ARTIFICIAL INTELLIGENCE

& ENVIRONMENTAL PROTECTION

THE PARADOX OF AN ENERGY-CONSUMING TECHNOLOGY
SERVING THE ECOLOGICAL CHALLENGES OF TOMORROW

PREFACE MYRIAM MAESTRONI

Open.
Studio

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Preface

Myriam Maestroni

Founder of Economie d'Energie
President of the E5T Endowment Fund (www.e5t.fr)

First of all, I would like to share how happy and honoured I was to be one of the first readers of this white paper and, a fortiori, to be entrusted with the task of prefacing it.

There are at least four different good reasons why I accepted and enjoyed reflecting on this innovative approach which, from the very title of the book, lays the foundations for a theme at the heart of current events and orientations aimed at building a post-carbon world: artificial intelligence and environment.

The first is to be able to pay tribute to the talent, work, perseverance and experience, patiently accumulated over the years, of Arnault Pachot, who is the author. I met Arnault a long time ago and, in any case, long before we could imagine that we would be able to - and today we should probably say that we have to - combine energy transition with digital transition, on the one hand, and to start talking about the role of Artificial Intelligence (AI) and the link with the environment, on the other hand. We are still in a phase where these associations are only nascent. Courage and commitment were needed to tackle this matter. Nowadays, it is rare enough to find professionals who have the time and energy to engage in research, so that I feel it appropriate to mention it in my initial remarks. Arnault Pachot is indeed a conscientious entrepreneur, open

to the culture of teamwork, concerned about his collaborators, and, above all, he has contributed to the development over the years, in Le Puy-en-Velay, of a remarkable company, OpenStudio, which has been able to create new world jobs in the heart of an area known more for its history and gastronomy than for its ability to write chapters in the great book of the new economy. I know that Arnault's work will resonate with and inspire his associates, colleagues, collaborators and clients, and thus become a stone in the edifice of contributions, actions and solutions that are underway to accelerate the logic of renewal in a world that will either be post-carbon or will not be.

The second reason is that this white paper is based on numerous experiences of remarkable personalities in the still almost new field of Artificial Intelligence. In each testimony we can feel a deep reflection, a will to be accurate in a field which is rapidly progressing, and which challenges us to generate new resources by pushing our usual ways of thinking outside their comfort zones. So, at such points we need to feel guided by people who know what they are talking about. This is why I think it is important to also pay tribute to the contributors to this white paper who have redoubled their efforts to make accessible the keys to a future that will be written in alphabets other than those we are familiar with. The testimonies and decipherments are clear, inspiring and sincere. Scientific objectivity seems to be required and this leaves a critical space to expose the limits, including the data centres' energy consumption, the problem of essential rare metals, the electronic waste that is piling up and the rebound effects. I am used to repeating, always convinced of the virtues of positive psychology, that a problem well posed is half solved... So if we have not identified all the solutions, the keys to finding

ways of combining the benefits of these new resources without having to pay a high price will be part of the equation, which still has some unknowns. Thank you to all the experts and researchers for accompanying us into the terra incognita, bearing in mind the Rabelaisian lesson, which is more relevant than ever, that "science without conscience is only ruin of the soul".

The third reason relates to the issue of environment, which this book gives a place of honour to. Throughout my professional career, which has taken me from the oil and gas sector, representatives of the old world, to energy efficiency and, more broadly, the energy transition, I have never lost sight of the issue of environment, or rather of the relationship that we, as human beings, have with nature and our planet. I started long ago, since in the early 90s I found myself having to take into account the hole in the ozone layer, which was then considered a high-priority environmental issue. This introduction however did not prepare me at all for the way in which global warming, barely mentioned at the time in a few very advanced expert circles, was going to disrupt our daily lives, and especially within such a short timeframe. I began to understand at the very beginning of the 2000s. We remember indeed that the extent of the problem was taken into account barely in the mid-2000s with Al Gore's documentary film, An Inconvenient Truth. At that time, we reached a 'tipping point', a point of no return that made us realise that we were becoming, and would become every day more, the executioners, victims and, potentially, saviours of the conditions that make the miracle of life on Earth possible. From that moment on, we took it to the next level of consciousness, understanding that our primary relationship with the world was linked to our ability to breathe a rare and

precious mixture of oxygen, which contained other invisible chemical components, sometimes beneficial to our health and sometimes, often, too often, harmful, and to the presence of natural water.

We understood that the Earth was a reality in perpetual motion. The lines of our world were constantly being reshaped, with coasts retracing their course, islands appearing, others disappearing, seas drying up, forests narrowing, deserts spreading out... to name only a few examples. We discovered that the excess of CO_2 and other greenhouse gases, which were accumulating as a result of the burning of fossil fuels, were creating the now well-known greenhouse effect, which is responsible for global warming. We realised, and paid a high price, that this warming was intensifying with increasingly frequent and violent climatic events: fires that were increasingly deadly and difficult to contain, devastating floods, violent storms, hurricanes, cyclones, but also ocean acidification, melting polar ice caps, etc. We were discovering how much the suffering of our planet was affecting us, with victims of the 'human and animal kingdom' becoming more and more numerous and distressed, and the set of consequences this meant: homes destroyed, biodiversity, the first shield against zoonoses, damaged, water stress making life impossible in entire areas of the planet, extreme conditions with the mercury breaking new records year after year and cities reaching levels of over 75°C. We were beginning to remember that human life is an epiphenomenon of just over 200,000 years on a planet that is 4.5 billion years old... and that every day runs the risk of being erased. How can we ignore the environmental issue when we know what the challenge of correcting the trajectory of global warming and therefore the

Paris Agreements represents? We still talk too often about the digital transition or AI without addressing the interactions with the environment... for the worst that must be taken into account but also for the best...

By the way, the fourth reason is related to this last dimension. It is the role of digital technology in the fight against climate change, since it is part of the problem, but also of the solution. This idea is condensed in one of the book's statements, which is thought-provoking about useful versus futile digital technology. AI, which fascinates as much as it worries, is positioning itself on the green market, inventing playgrounds and organic labels. According to AI researcher Kai-Fu-Lee, "AI belongs to the very closed group of Technologies with a major impact, i.e. inventions that are destined to disrupt our economic system on a large scale, like electricity or ICTs. Thanks to its ability to learn models from data, AI is revolutionising the power of servers; the profusion of data collected and the availability of environmental data have led to spectacular applications in recent years.

Thus, this White Paper takes us on a journey through the 7 areas identified to date as the major targets of AI for Green: smart cities, energy efficiency, connected agriculture, climate change modelling, environmental protection, sustainable mobility, and finally local and sustainable economy.

As I got to know talented computer enthusiasts who are convinced of their art, I realised that beyond the geek, we were dealing with new sensibilities full of unknown resources. When my IT teams realised that I hadn't yet read The Hitchhiker's Guide to the Galaxy - poor me! -, they urged me to discover that

their way of taking care of our beautiful Earth was to assess its vulnerability and to consider how to help make it more habitable by using algorithms.

It is undoubtedly on this path that AI, so energy-intensive, is set in its environmental conservation paradox. This is the subject of debate and reflection that has been chosen as the basis for the work of this avant-garde study. There are many debates on artificial intelligence, sometimes defended and praised, sometimes criticised and decried. We are often perplexed by conflicts between experts who are sometimes incomprehensible and intellectuals who are often so convinced of their truth that it is difficult to appreciate the relevance of the many issues underlying this vast theme. It is known that AI has invaded our daily lives, sometimes in an insidious way, without us being completely aware of it, but it was very difficult to imagine it serving one of the greatest causes of humanity: the planet and life themselves. I look forward to this White Paper becoming a reference work in the field, and through the E5T Foundation, we will continue to be involved in exploring these new paths and how they will be applied more and more concretely in the various fields mentioned

Open.
Studio

This white paper was written by the teams of the company OpenStudio[1]. The company is positioned in the IT for Green sector and assists individuals with their energy renovation work. The platforms developed in partnership with the company Économie d'Énergie[2] have contributed to the completion of 600,000 energy renovation projects, saving over 21 million tonnes of CO2. Committed to open-source, OpenStudio develops the e-commerce platform Thelia[3], thus contributing for several years to a transparent digital environment accessible to the largest possible number. In 10 years, the company has completed more than 300 e-commerce projects. OpenStudio is a member of E5T Foundation[4] and Alliance GreenIT[5].

Furthermore, OpenStudio is also involved in the development of numerous digital platforms and has had its own AI laboratory since 2018.

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[1] http://www.openstudio.fr

[2] https://www.economiedenergie.fr

[3] http://www.thelia.net

[4] http://www.e5t.fr

[5] https://alliancegreenit.org

OpenStudio's Artificial Intelligence services

Our AI experts are able to assist our clients in many fields :

MARKETING
– customer segmentation,
– product recommendation

SECURITY
– fraud detection,
– malfunction detection,
– detection of duplicates in the databases,
– detection of fraudulent reviews

CUSTOMER RELATIONS
– chatbots,
– automatic mail processing

LOGISTICS
– returns management,
– optimisation of depreciated stocks,
– load forecast,
– optimisation of occupancy rate

BUSINESS INTELLIGENCE
– sales forecast,
– margin optimisation

INDUSTRY 4.0

Authors

Arnault Pachot, Manager

After studying mathematics and computer science, Arnault Pachot worked in several R&D departments in France and Canada, particularly on the topics of automatic document reading, 3D modelling and quality control using neural networks. In 2006, Arnault Pachot founded OpenStudio agency, specialised in the creation of web platforms and innovative e-commerce solutions. He holds an MBA from EM Lyon and is currently working on a thesis in Artificial Intelligence about recommendation systems at Clermont Auvergne University.

Céline Patissier, Journalist

Céline Patissier is a journalist specialising in radio and print media. She has written for a number of editorial offices before devoting herself to corporate communications. Her journalistic experience and natural curiosity allow her to write on all subjects. She has been putting her editorial versatility to work on OpenStudio projects since April 2020.

Contributors

Alexandre Alaimo

Barely out of his engineering studies, Alexandre Alaimo went straight into entrepreneurship with a very specific project: to market Odevia, his intelligent road traffic management tool. After two years spent in a business incubator to mature his project, his company Odeven was born in February 2019. Alexandre Alaimo is now project manager for OpenStudio and simultaneously continues to develop Odeven.

Adélaïde Albouy-Kissi

Adélaïde Albouy-Kissi is a lecturer in Applied Computer Science at Clermont Auvergne University, a researcher at the Institut Pascal and a teacher within the Le Puy-en-Velay IUT Computer Graphics Department. She is also involved in a research programme on productive resilience. Her objective is to create a decision-making tool to help relocate sustainable industry throughout France.

Contributors

Laurent Bernard

A professional engineer, Laurent Bernard launched Ecojoko in 2017 with Fabien Berlioz. Ecology is at the heart of their approach with a tool that uses AI to help individuals save electricity.

Aline Bsaibes

Aline Bsaibes has been working for ITK for more than 10 years, she took the helm of the company as Managing Director in September 2019. ITK's objective is to develop decision support software for all stakeholders in the agri-food value chain. Artificial intelligence solutions for a more sustainable and responsible agriculture.

Contributors

Vincent Courboulay

Vincent Courboulay is a lecturer and researcher at La Rochelle University, a digital project manager and co-founder of the Institut du Numérique Responsible [Institute for Digital Responsibility]. He stands up for a more sober use of digital technology in order to face up to the current ecological challenges.

Cédric Vasseur

A lecturer and trainer specialising in robotics and artificial intelligence, Cédric Vasseur has been passionate about new technologies since he was a child. Today, he gives conferences all over Europe on his two favourite subjects. One of his most notable projects is BeepAI, an artificial intelligence that learns to program by itself. He also participated in Cédric Villani's public consultation on the strategy for developing AI in France.

Contributors

Félix Michaud

While studying for a Master's degree in Bioacoustics at Le Mans University, Félix Michaud took part in research in the United States on the return of biodiversity in an abandoned production site. This ecology enthusiast, now a doctoral student at Sorbonne, had to learn all about Artificial Intelligence in order to complete this project.

Andréas Von Kaenel

Co-founder of the Swiss start-up Cortexia with André Droux, Andréas Von Kaenel's mission is to rationalise the cleaning of our cities using Artificial Intelligence. The cities of Geneva and Basel have already called on Cortexia's services.
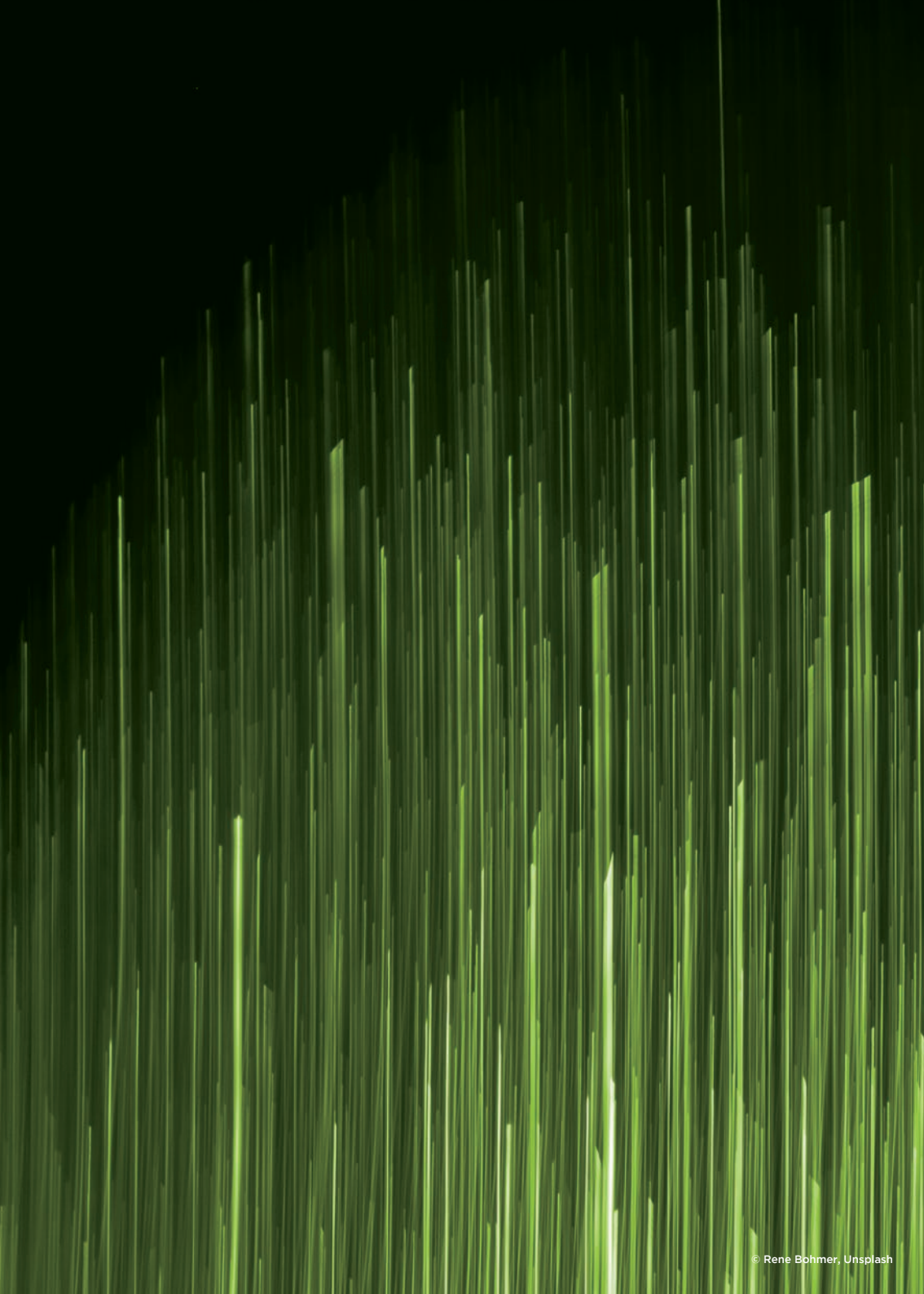
Introduction

Artificial Intelligence fascinates as much as it worries.

The computing times required for new architectures such as deep learning[1] have increased by a factor of 300,000 in 6 years[2]. The high computing power needed requires a large amount of energy, which increases the already negative impact of the digital industry on the environment. Voices are being raised to warn of the ecological disaster of AI.

