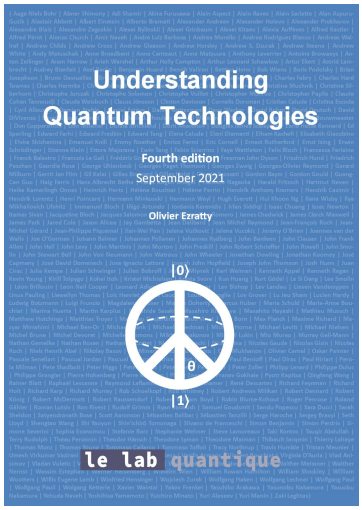
Hype related emotions are also easier to manipulate given the ignorance by its various target audiences of the various scientific or technology obstacles in creating actual solutions. It can build on magical thinking and occasionally use science-fiction references[15].

Gartner hype curve model

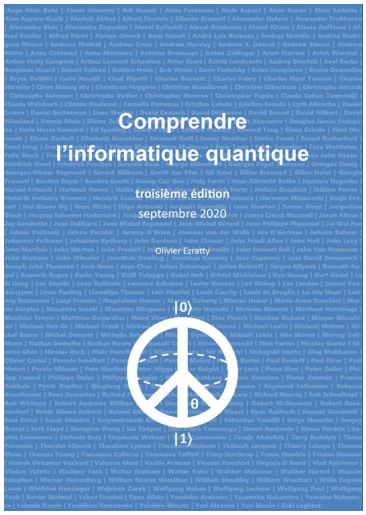
Technology hypes were practically defined by the Gartner Group with its famous hype curve model, created in 1995[16]. It tries to capture new technologies’ visibility and success cycles in some predictive way. The model uses a non-linear curve with unscaled time in X and visibility or expectations in Y. After a new technology appearance trigger, the first peak of visibility corresponds to a hype-driven “peak of inflated expectations” when some highly positive buzz is amplified by news media, frequently at the border line of magical thinking. This buzz can be created and fed by a variable mix of scientists, analysts, consultants, influencers, entrepreneurs, corporations and sometimes, governments themselves. This is where we are right now with quantum computing as shown in Figure 1.

Then, if and when over-expectations are not matched by actual technology capacities and benefits, trust vanishes in a “trough of disillusionment” with negative news coverage and an overall lack of confidence in the technology and its creators. This gap between expectations and the actual delivery capabilities of science and technology can drive disinvestments in the related science or technology, similarly to what happened with artificial intelligence during its two winters in the early 1970s and 1990s. It can also

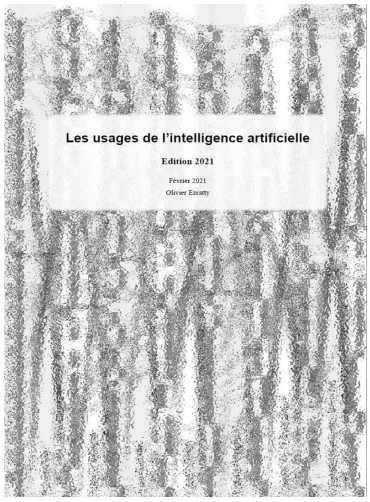
- L’ebook **Understanding Quantum Technologies**, quatrième édition, publiée en septembre 2021, 836 pages. C’est la mise à jour de la troisième édition, passée en anglais et sans version française.



- L’ebook **Comprendre l’informatique quantique**, troisième édition, publiée en septembre 2020, 682 pages, les deux premières datant de septembre 2018 et septembre 2019. C’est un condensé unique et complet qui fait un tour d’horizon très large des enjeux scientifiques, technologiques, industriels, géopolitiques et sociétaux de l’informatique quantique.

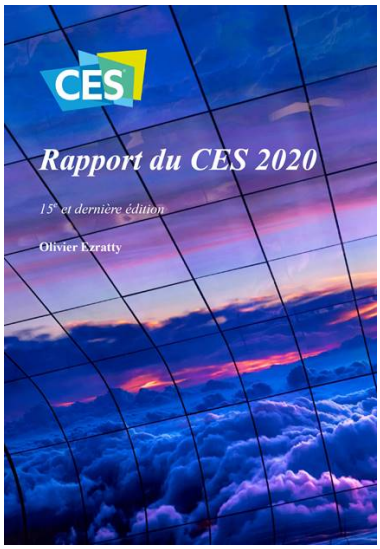


- L’ebook **Les usages de l’intelligence artificielle 2021**, en février 2021, 742 pages, une grosse mise à jour des éditions de 2017, 2018 et 2019.

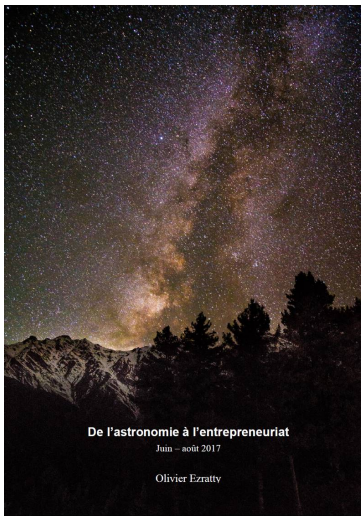


- Le **Guide des Startups 2019**, 23e édition, en avril 2019, 548 pages. C’est la dernière édition en date de 2022.

- Le **Rapport du CES 2020**, publié en janvier 2020, de 366 pages, le dernier d'une série lancée en 2006.

