Smart & connected products: a new industrial revolution
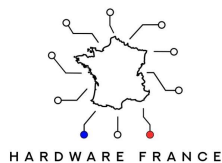
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EXECUTIVE SUMMARY

While artificial intelligence is revolutionizing the dematerialized world, it is also on the verge of revolutionizing the physical world.

Thus, we see new intelligent & connected products appearing every day, connected to reality and acting on it. This is only the beginning.

These new products have multiple advantages: innovative applications, instantaneous responsiveness, ultra frugality, servitization of physical products, reinforced data security, etc.

Analysts[1] estimate that this market will represent, by 2032, 140 billion dollars on an international scale.

France has many assets in this field: strong creativity, an excellent AI semiconductor sector, recognized know-how in the field of hardware products, a strong software industry, an ecological conscience, a strong sensitivity to respect for privacy and the responsible processing of users' personal data.

A new industrial revolution is underway, which affects all sectors of the economy. France must not miss it.

This white paper identifies the prospects of these new technologies and proposes concrete actions to respond to the challenges.

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[1] See the market.us market study on page 6.

WHAT IS EMBEDDED AI ?

Artificial intelligence as close to reality as possible

Also known as 'Edge AI', embedded artificial intelligence (AI) technologies are autonomous computing and electronic solutions that integrate AI capabilities directly into electronic devices, enabling them to make decisions and perform complex tasks themselves.

These new possibilities are the fruit of innovation work in two complementary fields: software on the one hand (e.g. optimisation and 'frugality' of neural network technologies), and electronics on the other (e.g. specialised chips for low-power AI programme execution).

Differences between Embedded AI and Generative AI

Generative artificial intelligence (AI) and embedded AI are two distinct sub-fields of AI, each with specific characteristics, applications and objectives:

- From an applications point of view, generative AI is mainly geared towards the creation of dematerialised services and content. Embedded AI, on the other hand, aims to provide AI functionalities on constrained hardware devices (for example, devices not connected to a fixed energy source and/or requiring very low latency).
- From a technical point of view, generative AI generally relies on remote servers capable of performing intensive calculations, which are then delivered to the end user via online services. Embedded AI, on the other hand, uses computing capacity located in devices operating at very low power consumption levels.

There is a gap of a few years between the advent of generative AI and that of embedded AI. This is due to the later maturity of embedded semiconductor technologies, which have to meet more demanding requirements.
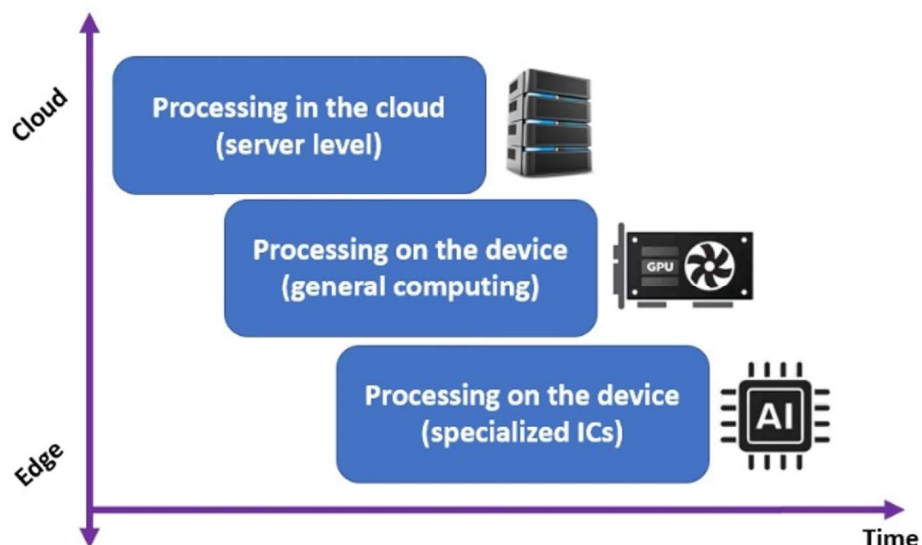
The deployment of 5G networks amplifies the potential of embedded AI technologies. Indeed, this generation of mobile networks has been specifically designed to offer low-latency connectivity, which is crucial for connected embedded AI solutions.