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[1] *Deep learning is based on complex, multi-layered neural network architectures. AI expert Kai-Fu-Lee defines deep learning as "algorithms that use huge volumes of data collected in a particular field in order to make the best decision for the purpose. They do this by training themselves to recognise deeply buried recurring patterns, as well as correlations between the many values and the question being asked."*

[2] *https://openai.com/blog/ai-and-compute/*

[3] *https://www.liberation.fr/debats/2019/10/15/le-big-data-ne-sauvera-pas-la-planete_1757672*

Yet this technology is also very promising. By giving it an ecological framework, AI opens the door to new applications. In recent years, the use of AI for environmental conservation has been developing in all fields. By offering the possibility of analysing large volumes of data, AI opens up a way of optimising natural resources and understanding our ecosystem[17]. In the areas we have analysed, AI complements traditional software tools to solve much more complex issues.

AI learns from its mistakes to become better at interpreting a multitude of weak signals within a contextualised data set. This ability to learn is fascinating because it takes us back to our own learning processes.

The potential of AI

According to AI researcher Kai-Fu-Lee, AI belongs to the very closed group of General-Purpose Technologies[13]. These are major inventions that will transform our economic system on a large scale, like electricity or ICT.

AI's ability to learn patterns from data is revolutionising the world of software. The power of servers, the profusion of data collected, and the liberation of environmental data4 have led to spectacular applications in recent years. In the first part of this book, we present a brief history of AI, its operating principles, and its greatest successes. To complement this part, we have gathered the inspiring vision of Cédric Vasseur, who is a lecturer and AI enthusiast.

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4 *www.data.gouv.fr/fr/topics/logement-developpement-durable-et-energie/*

Hopes for environment stemming from AI

AI offers us tools to better understand our environment. Thanks to sensor data and the availability of public data catalogues, new learning systems have access to the volume of data they need to operate. They are able to identify information within a large volume of data and thus offer new analytical capabilities.

In this book, we make a general survey of projects using AI for environmental conservation. These are often innovative projects that break with traditional approaches in their sector. The new "AI for Green"[5] market tends to specialise into seven main themes that we identified: smart cities, energy saving, connected agriculture, climate change modelling, environmental preservation, sustainable mobility, and local and sustainable economy.

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[5] *Term given to applications using AI to solve environmental issues.*

We went to meet the actors of this change. In this book, you will discover the testimony of Aline Bsaibes, who has taken over the management of a leading company in AG Tech[6], that of Alexandre Alaimo, a young engineer who has launched a start-up for the smart management of traffic lights, and that of Adélaïde Albouy-Kissi, a lecturer in computer science, who is working on AI-based models to steer environmental policies. You will learn about Félix Michaud, a student in bioacoustics who uses AI to identify and count animal populations. Finally, we interviewed Laurent Bernard, head of a start-up that provides a smart box to analyse and reduce electricity consumption, as well as Andréas Von Kaenel, whose start-up is developing an AI solution to steer cleaning crews in cities. Driven by great enthusiasm, they are passionately involved in building this new market, in which technology serves the environment.

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[6] *AG Tech [Agricultural technology] is associated with the use of technology in agriculture, horticulture and aquaculture to improve yield, efficiency and profitability*

© Alex Duffy, Unsplash

Above
ITK offers smart irrigation solutions to
reduce water consumption and runoff losses.

The need for a sustainable AI

However, we could not write this book without mentioning the less civilised aspects of digital technology, and in particular those of AI with regard to environment. Some people criticize the dark side of digital technology.

Behind the illusion of the immateriality of digital technology conveyed by the internet giants, we discover a genuine ecological disaster. AI misuses all digital technologies: servers, networks, data storage... As a result, it is making a major contribution to the depletion of scarce natural resources and to the global electricity consumption steady increase.

We met with Vincent Courboulay, a teacher-researcher in computer science and a campaigner for Digital Sustainability. He is one of society's essential whistle-blowers and makes us aware that uncontrolled development of AI would present a major risk for the environment. Intuition is no longer enough to guide a policy of AI for green development. The future lies in controlling the entire AI value chain. From data collection, storage and learning algorithms, the benefits must be real and measured.

Below
The amount of computation required to train Deep Learning Deep Learning models has increased 300,000-fold in 6 years. Source : https://openai.com/blog/aiand-compute/

AlexNet to AlphaGo Zero: A 300,000x Increase in Compute (Log Scale)

Petaflop/s-days

- AlphaGoZero
- AlphaZero
- Neutral Machine Translation
- Neutral Architecture Search
- Xception
- TI7 Dota 1v1
- DeepSpeech2
- VGG
- Seq2Seq
- Visualizing and Understanding Conv Nets
- ResNets
- AlexNet
- GoogleNet
- Dropout
- 3.4 month doubling

1e+4, 1e+3, 1e+2, 1e+1, 1e+0, 1e-1, 1e-2, 1e-3, 1e-4, 1e-5

2012 2013 2014 2015 2016 2017 2018
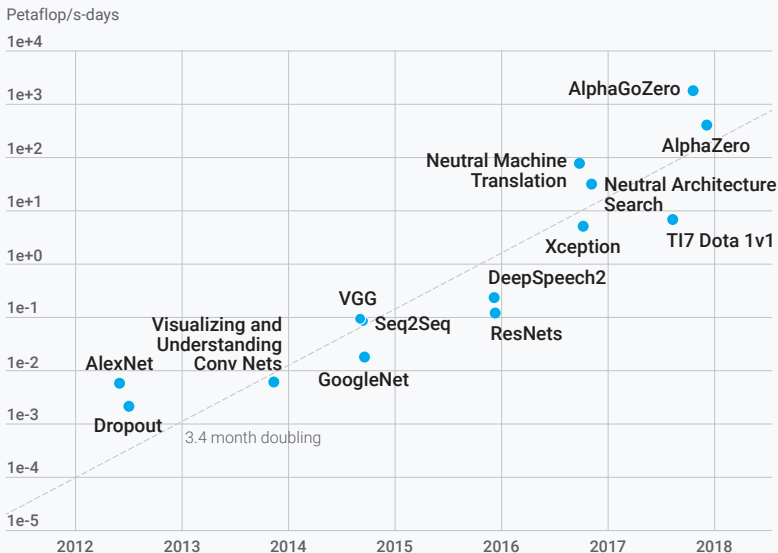
The environmental impact of an online service using AI must be assessed in its entirety.

The dream of a Green AI is still far away, but work is already underway to make AI progressively more responsible by drawing inspiration from the sobriety of our own brains. Biomimetism has always been an important vector in the development of AI: the evolution of AI feeds on a better understanding of our brain. With an energy consumption of only 12.6 watts[7], the human brain points the way to more efficient AI methods, but will these improvements be enough?

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[7] *Biomimicry is a process of innovation inspired by life.*

[8] *The calculation of brain consumption is to be found at:*
   http://www. bodyscience.fr/?L-activite-intellectuelle-intense
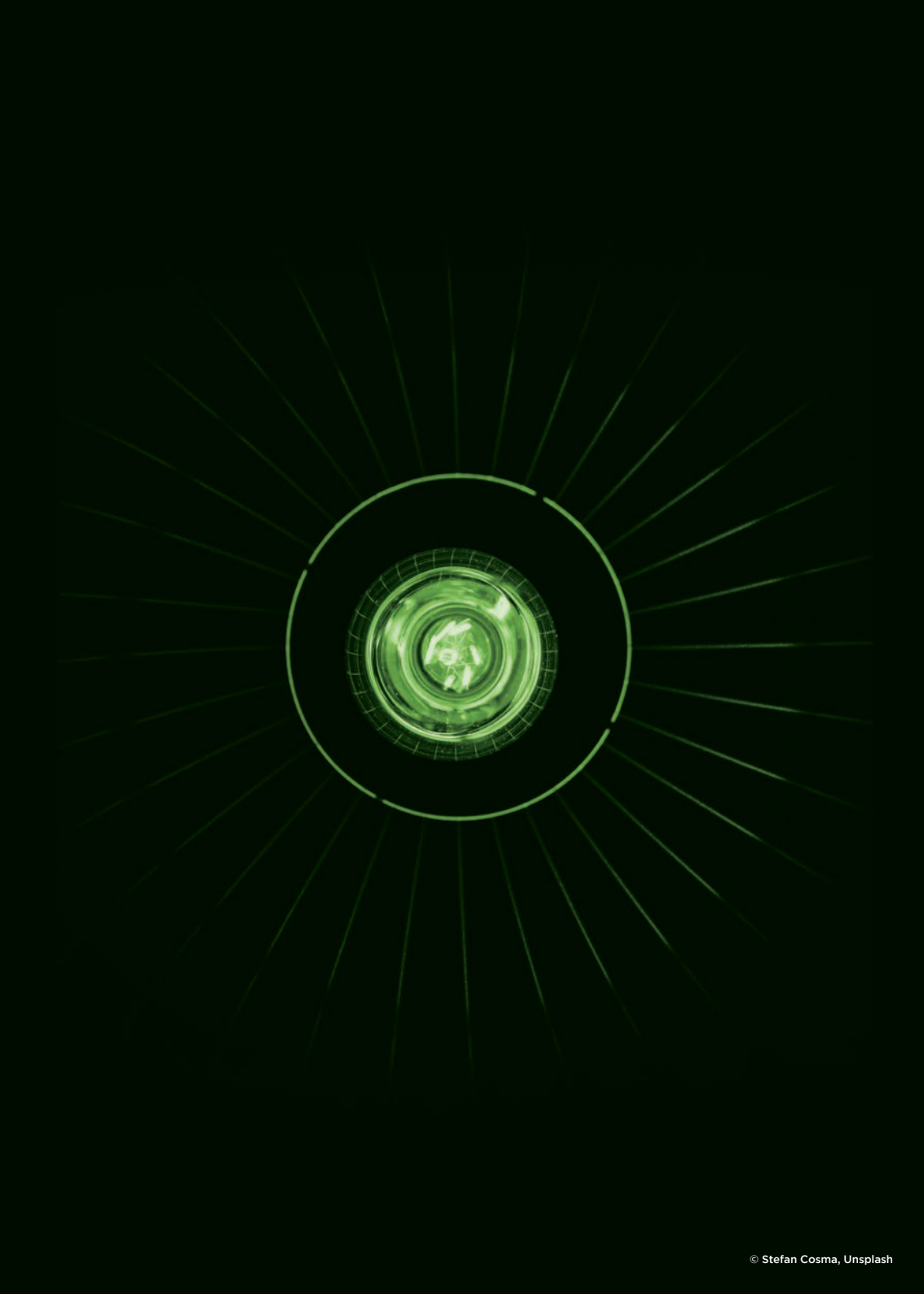
PART 1

Development of IA

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The term "Artificial Intelligence" can be confusing.

When we asked AI specialist Cédric Vasseur to give us a definition, he replied that it was "a machine that solves problems usually solved by humans or animals", referring to Marvin Lee Minsky, one of the founders of artificial intelligence who described it as follows: "Artificial intelligence is the science of making machines do things that would require intelligence if done by humans."

How to define AI?

The difference between a conventional computer system and a system with artificial intelligence is its ability to learn from examples. The former will need a developer to determine its behaviour, whereas artificial intelligence software programs itself to match its results to a series of examples provided to it.

If you teach a child to recognise an animal from a series of photos, its brand-new brain will automatically calibrate itself to recognise it next time in a different context. It is the same principle for AI, an intelligent system will be able, on the basis of learning data, to calibrate itself so that it can then "run" and give the expected results for new data.

Below
You can read about an amazing study of horses "dressed" as zebras to fool smut flies, an example of brain under-interpretation! [7]

© Tim Caro/UC Davis

The particularity of artificial intelligence is that it can produce a generalisation function from learned examples. One might think that a child capable of recognising only learned examples would have "learned by heart". This is not the case! His brain will carry out an abstraction consisting in extracting the common and specific characteristics of an animal, for example the horse, to differentiate it from other previously learned

Predicting, reasoning and deciding are three related notions.

animals. Thus, if he has not learned what a zebra is, he may confuse the two animals. Then, when he has examples of zebras at his disposal, he will be able to differentiate between the two species, by detecting the presence of stripes. His brain will have assigned a particular "weight' to the presence of stripes to differentiate a zebra from a horse. A tiger also have stripes? So the child's brain will take into account the presence of stripes, but also the colour of the stripes, again with a weighting system for each characteristic. And this is how a child's brain learns about the world that surrounds him or her. An intelligent system will work in the same way, depending on the complexity of the model it applies and the volume of training data, it will progress little by little in its ability to predict the category of objects or events that occur. It should also be pointed out that while the learning phases may be long, the classification (or "execution") phases are much faster.

Predicting, reasoning and deciding are three related notions. It is through its capacity to mentally predict the result of an action (or more generally the future), without having to actually carry it out, that the brain will be able to "reason" to decide on the best decisions to take. This probabilistic functioning of the brain consists in calculating the probabilities of various successive actions, by combining the probabilities between them. This ability to predict will enable an intelligent system to decide on the best option to take. This is often referred to as "decision support" software.

CÉDRIC VASSEUR
Lecturer and trainer
in AI and robotics

AI is the subject of many fantasies and approximations, how can it be defined simply?

To avoid getting into too much esoteric stuff, whenever I talk about AI or robotics, I always start with a definition. To define AI, I split the expression in two, first looking at the word "artificial". In the common sense, it may seem to mean "false". An artificial plant, for example, is actually a fake plant. But the words must be put into their context. "Artificial" means first and foremost "man-made". From there, it is easier to understand that AI is an intelligence created by humans. Then, the word "intelligence" is more complicated to determine from a philosophical point of view, but I put people in agreement by talking about "problem to be solved". This is actually the 1956 Dartmouth definition: AI is a machine that solves problems usually solved by humans or animals.

A long-standing story

When we talk about Artificial Intelligence, we immediately think of a futuristic technology, but the history of this science is not that recent. It was in 1956 that a handful of researchers met on the Darthmouth University campus to lay the groundwork for a new discipline, which they decided to call "Artificial Intelligence". This conference, organised by John McCarthy and Marvin Minsky, was to influence all future research. It already gave fundamental leads such as neural networks and machine learning. During the following decades, AI fluctuated between boom times and bust times. Because of low computing power or missing data, the capabilities of systems were limited and industry lost interest in AI. Then, interest in AI steadily picked up again, due to a new technological advance, new data or additional computing power.

© Famille Minsky

Opposite
The 1956 Dartmouth Conference was a historic moment in the development of AI. The founding fathers of AI were present: John McCarthy, Marvin Minsky, Claude Shannon, Ray Solomonoff, Alan Newell, Herbert Simon, Arthur Samuel, Olivier Selfridge, Nathaniel Rochester and Trenchard More.
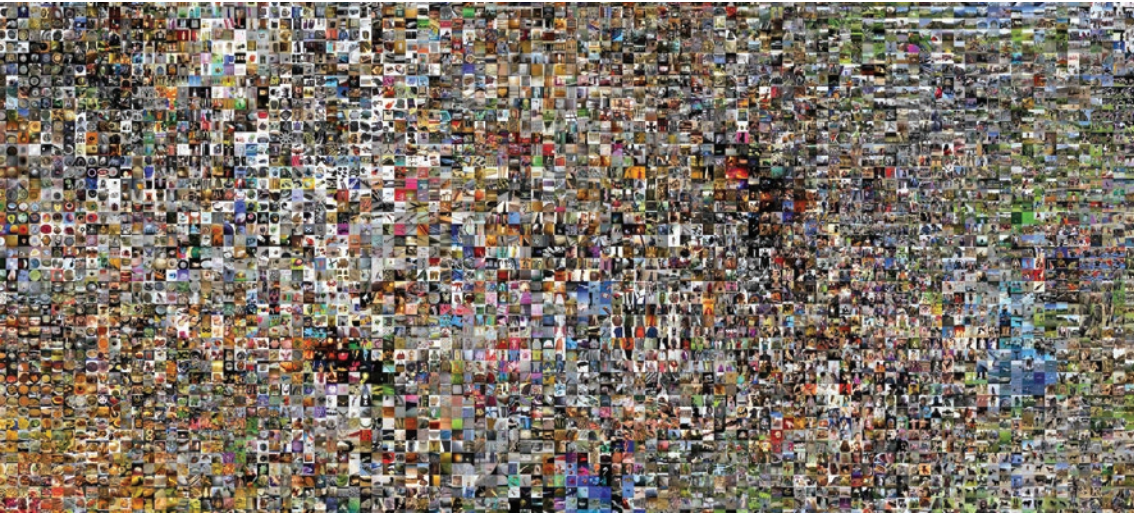
© Image Net

We are currently in the midst of a period of eupho-ria, since the spectacular results obtained by Geoffrey Hinton's team at the 2012 ImageNet competition, where algo-rithms based on the brand new "deep learning" outperformed their competitors in the recognition of objects in pictures.

Above
Over 10 million pictures are currently tagged in the ImageNet database.