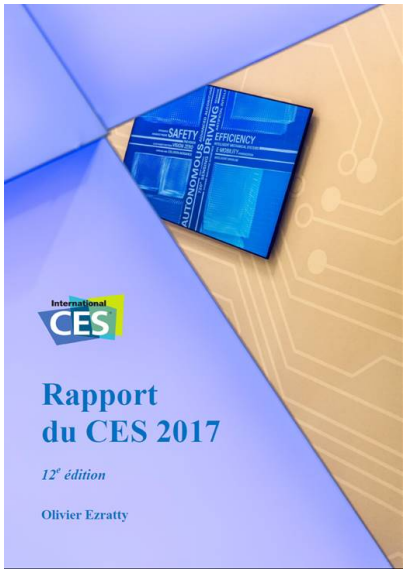


- Une compilation de 12 articles sur **l'astronomie et l'entrepreneuriat** publiée en août 2017 sous forme d'un ebook. Elle est focalisée sur la découverte des instruments d'observation de l'Univers, les télescopes spatiaux et terrestres ainsi que les radiotélescopes, puis sur les entrepreneurs qui s'intéressent à la conquête spatiale.



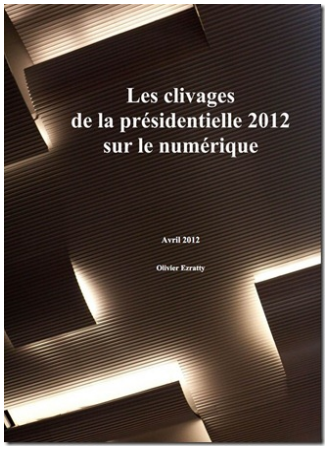
- J’ai rédigé la préface de “**Objets Connecté – La nouvelle révolution numérique**“, un livre paru en février 2016 aux éditions ENI et écrit par Renaud Acas, Eric Barquisseau, Yves-Marie Boulvert, Frédéric Dosquet, Eric Dosquet et Jérémy Pirotte.

- Le **Rapport du CES 2017**, publié en janvier 2017. 396 pages, dans la lignée des rapports précédents.



- “**Tout tout tout sur la high-tech**“, publié aux éditions Kawa. Il s’agit de la version “livre” du Rapport du CES 2013.

- Une contribution sur le thème des blogs et celui des réseaux sociaux dans le **Dictionnaire Politique de l'Internet et du Numérique**, un ouvrage collectif paru en 2009 et diffusé par La Tribune.
- Le **Rapport du CES 2013**, publié en janvier 2013. 272 pages.
- Le **Rapport du CES 2012**, publié en janvier 2012. 244 pages.
- Le **Rapport du CES 2011**, publié en janvier 2011. 246 pages.
- Le **Rapport du CES 2010**, publié en janvier 2010. 204 pages.
- Le **Rapport du CES 2009**, publié en janvier 2009. 192 pages.
- Le **Rapport du CES 2008**, publié en janvier 2008. Ce document de 178 pages dresse un panorama très complet des technologies présentées au CES et lancées pendant l'année 2007.
- Le **Rapport du CES 2007**, publié en janvier 2007. Ce document de 164 pages avec 435 illustrations fait le tour des nouveautés présentées au CES et de l'année 2006.
- Le **Rapport du CES 2006**, publié en février/mars 2006 qui décrit les grandes tendances de ce salon. J'y décris également la présence française sur ce salon et les leçons que l'on peut en tirer.
- Le livre blanc sur **Les opportunités de la télévision numérique** qui fait un point sur ce secteur d'activité et particulier sur le développement de l'IPTV. Il met en évidence les bouleversements en cours de la chaine de valeur de ce secteur et propose quelques pistes d'actions pour l'industrie française.
- Les **clivages de la présidentielle 2012 sur le numérique**, un recueil d'une série de six articles au format PDF sur la manière dont les candidats à la présidentielle 2012 ont traité le thème du numérique. Le document traité également des propositions des professionnels du secteur et fournit quelques pistes de solutions à différents problèmes notamment au sujet de l'entrepreneuriat et de l'enseignement supérieur.



- Un **panorama des logiciels photo** qui reprend et complète une série de sept articles publiés en septembre 2008 sur les logiciels et services en ligne dédiés au traitement de la photo numérique.

- Un ensemble de propositions pour les Assises du Numérique "**Développer l'entrepreneuriat et faire réussir les startups dans les TICs**" publié en juillet 2008. C'est un document conçu de manière collective avec un grand nombre de contributeurs, cités dans la couverture.
- Un essai comparant **Google et Microsoft**, dans leurs stratégies de croissance, les effets de leur taille, leur relation au marché et à leur écosystème.
- Un **Trop d'Etat – Oui mais où ça?**, un essai publié en mars 2007 analysant les dépenses du secteur public dans son ensemble et tentant d'identifier où des économies ou redéploiements pourraient être réalisés.
- La coordination d'un numéro spécial "Opportunités de l'industries informatique en France" de la revue Centraliens (des anciens élèves de l'Ecole Centrale Paris) paru en juin 2006 et dont l'un des articles est disponible sur ce blog: l'**interview de Bernard Liautaud** de Business Objects.
- Une série d'articles sur le thème "Décrypter Microsoft" publiés dans la revue **DecisionMakers IT**, le premier étant dédié aux **programmes partenaires** de l'éditeur.
- Un **comparatif de lecteurs RSS** sous forme de tableau commenté associé à **ce post**.
- Un **Compte-rendu d'installation de Windows Vista**, datant de novembre 2006.
- Une étude de cas sur "**Le défi de l'innovation dans Windows**", publiée à l'occasion d'une présentation

réalisée aux Entretiens de la Technologie de Louis le Grand organisés par l'Institut de l'Entreprise en août 2005. Je l'ai faite pour le compte de Microsoft France.