USER CASES

Health

- **Intelligent hearing aids**: Devices use AI to filter out ambient noise and improve sound quality for users, focusing on speech or specific sounds.

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French startup : WISEAR

Wisear is a French company that develops earpieces equipped with algorithms that interpret neural activity in real time to trigger a command action, silently and without contact..

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- **Medical diagnostics:** using AI to analyse on-board medical images and detect disease.

- **Personalised medicine:** genetic data analysis devices, implants that monitor physiological data (e.g. blood sugar levels) to maximise the effectiveness of treatments.

- **Surgical robots:** robotic assistance for precise surgical interventions.

- **Intelligent rehabilitation:** devices to speed up muscle rehabilitation

Smart Cities and Infrastructures

- **Building surveillance, securing public and private spaces using AI-assisted vision:** camera systems with embedded AI to ensure the security of a building or a public or private space (intelligent metering, control of access rights, etc.).

- **Real-time infrastructure monitoring** (telecoms, roads, gas and electricity networks, etc.)

French startup : ARTIFEEL

Artifeel is a French company that develops and markets 'Check'In' systems, infrastructure monitoring, surveillance and maintenance tools for a wide range of uses. In particular, they enable the detection of intrusions, obstructions or thefts from any infrastructure (e.g. telecoms networks, railways, pipelines, gas or drinking water distribution networks, etc.). These systems are based on the same technology, which intelligently analyses sensor data using an Edge AI tool.

They offer a number of advantages: the ability to monitor a large number of sites, sometimes located in remote areas where there is no connection to the electricity grid, thanks to an energy-efficient system (autonomy of 2 to 5 years); a significant reduction in false alarms: the system divides the rate of false alarms by 10 thanks to a process based on autonomous, on-board and learning AI. This enables managers to maximise the security of their infrastructures, while considerably reducing their costs.

The Orange and British Telecom groups have chosen Check'In technology to secure their infrastructures.

Energy

- **Energy Management:** Optimising energy production and distribution, smart grids

- **Energy efficiency:** Embedded AI algorithms enable precise, instantaneous management of electrical equipment (boilers, roller shutters, air conditioning, lighting, solar panels, etc.) in a household or building to reduce electricity consumption and/or encourage the best use of energy (e.g. delaying the start-up of energy-guzzling electrical equipment).

Communities

- **Critical infrastructure monitoring:** AI can monitor ambient noise around sensitive infrastructure (bridges, dams, water towers, etc.) to detect structural defects or sabotage activities.

- **Visual checks on rounds, raising doubts:** local authority staff can be helped in their work to detect and qualify an event (e.g. an alarm going off) and/or rule out false positives, thanks to an instant multi-criteria analysis made possible by embedded AI.

- **Detecting noise pollution:** In-vehicle AI systems can identify and map sources of excessive noise in urban areas, guiding efforts to reduce noise pollution.

- **Abnormal noise detection:** In buildings and/or premises managed by local authorities, devices with embedded AI can recognise specific noises, indicating suspicious or dangerous activity, such as broken glass, alarm cries or gunshots, and alert security teams accordingly.

French startup : SONAIDE

Sonaide is a company that has developed an innovative technology based on the use of acoustic sensors to monitor the health and well-being of the elderly. Their innovation involves detecting and analysing sounds in the everyday environment to provide valuable information about physical activity, sleep patterns and changes in people's behaviour, enabling continuous, non-intrusive monitoring in the home. This approach offers a proactive solution for detecting early signs of health deterioration and improving the quality of life of elderly or vulnerable people, whether in their own homes or in care homes.

Sonaide's products use embedded AI to analyse ambient sounds. The models developed by this company can discern non-obvious auditory cues. The devices, plugged into standard electrical sockets, equipped with sensitive sensors and powered by intelligent algorithms, are designed to operate discreetly and respect the confidentiality and security of personal information.

Environment

- **Environmental Monitoring:** Using AI to monitor and manage natural resources.

- **Biodiversity monitoring:** vision systems with embedded AI analyse and monitor the presence and diversity of animal species in an ecosystem, helping ecological research and the conservation of endangered species.