Deep learning, the innovation that changed everything

Deep learning has put AI back on the map. We owe this major advance mainly to Frenchman Yann Le Cun. To make deep learning work, the researcher explains that four conditions must be met: a huge volume of data, a strong algorithm, a limited field of action and a well-defined objective. Like many AI methods, deep learning is inspired by the way the human brain works in vision. Recognition starts with a general vision (recognition of the main shapes), and then goes "deeper" into the analysis of details (search for distinguishing details). This is known as a "convolutional neural network". This is the type of multilayer neural network that was developed by Yann Le Cun in 2010. Since then, there has been one innovation after another in the field of AI.
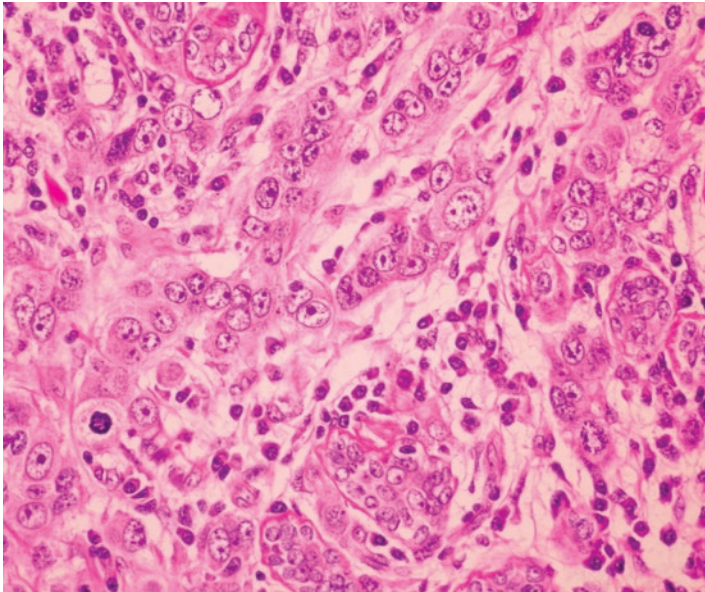
Opposite
Cancer detection using Deep Learning
[towers-clark_ cutting-edge_2019]

Limits of IA

What problems can be solved by artificial intelligence? Indeed, we can ask ourselves about the limits of these technologies. In general we can apply the following rule: if a problem can be solved by an expert from a certain volume of data, an intelligent system will be able to perform the same expertise provided it has access to the same types of data, but in greater quantity. We have entered the "Big Data" era and the volume of learning data is no longer a real problem. When we know

We have entered the "Big Data" era and the volume of learning data is no longer a real problem.

that Alpha Go, the DeepMind software that beat the Go game world champion, is capable in its new version of learning tens of thousands of games played by professional players, then training against 4.9 million instances of itself in 5 days, we realise how important the learning capacities of intelligent systems are. They are less optimised than a human being, since they need more learning cycles, but with the profusion of available data and the current computing power (as well as the parallelization of processing), their resources are considerably greater.

PART 2

Emergence of AI for Green

The solutions inherent in AI for environmental conservation are many and diverse, from optimal energy management to sustainable agriculture, smart cities, or ecosystem conservation, this emerging sector is bursting with creativity.

CÉDRIC VASSEUR
Lecturer and trainer
in AI and robotics

What are the concrete benefits of using AI today to preserve the planet?

I would immediately think of agriculture, where AI is making it possible yet to use fewer pesticides, to irrigate fields in a smart way, etc. There are also drones that are used to detect diseases in the fields. In the past, when you had very large fields to monitor, you had to use a helicopter, with a camera and several people on board. A drone consumes 1,000 times less energy than a helicopter. There are also autonomous tractors that can work day and night. Energy can also be optimised in a city, for instance by turning lights on and off at the right time when a person is detected in the street. AI is also used to prevent forest fires, we are able to model fire outbreaks more and more accurately, in order to know where to intervene to save such and such part of the forest. There are AI tools that exist today that have a true ecological utility.

Next page
The city of Singapore
has chosen to become
a smart city, more
intelligent and
therefore greener.

© Victor Garcia, Unsplash

Smart cities

Let's discover these new technologies that promise smarter and therefore greener cities.

Reduce urban pollution

In Pittsburgh, Pennsylvania, cameras at traffic lights are used to manage the alternation of traffic lights in a judicious way thanks to AI[1]. The system, which was installed in 2017, limits the amount of time vehicles spend stopped, unnecessarily emitting CO_2 into the air. This solution called Surtrac, devised by Stephen Smith, professor and researcher at The Robotics Institute at Carnegie Mellon University, enables vehicles to be halted by 30% fewer on average and reduces emissions by 20%. This is good news for the planet, but also for motorists, who save time in getting to their homes or work. In France, the company Odeven created by Alexandre Alaimo offers the same service but without the camera system. This technology, based on mobile data, is lighter and therefore less costly to set up for medium-sized cities. The Odevia solution is currently being tested in the region of the town of Cusset in the French department of Allier[2].

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[1] *https://www.lemonde.fr/smart-cities/video/2017/06/23/surtrac-l-intelligence-artificielle-pour-rendre-la-circulation-plus-fluide_5150306_4811534.html*

[2] *https://www.lamontagne.fr/cusset-03300/actualites/un-dispositif-de-gestion-innovant-des-feux-tricolores-a-cusset_12711436*

Another application developed by Green Horizon IBM in China uses AI to anticipate air pollution in cities[3]. By determining where the source of pollution will be, it enables authorities to implement a preventive and targeted strategy. Shutting down a power plant, closing down a polluting factory for two or three days, or introducing a traffic rotation system. Thanks to AI, concrete measures can be taken before reaching a pollution threshold that is dangerous for the health of inhabitants.

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[3] https://www.lemondeinformatique.fr/actualites/lire-ibm-vient-au-secours-de-pekin-pour-prevoir-et-controler-la-pollution-de-l-air-58028.html

© Frederick Tubiermont, Unsplash

ALEXANDRE ALAIMO
Founder of Odeven company

You have created Odeven in order to market your solution, Odevia, how does this tool work?

This is called a TMAS, a Traffic Management Assistance System. It is a tool that will make traffic flow more smoothly in the city, by improving the synchronisation of traffic lights. In the press, it is often referred to as "the intelligent red traffic light". The particularity of Odevia is that it is a system based on GPS data from cars and mobile phones. Traditionally, sensors installed on the road are used to collect and count the number of vehicles passing on the road. But this equipment requires maintenance, will age or may break down. With Odevia, the idea is to exploit what is known as floating data, floating car data and floating mobile data, which are data from the geolocation of mobile phones and vehicles. As Waze could do for traffic information, we use this type of data to estimate the number of vehicles on the road and improve the synchronisation of red traffic lights in order to make road traffic flow more smoothly.

It is an intelligent and above all ecological solution?

Yes, that is the aim. The intention is to reduce road traffic congestion and it is clear that traffic jams are responsible for a large part of the pollution. By limiting traffic jams, we obviously reduce vehicle halts and unnecessary CO_2 emissions. With Odevia, we will reduce nuisances such as pollution, but also energy consumption and noise, and this will also avoid wasting time for economic actors.

The particularity of your system is that there are no sensors, so it doesn't imply a too heavy installation for the communities?

Precisely, the lightness of the infrastructure is essential. We use Big Data, i.e. a very large volume of data to anticipate a phenomenon, in this case the evolution of road traffic. I would like to specify that the data is anonymous, we work with companies dedicated to processing geolocation data. These companies completely anonymise the data, so we cannot know that the vehicle or the phone belongs to one person or another. We can't even identify individually a car or a phone, we only get an indication of the nature of the traffic on a road section, we globally know that at such and such a place there is traffic at such and such a speed, and that the road is in a traffic jam.

Was your choice to limit the material guided by an ecological concern?

Yes, that's exactly the point. Lightening the infrastructure helps to be less dependent on equipment but there is also an ecological dimension. It would be a pity not to use the existing GPS equipped phones and vehicles networks which make it possible to gather a large volume of data and not require the installation of sensors.

Do you have other projects after Odevia that would make use of artificial intelligence?

We are developing a camera that can count and differentiate vehicles. This type of camera can be used to carry out traffic studies, but also to spot available spaces in car parks in order to direct motorists. We are also working on a project management tool called Progeo. This tool has been specially developed for road and network professionals, as this sector is currently undergoing a process of digitalisation.

Manage urban sanitation

For municipalities, street cleanliness and waste management are often unsolvable puzzles, both in terms of budget and efficiency. However, it is a fact that optimal management of cleanliness is a factor in attracting new inhabitants. Beyond aesthetics and hygiene, there is also the parameter of ecology that comes into play. How can we reduce water consumption for city cleaning? How can we optimise resources (road sweepers, bin lorries, etc.) to reduce the needs in terms of movement and improve efficiency (less waste in the streets)? In Switzerland, the start-up Cortexia, run by Andréas Von Kaenel and André Roux, has created a system for monitoring urban cleanliness. Thanks to AI, cameras on municipal vehicles spot the dirtiest areas in real time and make it possible to decide on the best itinerary and the ideal frequency for cleaning each neighbourhood[4].

[...] with the emergence of AI, solutions are appearing all over the world

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[1] *https://www.usine-digitale.fr/article/que-fait-cortexia-la-start-up-suissea-qui-cedric-villani-veut-faire-appel-pour-nettoyer-paris.N939246*
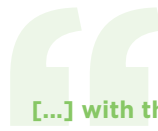
According to World Bank figures, the annual production of waste in cities is currently estimated at 2 billion tonnes per year and could reach 3.4 billion tonnes by 2050[5]. We are literally submerged by our urban waste, but without really being aware of it, since all this waste is sent to developing countries. However, with the emergence of AI, solutions are appearing all over the world. For example, the company Bin-e is developing an intelligent waste container which can automatically sort waste thanks to AI[6]. In Amiens, an AI-driven robot can perform 3,600 actions per hour to sort waste[7]. Wouldn't it be relevant to generalise this type of application to manage our waste more responsibly?

Below
The city of Zurich in Switzerland is the example to follow for its efficient and ecological management of the cleanliness of its streets. The company Cortexia was inspired by this to develop its urban cleanliness monitoring system boosted by the use of AI.

© Ricardo Gomez Angel, Unsplash

[5] https://www.futura-sciences.com/planete/actualites/

[6] https://www.constructioncayola.com/environnement/article/2019/12/17/127188/intelligence-artificielle-dans-gestion-des-dechets

[7] https://www.capital.fr/entreprises-marches/a-amiens-un-robot-intelligent-promet-dameliorer-le-tri-des-dechets-1310586

ANDRÉAS VON KAENEL
Co-founder of the start-up
Cortexia

With Cortexia, you propose to communities to better manage street cleanliness, how can you help them?

We started with a basic idea: what cannot be measured cannot be improved. We try to optimise three things: cleanliness, resource use and environmental impact. To guarantee a total level of cleanliness, you need a measuring tool. Today, cities are cleaned according to pre-established schedules based on habit but not necessarily where it is really dirty. With Cortexia, we can provide real-time mapping of the level of cleanliness by area, so that the city can commit resources to the right place at the right time.

How does your solution work technically?

To map the city's cleanliness and find out where the waste is, we use image recognition based on artificial intelligence. We place cameras on the city's vehicles, on bin lorries, buses, bicycles, any vehicle, and when they move, an on-board computer will directly detect the various categories of waste. With artificial intelligence, it's as if the camera has glasses that allow us to see only the waste, we don't see the people, nor the vehicle number plates. It was taught to detect all types of waste, the smallest being a cigarette butt. It was shown hundreds and hundreds of cigarette butts before it was able to identify them without error. Today it identifies 40 different types of objects, from which we calculate a cleanliness index with 13 categories of waste. It is a reference index that allows us to give a grade and guarantee a level of cleanliness and a quality of service.

So the idea is to make cities more attractive but above all there is a real ecological impact?

There are in fact a multitude of advantages for the city and its inhabitants. Indeed, if it is clean, it is more attractive because the quality of life is better. Cortexia also allows them to use fewer resources and therefore save money. And of course there is a big environmental impact. Simply having cleaner streets will prevent all the small waste from ending up in the sewers and then in the waterways or in nature because of a gust of wind. Less waste in cities means less polluting waste in nature. We therefore have a project with the city of Geneva where we have put filters in the sewer grates. This device will allow us to know, depending on the level of cleanliness, how much waste will be washed away by the rain so that we can then quantify the effectiveness of the cleaning and limit the amount of waste in the environment. The second impact is felt on the resources used to keep the streets clean, a large part of these resources are sweepers which consume energy and will emit CO_2. In a city, there are between 20 and 50 cleaning vehicles for every 100,000 inhabitants, so we know that energy consumption and CO_2 emissions are significant. When we manage to use the resources where necessary, we can expect to save at least 15% of CO_2. Finally, another impact, which is not talked about enough, will be on the use of water. Cities have very different cleaning strategies, some cities have almost water-free strategies like the city of Zurich, while others use a lot of water. I think that water is actually a scarce resource today, and if we can limit the amount of waste that pollutes the waterways, that's already good, but if we can also limit the use of water for cleaning purposes, that's even better.

Intelligent management of energy and development in urban areas

When it comes to the notion of "Smart cities", it is also about having energy management and urban planning based on reliable forecasts. According to an article published on the blog of the Earth Institute of the University of Colombia, AI is seen as an indispensable tool for more sustainable cities[8]. More responsible urbanisation inevitably involves saving energy. Thanks to AI, it is now possible to anticipate a city's need for energy resources and thus limit unnecessary expenditure. The help of AI will also be welcome to reduce the effects of climate change or natural disasters by making urban planning more intelligent. By using simulation software, it will be possible to determine with certainty the most favourable areas for a given type of development. This is the approach being taken by the City of Los Angeles, which has launched the Tree Canopy Lab programme in partnership with Google[9]. The aim of this programme is to fight global warming by mapping the city to decide where vegetated areas should be implemented to prevent heat. Using data based on aerial imaging (already collected for Google Maps/Earth) and external public data (heat risk, population density, land use, etc.),

> **Thanks to AI, it is now possible to anticipate a city's need for energy resources and thus limit unnecessary expenditure.**

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[8] https://blogs.ei.columbia.edu/2018/06/05/artificial-intelligence-climate-environment/

[9] https://www.ladepeche.fr/2020/11/22/quand-lintelligence-artificielle-de-google-permet-de-lutter-contre-le-rechauffement-climatique-dans-les-villes-9214509.php

the AI will analyse the images by combining them with 3D models to then recommend where trees are lacking and thus target planting locations. In its diagnostic phase, Tree Canopy Lab has already established that more than half of the population of Los Angeles lives in areas with less than 10% canopy cover, with 44% of them at risk of extreme heat. Google has announced that this programme could be applied to hundreds of other cities around the world.

To go even further in the intelligent management of cities, the idea of developing "urban dashboards" with real-time data on all the parameters related to the environment can be taken up: from water and energy consumption to traffic pollution and weather conditions. With such a system, cities could become truly environmentally responsible and offer a better quality of life to their inhabitants.

Save energy

While the digital industry, and therefore AI, are major consumers of energy, technological innovations are nevertheless moving in the direction of greener and more rationalised energy.

Understand the climate to promote sustainable energy

One way to save energy is to promote renewable energy as a substitute for fossil fuels. But it is still necessary for renewable energies to become efficient enough substitutes to be used on a massive scale. In this case, AI is proving to be very useful. Thanks to the intervention of an AI, it is quite possible to significantly improve the performance of wind farms, taking into account meteorological data. Indeed, AI is used to correlate the speed of each propeller with the direction and power of the wind. By analysing this variety of data, the AI will enable it to optimise and therefore increase the electricity pro-

Below
Using AI, wind farms are optimised to predict their electricity production and improve their efficiency.

duction of all the wind turbines. Artificial intelligence is also being used to help researchers understand the atmospheric conditions in which wind farms operate. The aim is to establish an ultra-precise forecast of future energy production.

It is precisely this idea that led Atos and Météo-France companies to sign an agreement for the creation of a platform for forecasting renewable electricity pro-duction[10]. This initiative is part of a European agreement that commits the EU countries to ensuring that renewable energies account for at least 32% of their total consumption by 2030[11]. It is therefore obvious that by anti-cipating this production, it is possible to find solutions to improve it.