Industry and Manufacturing

- **Industrial robots:** Use of intelligent robots for assembly. Thanks to embedded AI, their operation can, for example, enable optimised and secure collaboration with production staff.

- **Automated quality control:** real-time manufacturing defect detection systems on production lines

- **Securing industrial sites:** technologies to combat intrusions and theft of raw materials from industrial sites

- **Predictive maintenance:** monitoring equipment to anticipate and prevent breakdowns

French startup : NKE WATTECO

Bob Assistant, from NKE Watteco, is a predictive maintenance system. It constantly analyses the data supplied by several sensors to anticipate failures using machine learning models.

This ability to anticipate breakdowns is crucial, because it allows anomalies to be identified before they turn into major faults, which can sometimes have disastrous consequences.

Agriculture and agri-food

- **Precision Agriculture:** real-time monitoring of crops and resource management to maximize yields.

- **Agricultural Robots:** Embedded AI contributes to the efficiency and safety of automation systems for repetitive agricultural tasks such as planting, harvesting and weeding

Transport, mobility, logistics

- **Autonomous vehicles:** safe and efficient autonomous cars, trucks and drones, thanks to on-board piloting devices with almost instantaneous responsiveness

- **Electric vehicles:** optimization of battery operation and life, thanks to on-board algorithms

- **Predictive maintenance:** the vehicle itself can anticipate breakdowns or servicing by intelligently analysing information from sensors (e.g. abnormal vibrations or fuel consumption).

- **Recognition of road signs:** on-board intelligent vision systems automatically read road signs, helping to optimise road safety.

- **Transport infrastructure safety:** anomalies (e.g. cracks in a bridge, malfunctioning of a tunnel ventilation system) can be detected or even anticipated using on-board AI systems installed throughout the infrastructure, including sites with no connection to an electricity grid.

French company : ST Microelectronics

Thanks to technologies developed by ST Microelectronics, the safety of railway infrastructures is ensured by the precise, meticulous and continuous detection of any malfunctions (Vapérail).

This system generates an instant alert for the maintenance teams, enabling them to intervene quickly, check and even resolve the fault identified.

Home automation, household appliances

- **Household robots:** autonomous hoovers are already appearing in homes. Robotic systems with embedded AI are set to develop over the next few years and increase their functionalities.

- **Smart alarms:** new-generation alarm systems make the difference between, for example, the intervention of technicians for maintenance and the intrusion of thieves or squatters, without necessarily complicating access to the home.

Startup française innovante : ARTIFEEL

The company Artifeel develops and markets the "Check'In" system which, among its possible applications, offers property managers continuous efficiency of the intrusion attempt detection system, a deterrent to potential squatters (the AI recognizes and distinguishes intrusion attempts before opening and acts autonomously by activating the alarm and notifying in parallel the first responders of the alert scheme: agent, remote surveillance, police, etc.).

Artifeel, less than 4 years after its creation, already counts among its clients major accounts such as Securitas and the HLM of Turin, Lyon and Marseille.

Entertainment and media

- **Content Creation:** automatic generation of texts, images and videos.

- **Content Recommendation:** recommendation algorithms for streaming platforms.

- **Sentiment Analysis:** monitoring and analysing audience reactions to media content

Sécurity et Defense

- **Surveillance and Reconnaissance:** analysis of images and videos for national security and surveillance

- **Cybersecurity:** threat detection and automated responses to computer attacks

- **Autonomous Defence Systems:** development of drones and other autonomous systems for defence.
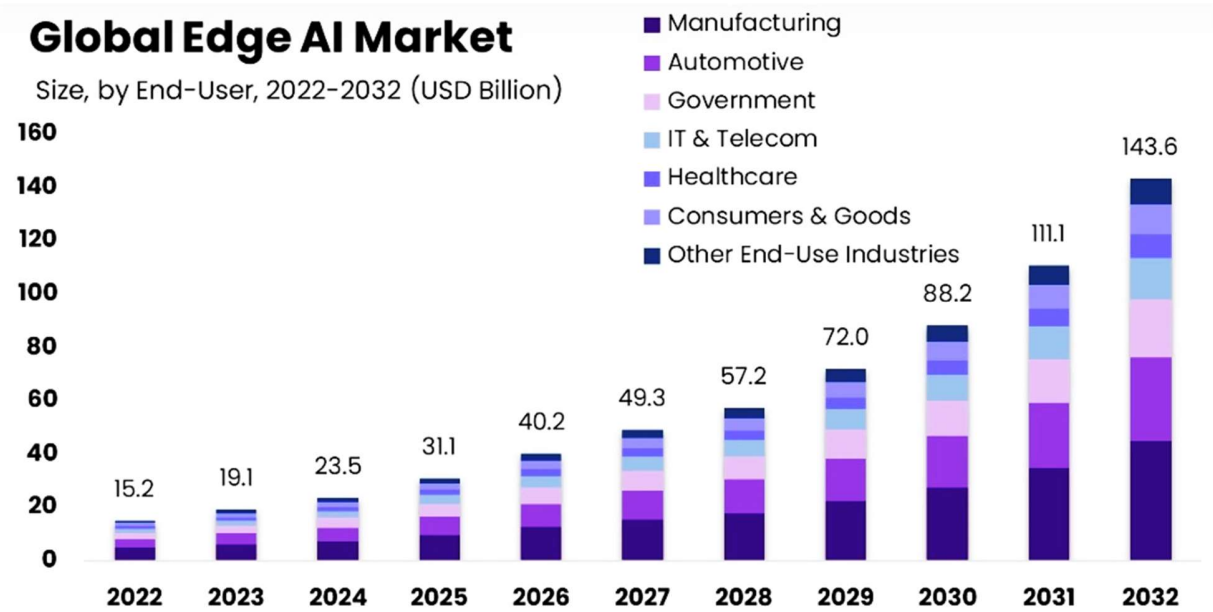
MARKET PERSPECTIVES

A market worth more than 140 billion dollars in 2032

Gartner[2] predicts that embedded AI/Edge computing technologies will reach sufficient maturity in 2024 to make it possible to market 'intelligent products' at an affordable cost.

The second half of the decade should therefore see a proliferation of 'intelligent' products and services targeting a large number of industries (see illustrations of use cases in the next chapter).

According to a study by Market.US (see chart below), the market is set to grow rapidly from 2025, reaching $140 billion worldwide by 2032, an annual growth rate of almost 26%.

Global Edge AI Market
Size, by End-User, 2022-2032 (USD Billion)

Legend:
- Manufacturing
- Automotive
- Government
- IT & Telecom
- Healthcare
- Consumers & Goods
- Other End-Use Industries

Values by year: 2022: 15.2, 2023: 19.1, 2024: 23.5, 2025: 31.1, 2026: 40.2, 2027: 49.3, 2028: 57.2, 2029: 72.0, 2030: 88.2, 2031: 111.1, 2032: 143.6

Source : https://market.us/report/edge-ai-market/

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[2] https://www.gartner.com/en/documents/4850031

An opportunity for electronics/hardware manufacturers

Embedded AI will be a major opportunity for manufacturers of electronic/hardware products, who will be able to equip their products with intelligent functionalities and offer innovative, value-added services that are a potential source of recurring revenue. Their evolution towards service operator businesses, which has been observed since the advent of IoT technologies, will be amplified and generate strong growth.

ADVANTAGES OF EMBEDDED AI

Enhanced data security

Embedded AI and Edge Computing technologies provide intrinsically enhanced confidentiality for personal data. Personal data will only be transmitted over communication networks once it has been processed and anonymised. For example, images are analysed directly in the surveillance device, without being transmitted to the outside world, totally protecting privacy.

Very low latency

These technologies deliver a service almost instantaneously, which can be crucial for many applications (robotics, servo-control, etc.). By processing information locally, they do not need to communicate information to a remote element (e.g. a cloud infrastructure) and wait for a return - which can introduce (depending on the technology) hundreds of milliseconds, or even several seconds or minutes.

Ultra-frugality

Designed to be used by constrained devices (mobile products or products without access to a constant source of energy), embedded AI uses very little energy. As a result, these technologies will considerably reduce the environmental impact of AI, both directly and indirectly, thanks to the progress made on the consumption of AI chips used in the cloud.