> **Artificial intelligence is also being used to help researchers understand the atmospheric conditions in which wind farms operate.**

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[10] http://www.meteofrance.fr/espace-presse/76913055-atos-et-meteo-france-optimisent-la-gestion-de-la-production-d-electricite-renouvelable

[11] https://www.vie-publique.fr/en-bref/273016-les-energies-renouvelables-en-hausse-dans-lunion-europeenne

Increase energy efficiency

Measuring to improve, anticipating to save, AI is becoming an indispensable tool for significantly optimising companies' energy expenditure. According to a recent survey by Capgemini Research Institute[12], with the help of AI, companies could reduce their greenhouse gas emissions by 16% by 2023-2025.

Above
Google is now using AI to cool its data centres and significantly reduce energy consumption.

[12] https://www.decideo.fr/Selon-un-rapport-du-Capgemini-Research-Institute-l-intelligence-artificielle-pourrait-aider-les-organisations-a-reduire_a12288.html

In the new technology industry, some companies have already implemented AI solutions to control the over-consumption of energy in their data centres. This is the case of Google, which uses AI to know in advance when its data centres are most heavily tasked. This system allows it to analyse the times of day when people watch the most YouTube videos or do other energy-consuming searches, in order to optimise the cooling of its data centres[13]. The results are impressive, as Google says it has reduced its energy consumption by 40%.

Huawei is taking a similar approach, deploying artificial intelligence solutions to completely renovate its data centres and increase their energy efficiency[14]. With its intelligent thermal management system, iCooling, the Chinese mobile phone giant is using AI to identify the parameters that increase energy expenditure and forecast the energy efficiency of its data centres. This solution is combined with other intelligent technologies, iPower and iManager, which enable Huawei to control energy consumption by ensuring the reliability of its data centres and optimising their management (power, cooling, space). This strategy seems to be paying off as the integration of AI at China Mobile's data centre in Ningxia has reduced its total energy consumption by 3.2%, resulting in savings of over 400,000 kWh of electricity per year.

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[13] https://www.futura-sciences.com/tech/actualites/intelligence-artificiellegoogle-ia-commandes-refroidissement-data centers-72482/

[14] https://www.chine-magazine.com/lintelligence-artificielle-aide-huawei-a-construire-des-centres-de-donnees-verts/

Microsoft, meanwhile, has teamed up with Swedish electricity provider Vattenfall to develop an intelligent grid management solution to optimise the production of green energy according to demand[15].

If AI can help lower the energy bill of companies, it can also do the same for the public sector. In France, the government is undertaking actions to promote the energy renovation of its public buildings, in particular via the CEE (Certificat d'Economie d'Energie [Energy Savings Certificate]) programme initiated by the Ministry of Ecological Transition. France wishes to invest 4 billion euros in the energy renovation of public buildings, but a question arises: how to target the most energy-intensive establishments and decide on the appropriate work that will have a real impact on energy savings? Concerning more specifically the renovation of schools, the start-up name.R has been chosen following a request for proposals, to develop a decision support tool using AI within the framework of the tRees[16] programme (energy transition of educational institutions). The objective of this tool would be to accelerate the implementation of these works by prioritising the schools, colleges or high schools most in need of rehabilitation. The idea would be to analyse buildings using AI, based on images, text and structured data, to pinpoint where the losses are and

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[15] https://group.vattenfall.com/press-and-media/news--press-releases/ pressreleases/2019/vattenfall-and-microsoft-pilot-worlds-first-h-ourlymatching-247-of-renewable-energ

[16] https://www.actuia.com/actualite/transition-energetique-focus-sur-le-programme-trees-porte-par-nam-r-en-test-dans-les-hauts-de-france/?utm_source=Actu+IA&utm_campaign=411a1f3069-newsletter_quotidienne&utm_medium=email&utm_term=0_984fe5c378-411a1f3069-47481873&mc_cid=411a1f3069&mc_eid=182c01e37b

give recommendations for undertaking the work in a judicious manner. If the tests carried out in the Hauts-de-France region are conclusive, the system could be extended throughout the country.

This same concept of diagnostics/recommendations can be found with the start-up Sensing Vision[17], which provides local authorities and companies with digital energy models of their buildings to identify anomalies, analyse them and then correct them. The solution proposed by Sensing Vision

> **If AI can help lower the energy bill of companies, it can also do the same for the public sector.**

is based on an ecosystem of low-power sensors and AI algorithms that process the data collected. This start-up guarantees 20 to 40% savings on energy bills, savings that ultimately result in a reduction in carbon emissions.

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[17] https://www.sensingvision.com/

Other AI solutions are available to individuals who would like to reduce the carbon footprint of their home. In 2017, the French company Ecojoko launched a sensor to measure energy consumption so that it is no longer wasted[18]. This quite easy-to-install device makes it possible to know which appliances are unnecessarily consuming energy, and gives advice on how to remedy errors of use or failures. With this help, Ecojoko claims that electricity consumption in a house can be reduced by at least 25%.

Opposite
The Ecojoko solution allows individuals to view their energy consumption in real time and to take action to reduce their energy costs.

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[18] *https://www.ecojoko.com*

Limit energy consumption of digital technology

One of the most energy-intensive aspects of digital technology is the transfer and viewing of photos and videos on the internet. And on this point, AI can be a source of improvement. As we have already seen a few lines above, the giant Google is already using AI to reduce its energy footprint in its data centres. Since 2017, the most famous search engine has also been using AI to compress its images and thus reduce bandwidth consumption[19].

After Google, it is now JPEG (Joint Photographic Experts Group) that is seeking to reduce the size of its photo formats (JPG, JPEG, etc.) without for all that losing quality. The company launched the JPEG IA programme in 2020 to find ways to achieve its goal through AI2. Other digital industry big names have already addressed this issue, such as Netflix, which uses AI to optimise the consumption of its videos[20]. Indeed, the platform has managed to halve its bandwidth consumption without losing broadcast quality.

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[19] https://www.rtbf.be/tendance/techno/detail_google-utilise-l-intelligence-artificielle-pour-compresser-les-photos?id=9504343

[20] https://siecledigital.fr/2020/02/24/jpeg-travaille-sur-un-nouveau-format-qui-serait-genere-a-partir-dune-ia/

[21] https://www.itespresso.fr/netflix-intelligence-artificielle-bande-passante-150168.html

LAURENT BERNARD
Co-founder of Ecojoko company

You created Ecojoko to avoid wasting electricity at home, how does your solution work?

As electricity cannot be seen, except for light bulbs, we do not realise that we are constantly wasting it. It can be a badly adjusted appliance, typically a fridge, or a radiator, or even appliances that do not work properly, a frosted freezer, a defective water heater... It can also be problems of use, appliances that could be used differently: by lowering the heating, by not leaving appliances on standby... Overall, this represents 25% of the electricity bill of the French people, i.e. about 300 € per year on average and it can be much more. If we add up all the French households, we reach 8 billion euros per year, which is equivalent to 8 nuclear reactors wasted for nothing. This is just aberrant economically and ecologically since, obviously, the cheapest energy is the one that is not wasted. That's the problem we're facing, and to remedy it, our solution achieves three things: it allows us to monitor electricity consumption in real time, so we can see how much it consumes each time we turn on an appliance. This is a first step towards becoming aware of the situation and making corrections. Then, the device will inform you of the distribution of the consumption on the different categories of devices and this is where the AI comes in. There are 9 categories that will define where you spend your euros and watts. Finally, you are offered actions, fun missions to act on these consumptions. At the end, the aim is to achieve a 25% reduction. By acting individually, if we all get involved, the impact can be very strong.

How does AI play a part in this solution?

Without AI, we would only be able to measure the total consumption of the house in watts, at a given moment. To know which appliance consumes, we will implement AI methodologies, machine learning, deep learning, in order to analyse the signal. We talk about electrical signature, a fridge does not consume in the same way as a cooker does, for instance. AI will therefore be used to carry out this segmentation and categorise the various types of appliances.

You use AI, sensors, all of this also uses energy, how do you ensure that you are consistent with your ecological message?

Our expenditure is really minimal compared to the energy Ecojoko saves. The device will only consume 1.5 watts, so it's not much. What will consume the most energy, if you consider the whole LCA (Life Cycle Analysis), is the manufacturing of the product itself. We have calculated that we had 14 kg of CO2 equivalent and with the reduction in our customers consumption, this cost is profitable after two and a half months of use. Comparatively speaking, a top-of-the-range smartphone will have a CO2 equivalent of 80 kg. The challenge in terms of savings is actually to decarbonise manufacturing as much as possible. Then with regard to AI, we don't process images, we process very simple data, so in terms of energy resources it's very light. We keep a close eye on the environmental impact and there is no rebound effect with our solution. On the contrary, some installers use Ecojoko to avoid it. For example, people who insulate their house better figure that they can increase the temperature in their house to enjoy a better comfort and in the end, they spend almost as much energy as before the insulation. If they were aware of the energy expenditure, they might change their practices.

To have a actual ecological impact, what would be the equipment rate to be reached in France?

Our goal is to reach 5% of equipped households. If we achieve this, we will switch off the equivalent of a nuclear reactor. 5% is achievable and can have a big impact.

A connected and sustainable agriculture

Intensive agriculture is also being blamed for its harmful effects on the environment and our health. Although the number of organic crops is increasing, pesticides are still widely used. These products used to ensure a better yield are unfortunately one of the causes of soil depletion, water pollution and, though less known, air pollution as well. According to an article in Le Monde, in France alone "40 to 90 different active species (herbicides, fungicides, insecticides) are detected and quantified annually on a national scale"[22]. AI could steer farmers along an eco-responsible path while allowing them to improve their yield.

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[22] https://www.lemonde.fr/planete/article/2019/12/18/les-pesticides-polluent-aussi-l-air-querespirent-les-francais6023286324.html
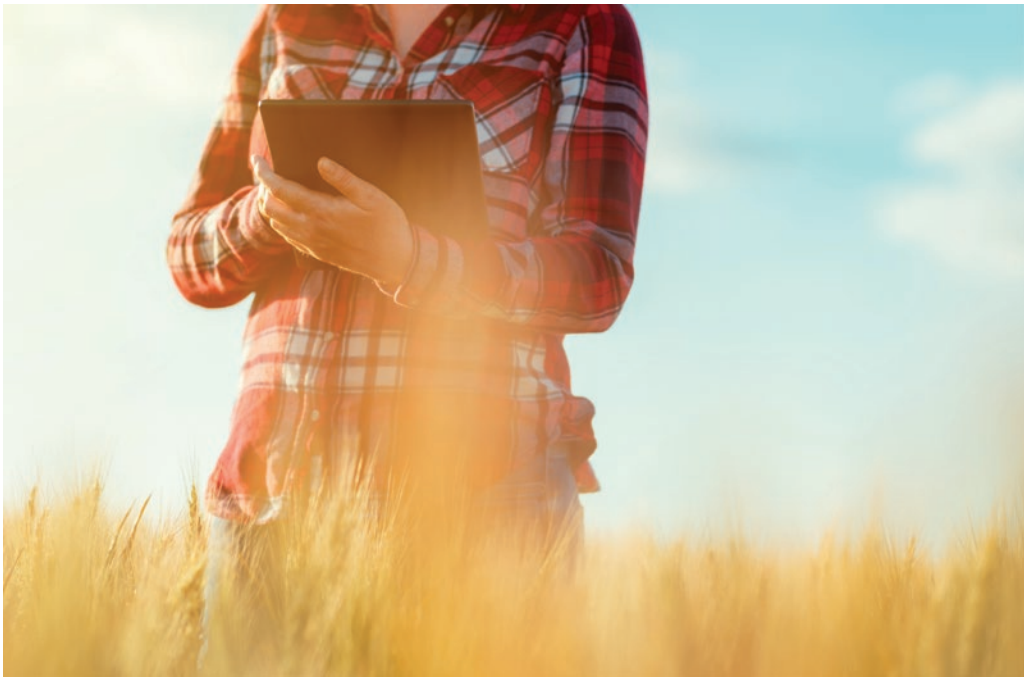
Avoid overuse of water and pesticides

Companies have taken this subject in hand, like the American start-up Arable[23], which raised 20 million dollars in 2020 to finance the development of crop monitoring tools. The idea is to install thermal and spectral sensors in the fields to collect data (weather, soil, plants, etc.). This data will then be processed by machine learning algorithms to determine the decisions to be made in terms of irrigation or nutrients. While Arable's solution involves the installation of sensors, ITK provides decision

Below
With AI, farmers are guided to optimise treatments.

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[23] https://www.usine-digitale.fr/article/ia-et-objets-connectes-arable-leve-20-millions-de-dollars-pour-ses-outils-destines-a-l-agriculture.N1022829

support tools with the same objective of saving water and pesticides, but using AI-based mathematical models, without any need for physical equipment[24].

Another example is the French start-up Chouette[25], which mainly targets winegrowers. This time it is a drone that flies over the vineyards autonomously and which, thanks to AI, will detect very precisely where the disease (mildew, Scaphoideus titanus flavescence, etc.) is likely to appear in the vineyard. Thanks to this real-time monitoring and analysis of the symptoms of diseases by deep learning algorithms, the winegrower will be able to manage his inputs rationally and thus avoid spraying all of his vines with pesticides.

These examples illustrate how AI represents an opportunity for more sustainable and responsible farm management, an ecological solution, yet also an economic one for farmers.

[24] https://www.itk.fr
[25] https://www.chouette.vision/#/

ALINE BSAIBES
ITK Managing Director

What are the services ITK provides to the agricultural sector?

Our activity consists in developing decision support software for all the players in the agri-food value chain. The users are agricultural advisors and farmers. Our tool will help them to manage their farms rationally: What is the best time to plant? Which variety to plant according to the climate and the soil? When to spray, fertilise, irrigate and in what quantity? The aim is to measure the impact of each decision the farmer makes on his crops. Three years ago we also acquired a company that was doing the same thing as us, but for livestock. Here it's not just about software, there are sensors fitted around the cows' necks which collect data. This data is then processed by deep learning AI algorithms. The farmer will be able to watch his cows in real time: he will know if they are ready to be inseminated, if they are well fed, if they are about to calve... These alerts greatly reduce the mortality rate of calves and cows that give birth.

Intensive agriculture has an undeniable impact on our environment, how can AI help agriculture to become greener while keeping the same productivity?

Today farmers rely on standards that were developed in the 70s, 80s and even 90s, based on past experience and research. This was very good at the time, but this standardisation of agriculture can no longer be applied. Everything is changing. Climate is changing, the varieties planted are not the same and the soil has been seriously depleted by years of overexploitation. The problem is that these changes are happening so fast that there is no time to research and experiment with new standards, they will be obsolete before they are applied. However, knowledge about the functioning of soils, plants, their interactions with the atmosphere, and about disease management is quite advanced, and we have the possibility of

putting all this knowledge into mathematical equations. With the multitude of elements to be integrated together, a human brain alone will not be able to process them, whereas an algorithm can. It will be able to take into account everything happening in the soil, anticipate the weather, know how the plant's genetics will react, etc. At ITK, we are integrators of this knowledge. We enable the farmer to adapt to each situation. As an example, the algorithm will be able to indicate that there is no disease pressure and that there is no need to spray pesticides. It's the same for irrigation. The quantities of water used in agriculture are astronomical, and while half of it runs off, another part is drained into groundwater table, carrying away the fertilisers in the process, leaving almost nothing for the plant. It is exactly the same with fertilisers. Farmers often use far too much fertiliser on usual dates. We have shown that, depending on the climatic situation of the year, the planting date, the recommended dates and quantities to be used are not always the same. This is important, because if the farmer fertilises his soil before a heavy rainfall, some of the fertiliser will leach into the groundwater table and thus pollute it, and another part will evaporate, producing greenhouse gases. AI makes it possible to create models that will simulate several possible scenarios and enable the farmer to make a reasonable and economical decision.

Do you think that new technologies represent the future for a more sustainable agriculture?

Yes indeed, it's just a matter of time. This approach needs to be supported by prescribers and subsidies that will help the first wave of large-scale adoption. This approach needs to be supported by prescribers and subsidies that will help the first wave of large-scale adoption. However, farmers should not be left with a multitude of tools, and spend their time inputting data into software. They yet have so much to do, and the aim is not to make their management more cumbersome; on the contrary, the goal is to help them make decisions and make their work easier. So the challenge is not just to switch to new technologies, it is also to find ways of making them easy to use for farmers.

Anticipate natural disasters and adapt to climate change

Mike Horn's latest widely publicised expedition to the Arctic in December 2019 is just one more evidence of climate change and its consequences. The adventurer was stunned by the incredible melting of the ice caps he witnessed on site. "The ice, which used to be 2.50 metres thick at the North Pole, is now five centimetres thick," Mike Horn told France Info. "In 2006, at the Arctic Circle, I saw bears, and there, for a hundred days, I saw none. Where are they? This is another indication of climate change" [26]. *Could AI play a role in helping us avoid the worst?*

Below
"In 2006, at the Arctic Circle, I saw bears, and there, for a hundred days, I saw none. Where are they? This is another indication of climate change" - Mike Horn.