Efficient use of resources

Embedded AI will gradually take the pressure off telecoms networks and cloud systems. The connected objects we use today are essentially vehicles for accessing or transmitting raw data to remote services, located mainly in the cloud. Given their exponential growth, even 6G would not be enough to carry all the traffic they generate if there were no delocalisation of intelligence to process much of the information locally.

STAKES

As shown by the use cases cited in this report, embedded AI today offers both an opportunity to reinvent hardware and product offerings and a complex challenge that public action can address as a key factor in driving the ecosystem forward.

By focusing on the sector of hardware products with embedded AI, France will gain on a number of fronts:

Contribution to reducing the ecological footprint of AI

Embedded AI applications operate in environments requiring very low energy consumption. As a result, the development of hardware and software technologies for frugal embedded AI is set to spread throughout the AI ecosystem, helping to reduce its ecological footprint.

Decarbonization of our societies

To reduce greenhouse gas emissions, there is no choice but to act on the real. Hardware products are one of the solutions to be implemented to meet the major environmental challenges.

Strengthening our software industry

The software and hardware sectors will become even more interdependent with the advent of AI-enabled hardware products. As a result, thousands of jobs in the software sector will be secured by identifying the hardware industry as a priority for our country and for Europe.

Boosting the service sector using data

Data will increasingly be stored and processed in hardware products. This represents a unique opportunity for our country to regain an advantage in the services market and benefit from new sources of value linked to the exploitation of data.

Reducing costs for local authorities

Automating certain maintenance, supervision and surveillance tasks for public infrastructure can, in itself, provide significant leverage for reducing the costs borne by local authorities.

Creation of thousands of jobs

The electronics sector is now one of the key sectors in the reindustrialization of France. Thus, according to the DGE report of May 2024 "where is the reindustrialization of France?"[3], the electrical and electronics sectors recorded the strongest growth in industrial jobs in our country between 2016 and 2019.

The advent of embedded AI represents a major opportunity to support this trend and enable, within a few years, the creation of thousands of jobs on our soil[4].

Reduction of the trade balance deficit

The electronic goods sector is an important vector for solving the trade balance deficit problem that France has been experiencing for almost twenty years. Imports of computer and electronic products are one of the items that increased the most in 2021, representing 1/4 of the total deficit in our country's trade balance.

Preservation of France's sovereignty

Recent news has continued to alert us to the challenges in terms of electronics sovereignty for our country. The Covid crisis has revealed the major importance of this sector for the medical sector in particular.

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[3] https://www.entreprises.gouv.fr/files/files/etudes-et-statistiques/2024-themas-dge-n20.pdf

[4] Assuming that France captures 1% of the global market for smart products assessed on p.6 (a conservative hypothesis since 1% is its current market share), its electronics industry would see its turnover increase by 1.4 billion euros by 2032, or 10% of its current turnover, which may suggest that the number of jobs (200,000 jobs today according to the Electronics Sector) would increase by 10%, or around 20,000 direct jobs, to which would be added thousands of indirect and induced jobs.

OPPORTUNITIES FOR FRANCE

A sector benefiting from numerous assets

France has significant assets in the field of electronic products:

- **strong creativity** in the design of innovative products, as we can observe each year at CES in Las Vegas or at Vivatech

- **know-how** in the field of hardware products, thanks to a solid and experienced electronics sector

- **strong software industry** that can support the revolution of embedded AI

- **strong ecological awareness** of French designers and manufacturers of electronic products, which meets customer expectations

- **strong sensitivity to respect for privacy** and the responsible processing of users' personal data

An opportunity not to be missed

France is currently enjoying a unique window of opportunity in the electronics sector that it must not miss. We are witnessing an "alignment of the stars", that is to say a convergence of several key success factors (see assets mentioned above), such as we have not seen for at least 20 years.

> **We believe that it is urgent to become aware of this "window of opportunity" and to seize it without delay to create value and jobs on our soil.**

PROPOSITIONS

Identify the hardware industry as one of the national priorities and restore investor confidence

France has not so far identified the hardware industry as one of its key industries and, consequently, investors have little faith in the innovative projects carried out by French startups and SMEs/SMIs.