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[26] *https://www.francetvinfo.fr/replay-radio/ils-ont-fait-l-actu/ils-ont-fait-l-actu-que-devient-mikehorn-l-aventurier-sauve-in-extremis-sur-la-banquise4026401.html*

Limit the impact of climate change on agriculture

As Aline Bsaibes, ITK Managing Director, explained, farmers can no longer rely on old habits to manage their farms. With climate change, the weather, which was already inherently difficult to predict, is becoming even more uncertain. Experience is no longer enough, so AI can be a great help. Thanks to its calculation capacity and the mass of meteorological data it can process, AI is a relevant solution for improving weather forecasts and anticipating extreme weather events. A precious help for farmers who can lose an entire harvest due to capricious weather.

Above
Weather damage is always unpredictable. Today, AI can help farmers safeguard their crops by anticipating these exceptional weather events.

ALINE BSAIBES
ITK Managing Director

To what extent could AI enable farmers to anticipate current climate changes and protect their crops?

Let me give you a very specific example that we are working on at ITK: the wine appellations in Bordeaux or Languedoc regions under threat from climate change. There are very precise specifications that farmers must respect to obtain the appellation. But these specifications will no longer allow farmers to produce the same wines because they have not evolved for years. We have made projections according to the different types of known climatic scenarios, and we have shown that it is absolutely necessary to change the winemaking and vineyard management practices to continue to produce an appellation wine with the same characteristics as today. In summary, we have seen how the vines will behave under different future climate scenarios and with AI, we are objectively encouraging to change the rules.

Protect populations from climate-related disasters

In cities, urban planning has not been designed to cope with those new natural disasters, which may have serious consequences from a material and human point of view. In 2018, the Municipal Authority of Hong Kong announced its intention to become a smart city, including, inter alia, research to ensure the safety of its inhabitants threatened by various climatic hazards[27]. With AI, it will be possible to predict the occurrence of typhoons, a meteorological phenomenon that is very common in Asia and that regularly causes significant damage. Another problem Hong Kong faces is that the hills surrounding the city are being deepened year after year to expand the urban area and could cause landslides in the event of heavy rainfall. This is an actual danger for the local population and the ecosystem. In order to avoid such a disaster, AI is helping the authorities to

Below
Typhoons are commonplace in Hong Kong, and to anticipate them and protect its population, the city is relying on advances in AI.

[27] https://usbeketrica.com/article/l-ia-peut-elle-sauver-la-planete

© Chromatograph, Unsplash

anticipate climatic phenomena, using meteorological data, analysis of aerial photographs and data from archives of previous disasters.

Another example is in Togo, where it is definitely not an ultra-urbanised area like in Hong Kong, but the Nangbeto dam, which is both indispensable (electricity production, fishing, water reserve, etc.) and a cause of problems for the population in the event of flooding of the Mono river. The Togolese Red Cross has therefore used AI technologies to help predict overflow of the dam[28]. Thanks to the integration of several sources of data, AI is able to predict the risk of flooding, which helps to better prepare the population and reduce the impact of flooding caused by the overflow of the dam.

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[28] _http://www.environnement.gouv.tg/fr/content/le-gouvernement-togolais-prime-au-sommet-mondial-de-dubai_

Analyse the impact of natural disasters on nature

While AI can help protect urbanised areas from extreme weather events, it can also be used to analyse the effects of climate change on biodiversity. Will the flora and fauna that inhabit our planet be able to survive this global warming and the natural disasters it causes? This is the question Maria Uriarte, professor of ecology, evolution and environmental biology at Columbia University, and Tian Zheng, professor of statistics at the Data Science Institute, are trying to answer. Thanks to a grant from Microsoft, the two researchers went to study the impact of Hurricane Maria on the El Yungue National Forest in Puerto Rico[29]. The damage caused by the hurricane was extensive, with thousands of trees destroyed by the high winds. The purpose of this study is to determine which trees survived the disaster and which did not. An analysis that would be impossible without pictures of the site from the sky, such as those taken by NASA in 2017. To distinguish all the tree species in thousands of such photographs would take an incalculable amount of time. This is where AI comes in. Thanks to the mapping and tree identification work carried out by Maria Uriarte, the AI, based on its data, is able to distinguish all the tree species seen from above in a photograph. The results of those analysis can then be transposed to other territories.

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[29] *https://blogs.ei.columbia.edu/2018/06/05/artificial-intelligence-climate-environment/*

In Chile, AI is used to detect forest fires as soon as they start in order to intervene more quickly[30]. Several research programmes also aim to predict fires before they occur, by processing past weather data[31].

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[30] https://www.geo.fr/environnement/au-chili-des-capteurs-dans-les-arbres-utilisent-lia-pouranticiper-les-feux-de-foret-200078

[31] https://theconversation.com/lintelligence-artificielle-comme-outil-de-lutte-contre-les-incendies143562

Below
El Yungue National Forest in Puerto Rico was devastated by Hurricane Maria in 2017.

© Alessandro Cai (OliverZena)

Preserve Earth's ecosystem

Global warming, fire, water pollution, poaching, overfishing, deforestation… all have catastrophic consequences for biodiversity. The latest UN report states that around 1 million animal and plant species are now endangered[32]. However, this report also indicates that the situation is still reversible if both local and global actions are taken now to preserve and restore nature. Only a strong political will can therefore guarantee the preservation of our environment, and artificial intelligence is a potential help in this endeavour.

Struggle against the depletion of the marine ecosystem

Given the urgency of the threat to biodiversity and the volume of work that lies ahead to repair the ravages of human activity on nature, advanced technologies seem essential to accelerate and initiate concrete action. AI is already being used to help conserve our ecosystem, notably through initiatives such as AI FOR EARTH created by Microsoft[33]. As mentioned in the previous section, Microsoft provides grants and also makes its AI technology available to support environmental projects. Among the actions supported by Microsoft is the monitoring of the Chesapeake Bay in the United States.

Many projects linking AI to ocean conservation have been launched.

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[32] https://news.un.org/fr/story/2019/05/1042791
[33] https://www.microsoft.com/fr-fr/ai/ai-for-earth

Thanks to the ultra-fine image analysis made possible by AI, the area is now mapped much more accurately than before, making it easier to monitor the bay and its rich but precarious biodiversity[34].

On a broader scale, Microsoft has also partnered with the conservation organisation The Nature Conservancy to geographically map all ocean species using AI[35]. The aim is to create decision support models to determine which areas can be exploited by humans (fishing, seafood harvesting, tourism, etc.) without endangering the underwater ecosystem. A solution for preserving marine life while taking into account the economy linked to the oceans.

Many projects linking AI to ocean conservation have been launched. One of the most striking is the Soft Robotic Fish project, a robotic fish capable of discreetly observing marine animals without disturbing their habits[36]. This is a way for scientists to gather information on the consequences of ocean pollution on fish while respecting their environment.

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[34] https://news.microsoft.com/on-the-issues/2018/01/26/ai-earth-aims-powerful-technologyplanets-biggest-environmental-threats/

[35] https://blogs.microsoft.com/green/2018/04/19/the-nature-conservancy-case-study/

[36] https://www.csail.mit.edu/research/sofi-soft-robotic-fish

Other initiatives are attempting to directly fight the pollution responsible for the depletion of ocean biodiversity. The first example is the Ocean Cleanup project, which uses robotics to clean up the waters on a massive scale. Autonomous AI-operated robots measuring over 600 m in length are tasked with recovering up to 5 tonnes of plastic per month, which should then be recycled[37]. Another effort to clean up the water has been launched by ellipsis.earth, which uses drones to find plastics in the water[38]. The detection of plastics is achieved through AI.

Below
*The Ocean Cleanup
uses AI to clean
the oceans.*

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[37] *https://theoceancleanup.com*
[38] *http://www.ellipsis.earth*

© The Ocean Cleanup

The number of uses of AI for underwater environmental conservation is increasing: mapping the seabed to protect corals[39], monitoring invasive species that threaten the balance of biodiversity[40], or controlling overfishing[41], AI appears to be a formidable tool for analysing data in real time that will make it possible to intervene rapidly and in a targeted manner.

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[39] https://www.lesechos.fr/tech-medias/intelligence-artificielle/lintelligence-artificielle-plonge-ausecours-des-coraux-1122142

[40] https://www.futura-sciences.com/tech/actualites/robotique-rangerbot-robot-va-defendre-grandebarriere-corail-72673/

[41] https://theconversation.com/artificial-intelligence-makes-fishing-more-sustainable-by-tracking-illegal-activity-115883

© The Ocean Cleanup

Safeguard inland wildlife

The biodiversity of the seabed is fragile, but the situation on land is not any better.

Animals and plants are also endangered. Just as it is used to map marine species, AI is also used to monitor terrestrial biodiversity. One such example is the partnership between the company SAS and the NGO NatureServe. SAS has provided its AI technology to help the organisation quickly identify endangered species[42]. The time saved will enable NatureServe to update its database more regularly at a lower cost and, more importantly, to take action to save endangered animals and plants.

More surprisingly, AI is proving to be a weapon in the fight against poaching. The University of Southern California has set up a project called "Protection Assistant for Wildlife Security" (PAWS) that uses AI to predict where and when poachers are likely to strike in the future[43]. Based on crime, poacher behaviour and past ranger patrols data, the algorithm will be able to give very accurate indications in order to arrest poachers and prevent the extinction of protected species.

Safeguarding biodiversity also means reinstating nature in areas that have been damaged by human activity and then abandoned. In Massachusetts, in the United States, an area destroyed by cranberry production has been rehabilitated to bring biodiversity back. To find out how nature was reasserting itself, MIT Media Lab researchers placed microphones to listen to interactions between species and to find out whether the actions taken to restore the site had been effective[44]. After four years of recording, the team specialising in bioacoustics has thousands of hours of sound to process.

A monumental task that would take an infinite amount of time without the help of AI. Indeed, to process such a mass of information, AI quickly emerged as the most suitable method for obtaining fast and reliable results.

[42] https://www.decideo.fr/SAS-aide-NatureServe-a-proteger-la-biodiversite-a-l-aide-de-l-intelligence-artificielle_a11944.html#:~:text=Compte%20tenu%20du%20risque%20d,les%20v%C3%A9g%C3%A9taux%20et%20les%20animaux.

[43] https://www.nationalgeographic.com/news/2016/06/paws-artificial-intelligence-fights-poaching-ranger-patrols-wildlife-conservation/

[44] http://www.univ-lemans.fr/fr/actualites/agenda2019/octobre2019/l-intelligence-artificielle-etla-bioacoustique-au-service-de-la-biodiversite-et-du-bien-etre-animal.html

FÉLIX MICHAUD
PhD at La Sorbonne Center
for Artificial Intelligence

Your specialism is bioacoustics, can you explain what does this consist of?

Bioacoustics is the study of how sound is produced by animals, how it is propagated in their environment and then how it is interpreted by other animals. In short, it is the study of sounds generated by living things.

Can you explain the context of your research?

The Responsive Environment Section of the MIT Media Lab, led by Joseph Paradiso, installed microphones on a protected area undergoing restoration in Massachusetts. This area had been destroyed by the cranberry industry and then the land was abandoned, and life could not re-emerge under those conditions. So there was a project to restore the site that the MIT Media Lab's Responsive Environment linked up with. Their aim was to implement a system to measure the restoration of biodiversity on the site and they have been continuously recording data for 4 years now.

How is AI involved in this project?

As I said, this represents 4 years of recorded sounds, so it's a huge volume of data implied, hours and hours of audio to process to try and understand the interactions between species on site. To process this mass of data, artificial intelligence algorithms are the most effective. These algorithms will allow us to correlate the data and to try to understand the various dynamics of bird and amphibian species.

Is the final aim of this research to understand how biodiversity reappears on this type of site?

First of all, we want to measure the extent to which life has reappeared on the site. This is the first site undergoing restoration that has been analysed in this way as far as I know, and the aim is to understand what impact the restoration of the area has had on biodiversity. The aim is to obtain an example, to know whether on the next sites to be restored it will be necessary to do the same thing again or to find other solutions so that life can come back more quickly and increase the number of species. The second aim is to carry out ecoacoustics. Thanks to all these years of listening, we obtain ecological data, i.e. interactions between living things and their habitat. Apart from restoration, we can try to understand what happens in nature if the temperature of the planet increases, for example. With parameters linked to climate change, we will try to determine how species will adapt or not and what endangers them. Artificial intelligence will help us, among other things, to analyse the audio to automatically count and classify the number of species on a site… This is a huge time saver.

Before this project, you already had a strong ecological awareness, do you think that AI brings real solutions to conserve biodiversity?

I was kind of expecting this question! I would refer to an article from the UN which says that the main threats to biodiversity today are the depletion of animal habitats, the overfishing and the exploitation of animals for food. So I would say no, neither AI nor any other technology will be the direct solution to this problem. This is a really important point because there are a lot of "dream sellers" out there promising us that technology will solve all our problems. In reality, when we consider the causes of the species loss, of the degradation of living conditions on Earth, it is not a technology developed by humans that will enable us to change the situation. However, it can help us to understand the relationships between species, and the interactions between animals and their habitats to fight against their disappearance. AI could also help us to know how climate change is affecting living things. This requires that AI research continues to progress. However, in this field there is a competition for getting published. There are huge investments that drive some people to carry out irrational research when we should be thinking about how we are going to live in a world where living conditions are getting worse and worse. I think that every investment in new technologies should be aimed at helping humans to live well in their environment, but not at generating consumer products that pollute nature unnecessarily. Research helps to understand, AI is only a tool, decisions to change things will remain political.

Autonomous transport and sustainable mobility

AI can limit transport-related pollution by promoting fuel-efficient driving and optimising engines to be more efficient. Companies in the automotive industry are heading for innovation in autonomous and sustainable transport. Autonomous vehicles have become the second biggest draw at the famous CES (Consumer Electronic Show) in Las Vegas, with an outbreak of prototypes on display in 2019[45].

Manufacturers are working on the development of shared, smart and ecological transport. This is the ambition of the French company Transdev, a mobility specialist, which has partnered with ZF (a German automotive supplier) and e.Go (an electric car manufacturer) to develop its ecological and autonomous shuttle: the e.Go Mover[46]. With a capacity of 15 people, these electric shuttles would aim to complement existing urban transport networks. Other manufacturers have also entered the innovation race to come up with their own shared transport solution, following the example of the company Transdev[47], which proves that the trend is heading for autonomous mobility but within communities. It is also conceivable that an attractive public transport network, both ecological and personalised, could trigger the renunciation of individual cars, at least for daily commutes.

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[45] https://les-smartgrids.fr/mobilite-propre-autonome-ces-2019/

[46] https://e-go-moove.com/en/

[47] https://www.transdev.com/fr/nos-solutions/transport-autonome/

Photo courtesy of e.GO Digital

Above
Autonomous
e.Go bus operated
by AI.

Local and sustainable economy

In March 2020, the health crisis caused a shock that revealed a clear weakening of our productive system in France. This awareness only confirmed the need to recreate an adaptable and innovative local productive fabric and to decarbonise the industry. To meet this need for productive resilience, OpenStudio and the Clermont-Auvergne University are working together to develop a tool using artificial intelligence called "Atlas des Synergies productives" [Atlas of Productive Synergies]. Since 2011, a team of Harvard researchers led by Ricardo Hausmann[48] has been developing an Atlas of Economic Complexity[49] based on imports and exports per country[12]. The Atlas of Productive Synergies is a decision-making tool to "reconcile public decision making and territorial knowledge", which is based on Harvard's work, and draws on the numerous data released at the regions' level[50].

What is "Productive Resilience"?

During the lockdown, we first experienced shortages of essential products, then we witnessed companies adapting quickly by making very few changes to their production facilities to manufacture the products that were missing: masks, hydroalcoholic gel, visors, scrubs, etc. This crisis revealed that an improvement in France's productive resilience was possible, but above all that it had to be done on a larger scale, very quickly, by developing a certain productive

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[48] https://growthlab.cid.harvard.edu/people/ricardo-hausmann-0

[49] https://atlas.cid.harvard.edu

[50] https://www.openstudio.fr/2020/11/03/les-donnees-territoriales-et-intelligence-artificielle-au-service-de-la-resilience-productive/

autonomy. The concept of "productive resilience" is defined by the capacity of a territory or a company to mobilise actions and synergies in an adaptable way to respond to a shock or to find new outlets. To achieve this task, the Atlas of Productive Synergies maps all the economic actors in a defined territory who could work together in a local production process.

Below
The Atlas of Productive Synergies uses AI to make recommendations to improve the productive resilience of territories and to develop the circular economy.
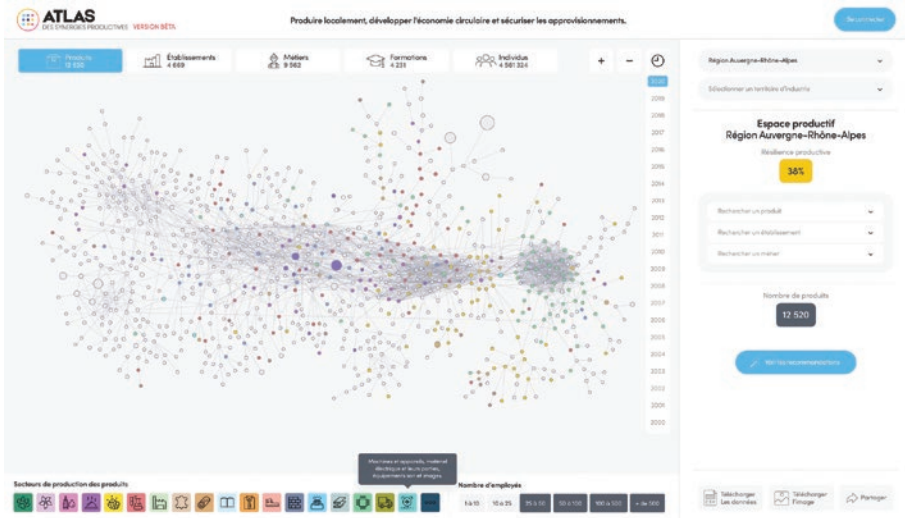
AI to support productive resilience

Artificial intelligence is obviously of prime importance: this is the technology that will make it possible to process the volume of data that is essential for linking the various economic players in a territory. The use of AI offers a recommendation system for the companies of a territory and the development officers. AI will suggest to companies potential customers or suppliers nearby, in a personalised way. AI can also suggest to a company to develop a new type of product, by making a leap in productivity, i.e. a slight evolution of its production tool, which will enable it to manufacture the part that is missing in its entire ecosystem (leap in productivity from product A to product B). Finally, AI will identify strategic products to be developed on a territory to improve productive resilience and thus secure supplies while limiting its carbon footprint.

How can this Atlas help to decarbonise industry?

In addition to the possibility of strengthening and diversifying the industrial fabric of a territory with an economic development purpose, the ecological side of the approach is absolutely fundamental. Indeed, the Atlas of Productive Synergies will make it possible to limit imports and to make local production a priority by relocating industry in a rational way to smaller areas. Thanks to the Atlas of Productive Synergies, it will be possible to set up strategies for relocating production to form an industrial network consistent with the energy transition currently taking place in France.

ADÉLAÏDE ALBOUY-KISSI
Lecturer and researcher
in computer science
at Clermont-Auvergne University

Through the Atlas of Productive Synergies project, how can AI help reindustrialise territories?

The basic idea is to consider primarily that the economy can be decarbonised and that we can get away from the binary approaches, between the "pro-globalism" supporters on the one hand, who do not want any type of autarky, and the "ultra-localism" supporters on the other. Our position is that, given the climate challenges, industry must be reintegrated into the territories, and this must be done in a framework that gets away from the Manichean debate on local production. Thanks to AI, we can process a lot of data that will enable us to make decisions and validate them in a rational way. This is in line with the idea that in the 2050 era, the "post-carbon era" as researchers call it, we will be able to imagine a more circular economy, more integrated, more local, more distributed across the territories and more environment friendly. On this basis, public policy development actors will have to appropriate a number of economic indicators. Thanks to AI, we will be able to bring all these indicators in line with public policies, so that our ideals are transformed into feasible and tangible actions.

How does your project fit into the ecological transition?

As I said, the purpose is to decarbonise industry, so we need to encourage local distribution channels and limit the transport of manufactured products as much as possible. Another advantage is that by diversifying our industry, it will be easier to deal with climate change or health crises like COVID-19. We will be able, in strategic fields, to produce locally, or to create synergies between the know-how of the same territory to compensate for the lack. And if the territory really doesn't have any solutions, we could imagine plug & play companies, i.e. the possibility of the territory hosting a small production unit that will function like a Lego: it would be modular and able to take root in the territory to create a productive value chain. Thanks to this tool, we shall have a long-term solution that shall enable us to significantly decarbonise the economy by creating actual productive synergies in the long term, and also a temporary solution that may enable us to react in the event of a climate or health emergency.

PART 3

Environmental issues of AI

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It is important to be aware that AI is a multifaceted technology. It is even essential not to bury our head in the sand, in order to start on the right trails, in search of innovations that will limit the harmful effects of AI development. Keeping our eyes wide open to the current drifts does not prevent us from believing in the potential of AI. We now have a duty to keep control of it in order to reap its benefits without dooming our future. We must resolve today to use AI intelligently and responsibly.

The smokescreen of digital immateriality

As you may have noticed, for the past few years we have been overwhelmed with emails and letters urging us to decide to go paperless with our documents. Gone is the paper, replaced by the digital, but is it really more ecological? We tend to think that digital is "cleaner" because it is only virtual. But digital is anything but immaterial. As Florence Rodhain points out in her book La nouvelle religion du Numérique : Le numérique est-il écologique ? [The New Digital Technology Religion: Is Digital Technology Green?] [16], the evanescent vocabulary used in the field of ICTs could lead us to believe that the digital world is not well-grounded. However, this famous change to paperless and the storage of data in the cloud have a very real and palpable physical presence: cables, chips, and servers that are often well hidden so that they are forgotten by the general public. The fantasy of a full virtual dimension is also often associated with AI, whereas this branch of digital technology involves physical resources that can be considerable. Its environmental impact is therefore undeniable.

Opposite
Digital is not immaterial.
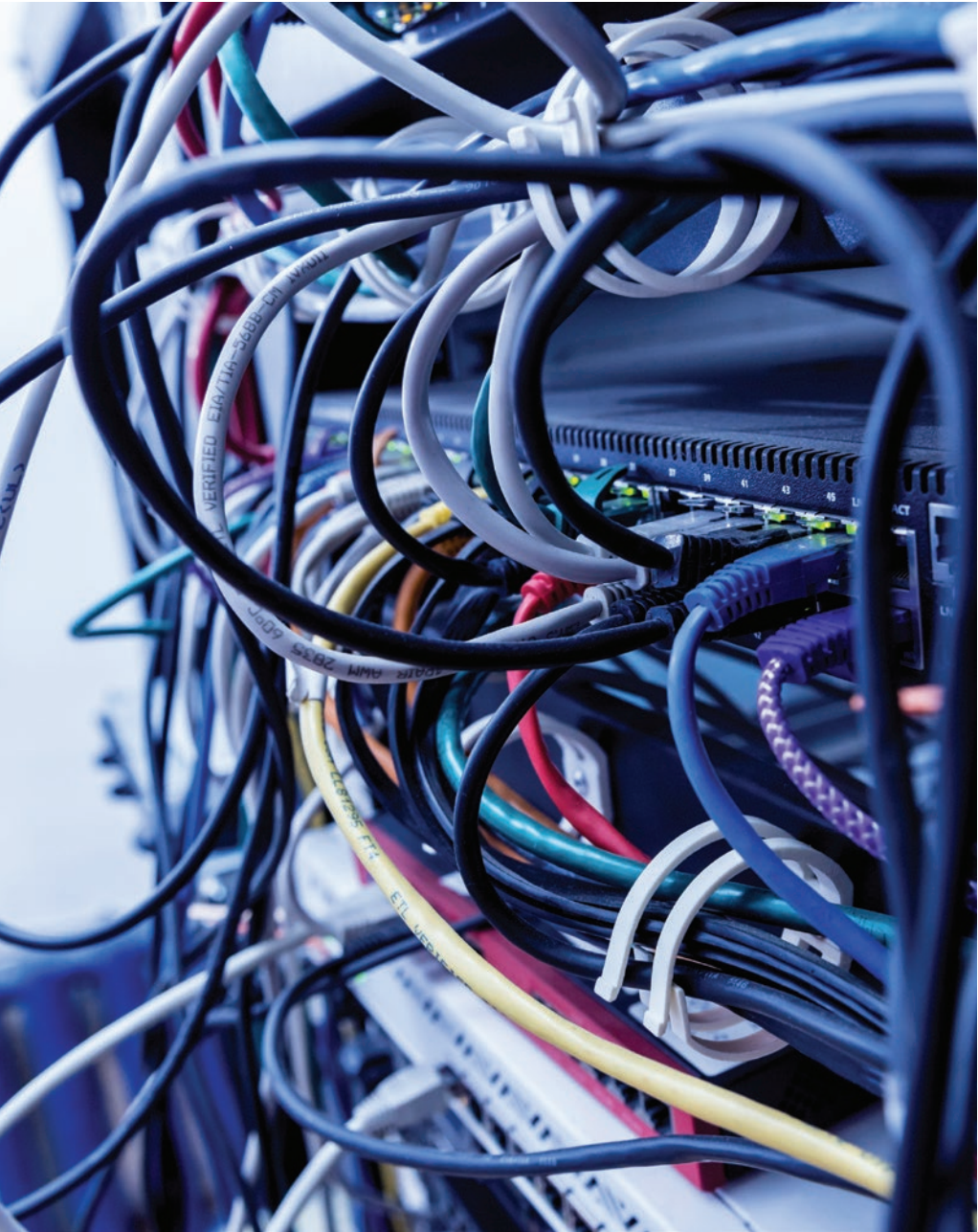
VINCENT COURBOULAY

Teacher-researcher at La Rochelle
University, Co-founder of the
Institut du Numérique Responsable
© *La Rochelle Université - Mélanie Chaigneau*

Why is digital technology currently considered one of the most polluting sectors on the planet?

Digital technology has two faces, like all solutions have, from vehicles to medicines or money... Everything stemming from human economy has a more or less dark side and digital technology has the particularity of impacting the environment throughout its whole life cycle. From the extraction of the materials that are needed to make it, to the fact that it is not handled at the end of its lifecycle, all stages of digital existence are harmful to the planet. First of all, the extraction of minerals and rare earths is carried out in catastrophic conditions, both environmentally and in terms of health. It causes the depletion of biodiversity, does not respect health standards for the people working in the mines, uses highly polluting acid solutions, and requires massive use of primary energy. Once these raw materials are extracted, they are then transported to factories in South-East Asian countries, where the environmental and health conditions are again deplorable. The manufacture of digital objects alone accounts for three quarters of the negative effects that this type of products can have on the environment. Then you have the pollution of transporting them in containers on cargo ships. And then you have the necessary infrastructure such as data centres and terminal equipment that will use energy to run it all. Entire agricultural areas are being wiped out the map in order to build more and more data centres that will support all the 4G, 5G and soon 6G technologies. Once this equipment has reached the end of its short life, it is mostly found in mafia circuits and dumps.

Can we put a figure on the impact of digital technology on the environment?

To give you an idea, digital technology pollutes more than civil aviation! Digital technology is responsible for about 5-6% of greenhouse gas emissions. It consumes about 10% of the world's electricity and this figure is constantly rising. Lastly, we will soon reach nearly 80-90 billion kilos of electrical and electronic waste, including digital objects.

Which uses actually pollute?

Your purchases. Everything you buy pollutes, whether it's hardware, smartphones, TV shows or movies… And then the use of those videos and photos. When you buy a car, what pollutes is buying a new one and then leaving the engine running. It's the same with digital: what really pollutes is the purchase and then leaving the servers running. The more data you store, pictures, videos, the more it makes the data centres run, which are like engines that run 24 hours a day.

Digital technology is a drain on scarce natural resources

Today, the large-scale production of digital objects is to a considerable extent responsible for the depletion of the Earth's natural resources. Whether it's the manufacture of consumer devices (smartphones, tablets, etc.) or related to the spread of AI (sensors, cameras, robots, etc.), the problem is the same: the materials they are made of are becoming increasingly difficult to extract. The more digital technology gains ground, the deeper we dig to find those precious metals and rare earths that are essential for the production of these digital objects[3]. From the depletion of scarce natural resources to soil pollution and deforestation, ever-expanding mining operations are causing serious environmental damage.

Below
Extraction of rare earths in China.

© Reuters

CÉDRIC VASSEUR
Lecturer and trainer
in AI and robotics

To develop AI, we need rare materials and therefore have to draw on natural resources that are not renewable. Can we believe in the development of AI if we can no longer find these rare earths and precious metals that are essential for the manufacture of connected objects?

It is believable because other manufacturing techniques are about to emerge. For instance, a company called LightOn uses laser beams with glass plates to make AI. Work is also being done on biological processors that use organic material. Even though most AI development today does indeed use rare metals, some research is underway into new materials and new processes that are more environmentally friendly and require fewer rare metals. Efforts are also being made to find ways of reprocessing these rare metals to avoid wasting them and causing them to disappear. Since these are rare and therefore expensive products, and since we are in a consumer society, we are necessarily trying to save money by using less non-renewable materials. It's just as simple as that. There is ecological thinking, but the financial thinking behind it will lead us to find other solutions. The day we succeed in incorporating fewer rare metals in our mobile phones, we will really be on the right track.

© Joshua Sortino, Unsplash

Energy-consuming data centres

In addition to the various forms of pollution caused by the manufacture of connected objects, we shouldn't forget the data centres used to store all the data collected in the cloud. A cloud that devilishly weighs a lot[1]. All these overheated servers are monsters that swallow phenomenal volumes of water and electricity. Hidden under the ocean or in air-conditioned sheds out of sight, these data centres are not necessarily known to the general public. The Internet user who innocently sends an e-mail does not suspect that it passes through cables and ends up on ultra-energy-consuming servers. When we save our 3,000 holiday pictures in the cloud, we don't even perceive we are spending energy, yet they are stored in these physical places, on servers that are growing exponentially to meet our ever-increasing needs. Today, there are 8.4

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[1] *https://www.lebigdata.fr/cloud-energie-chine*

million data centres around the world[2]. This figure is defi-
nitely not likely to decrease with the widespread use of AI
and deep learning. To train itself to identify a type of ob-
ject in a picture, for instance, it needs many hours of
training and therefore powerful servers that run conti-
nuously for months. The interest of AI also lies in its abi-
lity to process huge volumes of data to help make decisions.
Just like our 3,000 holiday pictures, all this data must be stored
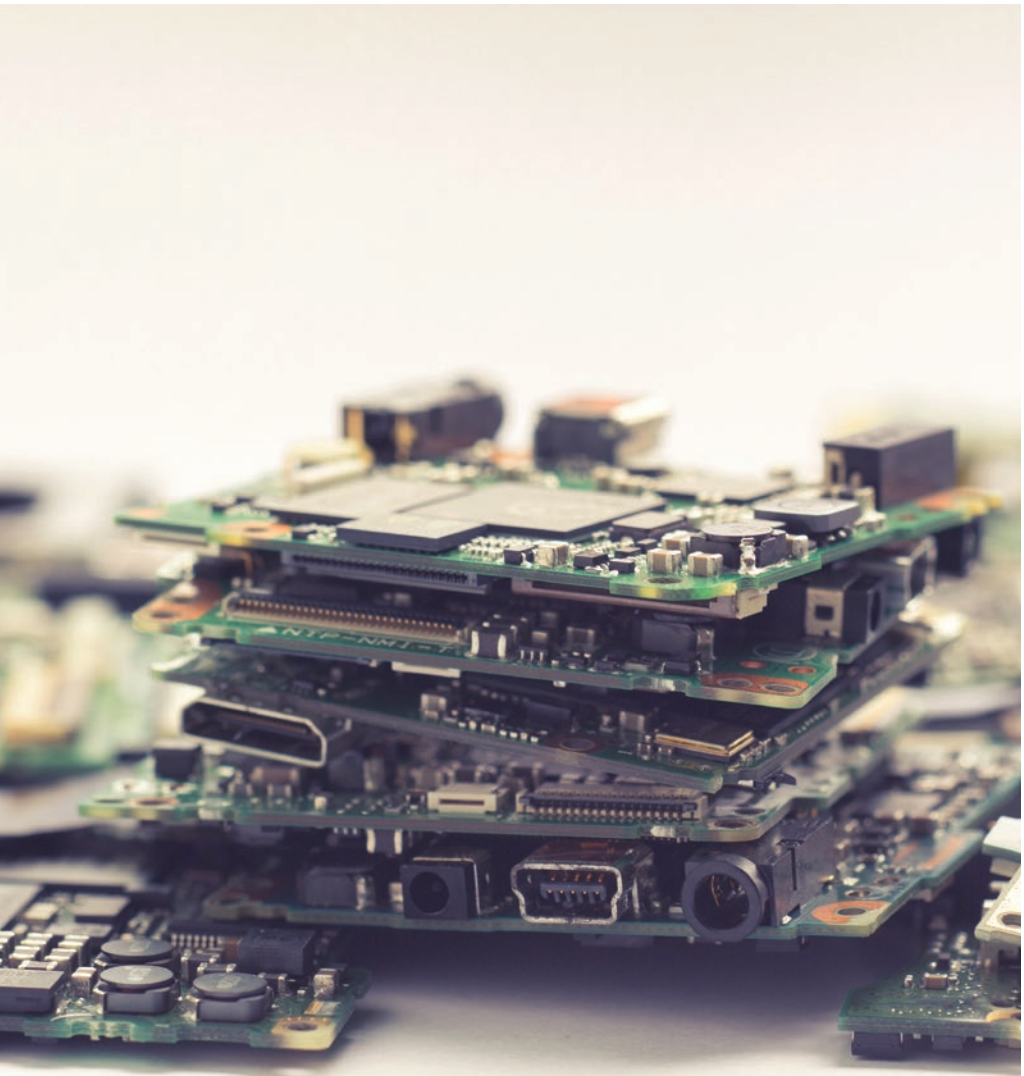somewhere. So AI is rapidly generating very high energy costs.