We believe that this situation should be radically reversed and the **electronic finished products industry identified as one of our country's priorities.**

This could involve massive communication by the public authorities to :
- promoting and enhancing the value of French start-ups and innovative hardware products based on embedded AI, in France and internationally
- restoring the confidence of private investors in this sector, by showing the strong opportunities that the sector is now making possible thanks to the expected boom in embedded AI

Promote public and private investment in development projects and boost the industrialization of finished electronic products in France and Europe

We call for the establishment of a policy favourable to public and private investment in development and industrialisation projects for goods containing electronics, a sector which represents significant strategic issues for our country and for Europe.

To be fully effective, this policy should take into account the specificities of the sector (project timescale, investment levels, regulations, etc.) and encourage risk-taking by stakeholders.

In particular, we propose to implement the following measures:

- **Stimulate the growth of the strategic sector of innovative hardware products:** as previously mentioned, this sector is indeed a vital issue for a nation. In other parts of the world, States are aware of this and provide direct and indirect aid to this industry. We believe that it is time for France and Europe to draw inspiration from these voluntary industrial

policies so as not to find themselves permanently distanced and dependent on other regions of the world. For example, an innovation support policy could be put in place, in the form of public subsidies and investment funds fuelled by popular savings, stimulated by tax incentives, and institutional actors. Such a policy would benefit from being oriented towards the expected benefits of innovations rather than towards technological sectors, by leaving innovative startups and SMEs the choice of technologies and functionalities they use and by focusing solely on the value proposition.

- **Create a tool to reduce the risk taken by industrial partners with regard to innovative hardware startups and SMEs**: the creation of new factories makes little sense in our sector. Indeed, French companies of innovative electronic products have at their disposal a very rich ecosystem and industrial tools allowing them to industrialize their product in France much more quickly and surely than by creating their own factory. Rather than subsidizing the creation of new factories, we believe that it would be, on the contrary, appropriate to encourage startups and SMEs of innovative hardware products to form partnerships with industrial subcontractors in order to gain competitiveness. To do this, it is necessary to both promote the networking of companies in the sector but also, and above all, to set up a mechanism to reduce the financial risks incurred by subcontractors when they contract with young companies for the pre-industrialization or industrialization of their products. Such a system should of course be accompanied by reciprocal commitments from the companies concerned. It could be entrusted to the BPI and draw inspiration, for example, from Coface's experience in export risk coverage.

- **Create a system to prioritize, in public procurement, innovative solutions created by French startups and innovative SMEs**. Indeed, startups and SMEs need customers, particularly customers who are supportive of their start-up. Therefore, rather than placing orders with historical players, public buyers could be usefully encouraged to place orders with national startups and innovative SMEs. Such a system already exists in the United States[5] to meet the needs of both public administrations and structures and industrial policy objectives.

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[5] Dispositifs IRA et Buy American Act

Such signals would energize our entire ecosystem and reassure private investors, by showing our country's desire to create world champions on our soil in the coming years.

Help and structure the ecosystem of French electronic and technological goods

We believe that the success of the French innovative electronic goods industry will necessarily involve support and structuring of the sector, with the help of public authorities. Asia's current dominance is largely explained by its highly organized and well-informed ecosystem, from which we should draw inspiration.

We propose that the Hardware France association and the professional organizations representing the professions in the electronic goods ecosystem be mandated to create an exchange platform specific to this sector and to network the players.

> **By implementing these actions, we believe that the essential conditions will be met to release energies and ensure that the excellence of our ecosystem translates into success and growth.**

ANNEXES

ANNEX 1 - DEVELOPMENT AND INTEGRATION OF MACHINE LEARNING

As soon as a machine learning algorithm is integrated into its product, it will have two major phases of life:

- The implementation of an algorithm
- Its monitoring and maintenance.

Indeed, even more so than for a traditional electronic product, "after your product is first deployed in the field, you may only be halfway there. There is still a lot of work to do in monitoring and maintaining the system" (Andrew Ng, Founder of LandingAI and DeepLearning.AI). Here are the two main reasons, according to Andrew Ng:

Data drift: Your model was trained on a certain dataset, but the input data may change over time. For example, a model may have learned to estimate electricity demand based on historical data, but climate change is causing unprecedented weather changes, so the model's accuracy degrades.