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[2] _https://www.statista.com/statistics/500458/worldwide-datacenter-and-it-sites/_

Electronic waste piling up

According to Éric Vidalenc, a specialist in energy issues, "the more high-tech a product is, the less recyclable it is". Based on a study by the Belgian recycling company Umicore, he reveals in his essay Pour une écologie numérique [For a digital ecology] [21] that out of 60 metals contained in a smartphone, only 17 are likely to be recycled. The concern is the same with the equipment needed for AI to function. Sensors, robots, and other intelligent cameras are crammed with technology: they are already being used more and more frequently in our everyday objects and they will end up being thrown away sooner or later. E-waste that

> [...] out of 60 metals contained in a smartphone, only 17 are likely to be recycled

has a recycling rate close to zero due to its miniaturisation and the multitude of materials it is made of. Obviously, this waste does not remain in Western countries under the eyes of consumers; it is sent to developing countries in Africa or Asia, which are overflowing with our old, out-of-use equipment[3]. This has catastrophic ecological consequences for the local population, who cultivate soil polluted by the dissolution of heavy metals present in these digital objects. Not to mention the chemical products that are essential to the production of ICTs: phthalates, solvents, nonylphenols, etc., which seep into the water table and pollute the water [3].

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[3] *https://www.digitalbusiness.africa/dechets-electroniques-comment-lafrique-est-devenu-ledepotoir-de-leurope-et-quelles-solutions-adopter/*

The rebound effect of digital technology

What is the rebound effect? In the context that interests us, i.e. the impact of digital technology, and by extension AI, on the environment, it is the cancellation of the beneficial effects of a technology due to the new behaviour it induces. Let's give a concrete example everyone will understand: paper consumption. We might think that the famous digitisation would have had a positive effect on our paper consumption and would have helped to slow deforestation. Unfortunately, the situation is quite the opposite. According to the authors of the book Impacts écologiques des Technologies de l'Information et de la Communication [Environmental Impacts of Information and Communication Technologies] [11], a report shows that global paper production amounted to 375 million tonnes in 2009, whereas it was around 170 million tonnes in the 1980s. Why is this happening? There are several explanations: first of all,

© Christa Dodoo, Unsplash

the Internet has given us access to a mass of printable information. Second, it is now very easy to get a printer, so everyone can print their documents at home, which was not the case before. Finally, even if our important documents are sent to us by email, the temptation is great to keep them on multiple storage spaces: USB key, external hard drive, not forgetting a paper copy.

Another very noticeable rebound effect relates to transport. Thanks to the Internet, we have the possibility to communicate easily from anywhere in the world. Therefore, videoconferencing and teleworking should have reduced our business travel and the pollution caused by transport. As human contact is still preferred, travel has not decreased. For those who have chosen to telework, it often means a longer distance between home and work, which means more travel time when they still have to go to work from time to time. So digital technology has not solved the paper problem, nor the transport pollution one, as promised, but rather has amplified them. This therefore raises the question of whether AI applications such as autonomous cars would not have the same undesirable result. This is the point of view defended by the website Reporterre.net in an

> **autonomous vehicles would therefore be a great opportunity to reduce energy costs and CO$_2$ emissions linked to mobility**

article denouncing the rebound effect that could be caused by the generalisation of autonomous cars, which have nevertheless been announced as the future of sustainable mobility1. In particular, the article mentions the report by the financial analysis firm Morgan Stanley [18], which argues that an overly attractive autonomous car would have three major negative outcomes: it would draw people away from public transport, it would multiply the number of vehicles on the road, and it would extend travel times as driving fatigue would no longer be an issue: "If the automobile becomes a stress-

free moment of comfort that offers the consumer his or her own private space, flexible hours, and almost no driving tasks, the consumer could avoid the inconvenience of public transport by opting to "drive" a personal autonomous vehicle." As mentioned in the first part of this publication, autonomous vehicles would therefore be a great opportunity to reduce energy costs and CO_2 emissions linked to mobility, if this technology were initially reserved for shared transport.

LAURENT BERNARD

Co-founder of Ecojoko company

What can be done to raise everyone's environmental awareness?

Studies show that in France, people want to take individual action but cannot find solutions. It's not a solution to tell them not to travel by plane, it's just a constraint. Simple actions should be proposed to them. France is a major world power, I believe that a French person consumes three times the resources he or she should, and other countries will soon reach our western standard of living, so we must show the way. If we step down, the other countries will follow. This is virtuous. It will take time, Rome was not built in a day, but it makes sense to start proposing another model. For our part, what we want to pass on goes beyond a simple reduction in electricity bills, even if this is not negligible, it is also another way of considering life, to seek a little less comfort and consumerism for more sobriety. We are convinced that this kind of sobriety can be cool, nice and fun, while being far from the old models, i.e. consuming more and more, cheaper, but with poor quality products. You cannot force people, the French state has been telling us for 50 years how to regulate our home's temperature and people don't do it, so this is not the way to get them. What is needed is to get the message across in a benevolent and very targeted way. Instead of being unclear about the average amount of money that could be saved, we'll tell you how things are going in your own home. We can tell you that you have spent €150, and that you could go down to €30 and we are able to provide you with the solution directly! If people try it and see that it works, they will stick to those good habits. It's a paradigm shift, giving a measure and the means to improve it in a positive way through a fun and very simple application.

Digital malpractices

Throughout their lifecycle, connected objects cause various ecological disasters: extraction of rare, non-renewable materials, energy-intensive data centres, difficulty in recycling electronic waste, and even an increase in paper consumption. Pollution of the soil, water and air, digital technology is far from being virtuous to date. To sum up, the more computer equipment we manufacture, the more powerful our Internet speeds, the more we damage our environment. This alarming observation raises questions, because if we want to continue to benefit from the comfort digital technology brings us, to develop the use of high technology such as AI and to live on a breathable planet, it is high time to question certain practices that are the antithesis of an eco-friendly dynamic.

Planned obsolescence

As we have seen before, we know that very little e-waste is recycled, ending up in dumps on the other side of the world. One of the reasons for this increase in e-waste is the early obsolescence of our digital devices [3].

We can speak of planned obsolescence when the reasons for buying new digital equipment come from worn-out and irreplaceable batteries, peripherals that are no longer adapted, or software updates that are incompatible with our current devices... More powerful, more efficient, more beautiful, and sometimes even more "ecological", the marketing arguments are also overabundant to make us believe that our devices are obsolete and must absolutely be replaced by new ones, even if they are still operational. It is not difficult to understand why the French keep their smartphones for only one and a half years on average.

This premature obsolescence is also due to the lightning progress of digital technology, particularly AI, which requires constant renewal of computer equipment to adapt to new discoveries and remain efficient. Moreover, AI algorithms, which are sometimes very complex,

One of the reasons for this increase in e-waste is the early obsolescence of our digital devices

require impressive computing power, which will inevitably accelerate the wear and tear on the computers we use. The obsolescence of digital objects, accelerated by all the reasons we have just detailed, increases the amount of waste but also the production of this equipment, and therefore the depletion of the rare natural resources required for their manufacture.

VINCENT COURBOULAY

Teacher-researcher at La Rochelle University, Co-founder of the Institut du Numérique Responsable

© *La Rochelle Université - Mélanie Chaigneau*

In your conferences, you recommend that we get our broken appliances repaired, but this is often impossible or much more expensive than buying a new one, so how can we be "digitally responsible"?

80% of the appliances that are replaced are repairable. But asking this question is already asking the question too late. We should ask ourselves before we buy: how do I buy and what do I buy? We can start by choosing appliances the most common breakdowns of which can be easily fixed. We must also make companies understand that it is a major financial issue to renew machines as late as possible, then offer them a second life, or even a third life in associations for instance.

These are actions that we can take as individuals or as companies using digital technology, but isn't there something that can be done in the digital sector to ensure that manufacturers produce more long-lasting and repairable devices?

Some good initiatives and attempts have already been made, but there is a market out there. I think we should rather act at the political level. There are a certain number of laws that have already been passed and others that are coming up on repair and durability, which will change the situation, because they will provide the necessary information to the consumer. If they are informed, most of the time consumers will opt for repairable or more virtuous equipment.

You defend the principle of digital restraint, but how can we do this when digital technology is everywhere in our lives?

To adopt the right actions, you must already be informed and aware of the impact of digital technology. You cannot ask people to use their cars less if they are not aware that their cars pollute. They also need to have an idea of what really pollutes. We can try to delete the 3 kB email we have just received because we think it won't be stored in the data centres, but if we then want to binge-watch all the seasons of Black Mirror in 4G, or take a picture of our coffee cup because the foam has drawn a four-leaf clover and post it in very high definition on all our social networks, we should start asking ourselves some questions. Restraint can be a little bit guilt-inducing. We should therefore ask ourselves an essential question: "Do I need it, or do I want it?" If the answer is "yes, I want everyone to see my cup of coffee", then we know that this desire has an impact, and we will think twice about it. But if I need to do a video conference with my clients because the financial health of my company depends on it, it's not the same issue. I used to say: "If you need it, do it; if you want it, don't do it." However, the problem with what we want is that we also need to treat ourselves, although today we live in a society where the climatic and social emergency is such that we really have to ask ourselves whether this desire is necessary.

You are a university teacher and researcher, so you work with students. Young people often feel very concerned about the environment, but they are also very connected. Do you think it would be possible to ask these young people born with the Internet to use digital technology in a responsible way?

This is a question I am often asked. I'm 43 years old and it's my generation and our parents' generation that are to blame. It's not reasonable to ask young people to make this effort, when indirectly they're already doing the job, because they often don't have much money and they don't constantly replace their digital devices and keep them even when they have a broken screen. Just because they watch Netflix doesn't mean we should blame them, while we cram into air travel, new cars, and the latest devices because we've reached a certain financial security. So let's inform young people and leave them alone. All the more so as the social networks they use are designed to be as addictive as cigarettes.

The new generations are familiar with using screens from early childhood, including at school, isn't this conditioning them to massive use of digital technology?

We are starting to move away from the all-digital approach in schools. Politicians are changing their minds. It's true that for 10 or 15 years, digital technology was the Holy Grail, but today we're starting to have the benefit of hindsight and to move towards greater restraint. The lack of resources in local authorities also means that we are now pushing for a little more digital restraint, at least in France.

Useful digital technology versus Futile digital technology

New technologies are a source of incredible progress in many areas. Digital technology has quickly become essential in our personal and professional lives. The aim is thus not to go backwards, but to innovate without forgetting our common sense. Today, certain uses of digital technology, such as the widespread use of tablets in schools, denounced by the engineer Philippe Bihouix [4], or the digital e-book readers, condemned by Florence Rodhain [16], are actually proving to be of little benefit and even less ecological. In order to find a balance between the development of new technologies and a strong ecological awareness, the question of utility seems essential.

> **In order to find a balance between the development of new technologies and a strong ecological awareness, the question of utility seems essential.**

This issue of the usefulness of digital technology is particularly relevant in the field of AI. As we have seen, AI is used in many environmentally friendly projects, while being a very energy-intensive technology. When AI is used to suggest which series we might like on our video platform, or to complexify the reactions of characters in video games: the ecological cost seems disproportionate.

But appearances can be misleading, as we have seen, there are many AI technologies that have been created specifically for their ecological utility. But sometimes the cure is worse than the disease. Some applications of AI tools and more broadly of digital technology have a real benefit for the environment, others raise questions.

The Shift Project, a think tank chaired by energeticist Jean-Marc Jancovici, after having issued alarmist reports on our reckless use of digital technology and its consequences on the planet, has produced a new study proposing solutions to measure the actual interest of a technology on the environment. This would be an evaluation method called SMERT[4] (Smart Technologies Energy Relevance Model) which would enable us to know whether the energy saving achieved by the technology implemented is greater than the energy expenditure of this tool itself. The whole lifecycle of the technology needs to be scrutinised to measure its actual environmental benefits. The

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[4] *https://www.msn.com/fr-fr/actualite/technologie-digital/faut-il-encore-essayer-de-concilier-num%C3%A9rique-et-environnement/ar-BB1a3Xxj*

Shift Project reports among others the example of connected lamps that vary the light level in a room depending on whether people are present or not. According to the analysis carried out using the SMERT method, they would be useful in the case of collective use (offices, for instance) but not in a private home. Many parameters therefore need to be taken into account, a laborious but essential task according to the members of the think-tank, who would like society to move away from the idea of "instinctive digital technology" towards "thoughtful digital technology".

VINCENT COURBOULAY
Teacher-researcher at La Rochelle
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Do you think artificial intelligence and sustainable digital technology are compatible?

Yes, but not in the way it is currently being done. Artificial intelligence should be turned towards humans instead of humans being turned towards AI. With a genuinely useful AI that can be fully used and shared by everyone, yes, I do think it would be an actual opportunity for the environment. Using AI to predict pandemics, to find new medicines, to anticipate where this or that climate disaster is going to happen, fine. However, if we use AI to be told that we have brushed our teeth well, apart from perhaps the top left tooth, then we are on two levels of action: an action of utility and an action of futility.

The futility side of AI is often the one that gets the most media coverage...

Yes, it's like with smartphones, there was a time when each new functionality appeared, it was quite showcased, and finally today all smartphones do almost the same thing. Today, to stand out, the trend is rather to focus on batteries that last a week and consume less energy. For AI, it will be the same. There will be a period that will allow each slightly silly innovation to stand out and then at some point, when it is made more accessible, we will come up with a responsible artificial intelligence. Our role here is to ensure that this period is as short as possible.

LAURENT BERNARD
Co-founder of Ecojoko company

You use AI for Ecojoko, but do you think AI is always the right answer to solve environmental issues?

Technology as a whole has proven to be an effective tool for problem solving. AI is a tool among others, low tech tools can be as relevant as AI. In the end, it doesn't matter what the means are, the important thing is the result. And above all, what matters is the problem to be solved. AI, like any other technology, can be useless if it solves a problem nobody cares about. Regarding the environment in particular, it is a very powerful tool, we can do things we were unable to do 5 or 10 years ago. Developments are fast, AI is an exceptional accelerator, we would be unable to offer our solution without AI. It can be criticised in many other ways, but the key question remains: what problem are we solving? If AI is used, for instance, to optimise algorithms on our personal data to better target us and sell us consumer products, then we are not dealing with the same goals! From a business point of view it's interesting, but will the planet be better off, I don't think so. The good news is that in France there are many people concerned about environmental issues. Everyone should propose solutions, companies, associations, politicians, we need everyone on these environmental issues. With our skills, we try to propose a solution, but given the problems that arise, we all should get involved.

Digital obesity: a diet is needed

Frédéric Bordage, creator of greenIT.fr and apologist for digital sobriety, tackles the phenomenon of bloatware, a contraction of the words bloat and software, in his practical guide [6]. The "obesity" of websites, this digital "bloat" is one of the factors of planned obsolescence. The more poorly constructed a software program is, the heavier it is to use, which leads users to regularly change their smartphone, computer or tablet to gain performance. To better understand this problem of bloatware, Frédéric Bordage gives a very revealing figure: the average weight of a web page has multiplied by 115 in 20 years, going from 14 kb in 1995 to 1600 kb in 2015⁵, a weight gain that is of no actual use since the provided service is still the same, especially when it comes to buying a train ticket or checking one's bank account. Apart from the acceleration of planned obsolescence, it is important to know that a website that is too heavy will unnecessarily mobilise the Internet network and its physical servers. Given this, how can we ensure that AI does not further burden an already overweight digital tool?

Hereafter
The 70 KB of software that made it possible to go to the moon in 1969 is now barely enough to send an e-mail[5].

⁵ https://www.greenit.fr/2015/06/04/comment-reduire-l-empreinte-environnementale-du-web/

© Nasa image and Video Library

Developing a green AI

The energy cost of AI is not yet really taken into account. Researchers working to develop new AI methods focus mainly on the accuracy of the results obtained: number of different objects recognised in a picture, prediction score, etc. These are important indicators, but they must be put into perspective with the energy cost that was necessary to obtain each score: for instance, does a gain of a few thousandths of a percent in recognition always justify an energy cost multiplied by 1,000? The answer will not be the same when it comes to detecting a serious disease and saving lives, or when it comes to an online video recommendation system. The example of platforms such as Kaggle[6] illustrates that awareness of energy costs (both financial and environmental) among data scientists is not yet widespread. Kaggle organises international prediction competitions where teams from all over the world compete to get the best prediction score from the same dataset. There is never any question of efficiency. However, several studies have been done on the energy efficiency of AI by comparing the efficiency of various methods [15, 14, 9]. But in 2019, a publication by a team of researchers from the University of Massachusetts came as a bombshell within the AI community. This team measured the energy required to learn an AI model for natural language processing [19]. This deep learning model named "Transformer"[7] was introduced in 2017 by Google [20]. The originality of this study was to take into account the overall energy needed to develop the model. Indeed, the development of an AI always involves long phases of testing to calibrate the system: during the learning phase

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[6] https://www.kaggle.com

of a model on the one hand (phase when the AI looks for an optimal value of the weights of its network by successive tests), but also during the search for so-called hyperparameters. These are a series of global parameters that define the architecture of the network and the learning parameters.

Each time a new hyperparameter is tried, a complete relearning of the model is necessary. Thus, after many trials, an optimal model is determined. In the example quoted by the Massachusetts team, the overall cost of developing an AI turned out to be 3,200 times greater than the cost of learning a single model.

The research team compared the CO_2 emissions required for the overall development of a Transformer-type model and compared them with known CO_2 emissions for typical energy expenditure[8]. The study found that the development of this AI generated as much CO_2 as 5 cars over their whole lifetimes and as much as 315 airplane return trips from New York to San Francisco.

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[7] *https://medium.com/inside-machine-learning/what-is-a-transformerd07dd1fbec04*

[8] *En se basant sur les émissions de CO2 moyennes par Kw/h aux Etats-Unis, qui peut donc varier selon les pays.*

Consumption	CO2e (Ibs)
Air travel, 1 passenger, NY<-> SF	1984
Human life, avg, 1 year	11,023
American life, avg, 1 year	36,156
Car. avg incl. fuel, 1 lifetime	126,000

Training one model (GPU)	
NLP pipeline (parsing, SRL)	39
w/ tuning & experimentation	78,468
Transformer (big)	192
w/ neural architecture search	626,155

Above
Estimated CO2 emissions for language processing AI learning, compared to current consumption [19].

FÉLIX MICHAUD
PhD at La Sorbonne Center
for Artificial Intelligence

AI is part of a larger sector, the digital technology one, which we know is a very polluting sector, partly responsible for the depletion of forests, air and water pollution: how can we reduce this harmful impact to keep only the best of AI?

It's complicated. Indeed, digital technology poses big problems in terms of resources used and habitat destruction, but I have also read that AI researchers are increasingly aware of energy issues. Some companies are embedding algorithms in their code that will calculate their energy consumption. We are beginning to understand that we should not engage in a technology race without taking the planet's limits into account. More and more energy and climate specialists agree. Jean-Marc Jancovici* explains that, thanks to energy resources such as oil and coal, we now have machines able to do the tasks of a million people, with just one person at the helm. When economists conceived this model of mass production, they did not take into account the limits of the Earth's resources. Until today, we have always done things without taking into account "the rights of the nature". Soon, we will run out of oil, and we will have a big energy issue, as Mr Jancovici says. We will therefore have to be reasonable and invest in new technologies that are really useful and efficient, and no longer run an algorithm for months so that an artificial hand can solve a Rubik's cube. For me, AI research must come in the scope of the historical, political and ecological context in which we live. We need to carry out research in line with our present and to preserve our future. Personally, this is the path I want to take: to carry out scientific research for the benefit of the ecology and to campaign to make as many people as possible aware that we must be attentive to our planet.

* *Jean-Marc Jancovici is a French engineer, consultant and specialist in energy and climate*

CÉDRIC VASSEUR
Lecturer and trainer
in AI and robotics

Today, environmental issues are a concern, do you think AI is an opportunity or a threat for the planet? Is it both?

I would say both at the same time! It's a bit like pouring water on a field, if you use it wrongly you might flood the crops, but without water nothing would grow… So it has to be used wisely at the right time. AI offers a lot of opportunities to improve things on an ecological level. But it becomes a threat when it is developed for futile purposes, like detecting cats in a picture. Just to recognise a cat in a picture, it requires a lot of energy, a lot of calculations, and heat, which is not good for the environment. At the present time, we are still in the analysis and development phase, AI will be increasingly streamlined as time goes on. Companies like Facebook are already committed to using green energy for their research.

So for you the digital technology sector is becoming more aware?

Yes, the new generation needs their work to make sense, and a sense of ecology is something that is quite strong. Now it is more and more rare for a company not to be interested in the environmental and ecological impact of its work, so whether you are in AI or something else, ecology is important. This awareness is gradually emerging year by year.

Would it be possible to find a balance and be more responsible about our use of digital technology and the development of AI?

Even if, as I said, more and more companies in the digital sector are paying attention to their carbon footprint, there is still no organic AI label. Perhaps this will emerge little by little, as it already exists for household appliances with letters grades. This type of indicator would make it possible to better communicate on the actual consumption when using this or that AI. On the other hand, the Research & Development part also consumes a lot of energy, and no results are guaranteed. This may seem like a waste to the general public, but that's normal when you're conducting research, you don't know where you're going, you know that something will come out of it, but you don't know when. It's a bit like researching a vaccine, thousands of companies around the world will invest time, money and energy, but maybe only one or two will really find the solution.

Some people are pushing for a step backwards in our use of digital technology to limit environmental damage, do you think that slowing the spread of digital technology is possible and advisable?

A magazine has built its website on a little computer called a Raspberry Pi, in black and white and running on solar power only. So it wouldn't be impossible. This rebound may occur, and it would be a good thing to go back on certain technologies: for instance, to get information, we don't need to have HD pictures, videos and lots of ads. At least if we could limit the ads, it would not be bad. A step backwards, or at any rate a limitation, could be adopted for certain actions. However, the general public will find it difficult. If tomorrow people are told "there you go, you don't have a washing machine anymore, you don't have a dishwasher anymore, you'll have to go and clean your clothes in the nearest stream", I think that very few people will choose this step backwards. I'm exaggerating here, but it's the same with new technologies, if we were asked to limit the number of hours we use our computer and our phone, we wouldn't be willing to do that either. Unfortunately, we live in a consumer society, which means that the more we consume, the better our society runs, the more money it spends… etc. It would be very difficult to step backwards in the society we live in today. In any case, if there is a change to be made in the next few years, it must not be carried out by a single country. It must be a global choice, because if one country decides, and I'm going to say something stupid, to limit the number of hours a computer can be used per day in companies, and the neighbouring country has no limits, this will cause competitiveness difficulties. We really need technological and ecological rules at global level so that everyone is on an equal footing.

Ecodesign of AI

Compared to the consumption levels mentioned, the brain's very low consumption is a source of interest. Researchers are inspired by the way it works to develop AI methods[9]. They are seeking to save energy, particularly in the choice of hyper-parameters based on Bayesian optimisation or evolutionary algorithms. The French company Another Brain[10] is developing a new approach to bio-inspired AI that opposes deep learning and the volume of data and processing it requires. Little data and computing power are needed for this promising AI. Another energetic interest is transfer learning, which is a branch of AI that consists of reusing all or part of another AI and adapting it to meet new needs. In this way, AIs learn from each other, in the same way humans pass on knowledge. The principle is to save computing time, since it is not necessary to relearn everything, and thus to achieve the associated energy savings.

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[9] *https://www.nature.com/articles/d41586-019-02212-4*
[10] *https://anotherbrain.ai/home*

The same objective is also pursued by the Carbontracker[11] pro-gramme created by students at Copenhagen University, which measures and forecasts the energy consumption generated by a deep learning model. The aim is then to modify certain parameters in order to reduce its carbon footprint, for instance by reducing the computation time not required for a certain type of algorithm or by training its model in countries with a greater supply of green energy.

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[11] https://www.rtbf.be/tendance/green/detail_avez-vous-une-idee-de-l-empreinte-carbone-qui-se-cache-derriere-un-algorithme-de-deep-learning?id=10625814

Electronic components optimised for AI

Simultaneously, new neuromorphic chips are being developed to replace the transistors normally used with components directly inspired by neurons, in order to increase efficiency[12].
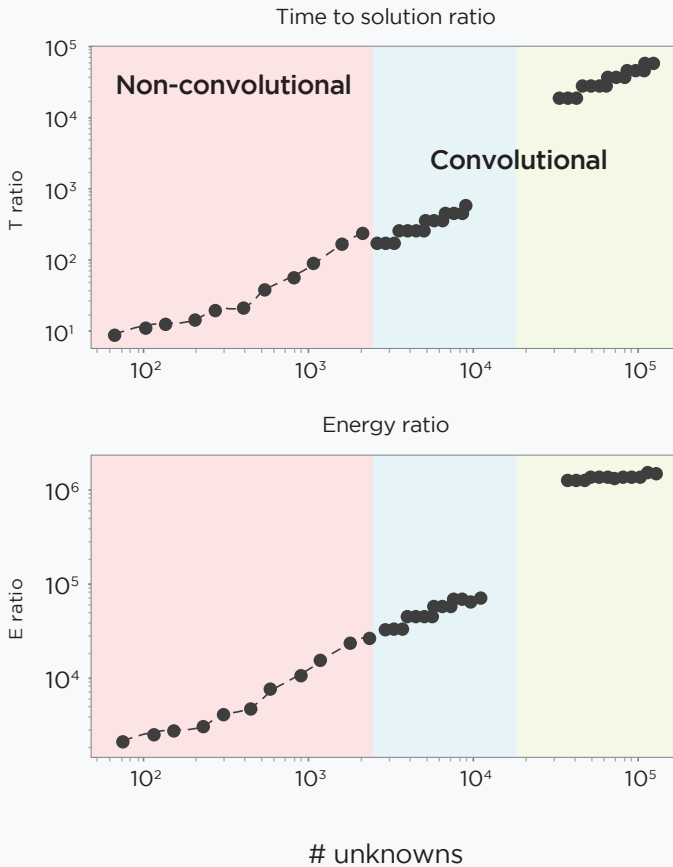
Intel claims that the new Loihi neuromorphic chip is 10,000 times more energy efficient than a CPU [10][13].

As for the chip manufacturer GraphCore, it promises a 20% energy saving with its IPU (Intelligent Process Unit) chips optimised for AI[14].

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[12] https://www.industrie-techno.com/article/intel-devoile-un-ordinateur-neuromorphique-a-8-millions-de-neurones.56725

[13] https://www.usinenouvelle.com/article/intel-construit-un-systeme-de-calcul-neuromorphique-a100-millions-de-neurones.N942576
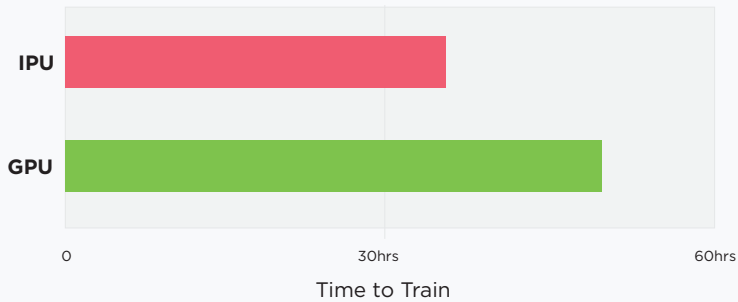
[14] https://www.graphcore.ai

Above
Ratios of execution time and energy required to solve a LASSO regression (between 60 and 120,000 unknowns) between a CPU and the Loihi neuromorphic chip.
Source : https://www.intel.com/content/www/us/en/artificialintelligence/posts/exploringneuromorphic-computing-forai-why-spikes-part-two.html

> 25% Faster Time To Train : 36.3 hours on IPU @ 20% lower power

Above

Comparison of the efficiency between GPU and IPU on the example of learning a language recognition model.
Source : https:// www.graphcore.ai/ posts/microsoft-and- graphcorecollaborate- to-accelerate-artificial- intelligence

Environmentally friendly data centers

As Cédric Villani [22] points out, efforts on the efficiency of AI architectures must go hand in hand with a "greening of the data center value chain." There have been many initiatives by data centers to use renewable energy to power servers[15] or to cool them, such as the partnership between the start-up Verne Global and the telecom operator Colt in Iceland[16].

The environmentally responsible hosting market is becoming more structured with the emergence of an energy performance indicator (called PUE) since 2007 by the consortium The Green Grid[17]. This indicator has been supplemented by the European DCEM (Data Centre Energy Management) indicator, which also takes into account reused and renewable energy.

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[15] https://www.zdnet.fr/actualites/microsoft-promet-des-data-center-fonctionnant-a-60-a-l-energie-renouvelable-d-ici-a-2020-39883543.htm

[16] https://www.lesechos.fr/2012/02/lislande-inaugure-le-premier-data-center-propre-351368

[17] https://www.thegreengrid.org

By using renewable energy, cooling servers with natural resources or reusing the heat emitted, environmentally responsible data centres represent the most important lever in reducing the CO_2 emissions necessary for the operation of AI. For instance, we can cite the example of the Green Mountain data center in Norway, which, by cooling its servers with fjords and rivers, has been able to cut its energy costs by more than half[18].

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[18] https://greenmountain.no/

Conclusion

It was a difficult but fascinating challenge to write a white paper at the crossroads of "ecology" and "new technologies". We have browsed through hundreds of references on the subject in which the authors set out their often diametrically opposed points of view. Two visions of the world seem to be in conflict: the conviction that technology will solve environmental problems and develop a green economy, creating wealth for society; and the praise of sobriety to save the planet, requiring a more general questioning of the current political system.

Is it possible to carry out an environmental policy that reconciles these two opposing visions in a measured way?

A virtuous AI with actual quantifiable gains will be able to solve environmental issues. AI is used today in many applications, without however always being of real interest. This has been the case with the emergence of other technologies such as blockchain or connected objects[1], and time will sort out gadgets from genuinely useful innovations.

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[1] https://www.rtl.fr/actu/futur/blog-numerique-ces-2014-les-objets-connectes-stars-a-las-vegas-7771237950

The scientific community must take up the ecological issues of AI, as it did with the issues of ethics and transparency[2]. AI is not immaterial. Requiring partly non-renewable natural resources, AI is a limited resource, which should be used responsibly.

AI must evolve towards more frugality by limiting as much as possible the resources it needs. Deep learning and the volume of data and calculations that go with it must be progressively replaced by other, less energy-consuming AIs, following the example of the start-up Another Brain. To put an end to Green Washing, we need to enhance projects that really integrate energy optimisation and demand transparency on the environmental impact of AI solutions.

Combining AI and energy transition is a delicate mission, but this challenge can also unite a virtuous ecosystem. By giving meaning to AI [22], Europe can play a leading role in the AI ecological revolution. In doing so, the ecological constraints of AI become opportunities for our companies to stand out by developing a specific know-how, such as a competitive advantage, linking AI and energy efficiency.

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[2] *After the awareness of the ethical issues raised by AI, dedicated scientific conferences were organised, providing researchers from all over the world with a means of publishing work aimed at limiting cognitive biases in AI and making it possible to explain a result. The FAccT conference is an example: https:// facctconference.org*

As a sign of an emerging awareness, at AI Paris 2020 show, for the first time two conferences were focusing on the energy consumption related to AI.

We are currently witnessing a strong orientation of AI towards more equity, responsibility and transparency. In this context, the environmental ethics of AI will naturally become a key objective.

The ecological transition of AI is underway.

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AI is a multifaceted technology.
On the one hand, AI is a great opportunity
to better understand and solve environmental
concerns, but on the other hand, the computing
power it implies leads to excessive energy
consumption. By committing to a responsible
use of digital technology, it will be possible
to find ways to make AI greener and free from
its paradoxes.

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