Concept drift. The model was trained to learn an x->y mapping, but the statistical relationship between x and y changes, so the same input x now requires a different prediction y. For example, a model that predicts house prices based on their square footage will lose accuracy as inflation drives prices up.

The important thing to remember is that **developing your product may require additional work after the first deliveries.**

Let's now look at the first phase, that of developing the algorithm.

To know how much its development costs, let's look at how it is designed.

It is generally considered that it is done in **5 main stages:**

Data collection

This is the recording or retrieval of raw data from sensors, corresponding to the target use cases.

For example, to detect the failure of an engine, we can choose to use an accelerometer fixed to a strategic location on the engine to detect vibration anomalies. This data will be provided after processing to the machine learning model, so that it can extract the rules that allow us to distinguish the information that interests us, the vibration anomaly of the engine for example.

Data pre-processing

Raw data is transformed to extract useful data and format it efficiently.

This may include steps such as data cleaning, normalization, filtering, creating synthetic data that resembles real data (data augmentation), creating and extracting new features, i.e. information characteristic of the problem we are trying to solve. For example, the frequency spectrum of engine vibrations will probably be useful to help characterize the vibration.

Machine Learning model development

Creating or modifying an existing model, training it, optimizing it.

The choices made here are the result of a compromise between algorithm performance and resources used on the target chip. This complex step requires in-depth expertise in artificial intelligence, including the essential contribution of a data scientist.

Model evaluation

Analysis of accuracy, robustness and memory footprint (RAM and Flash). If the results of this step are inconclusive, the previous steps must be repeated.

Deployment

In this last step, the algorithm is converted into C/C++ language and optimized for the target platform.

Each of these major steps actually groups together many others, each requiring important technical decisions. There are generally several back-and-forths between each step throughout the development, to refine or repeat the choices made previously.

The complete development of a system therefore represents a very heavy workload, requiring strong skills in different areas.

Le cycle de développement et du déploiement
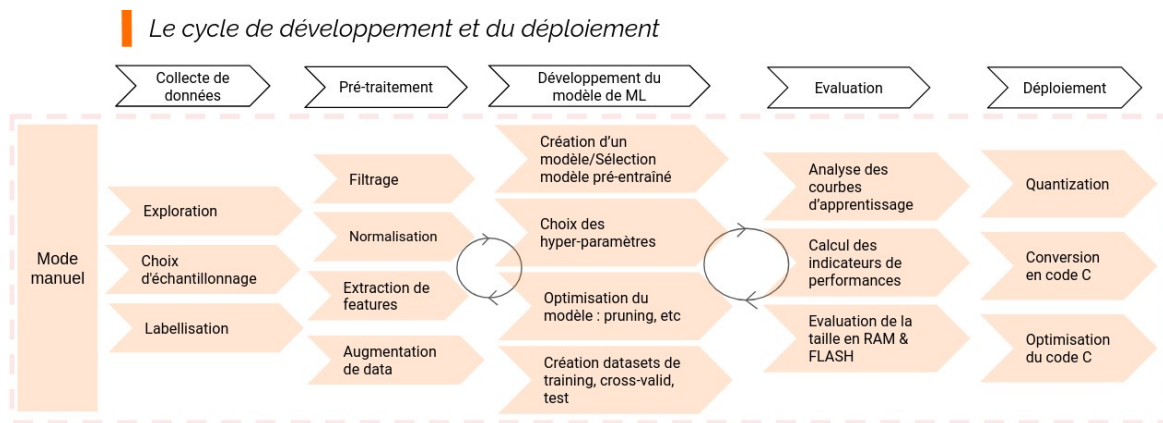
Some tasks such as sampling choices during Data Collection, or Filtering in the preprocessing phase, require knowledge in signal processing.

Others are specific to machine learning[6], and require some experience to tackle them. We will not describe them here, but they are the heart of the system, their mastery allows to adapt to a maximum of use cases and optimize the solution as best as possible.

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[6] Auto-ML is a solution for rapidly developing embedded computing projects.

ANNEX 2 – ABOUT THE AUTHORS

STEPHANE ELKON

Chairman of Hardware France

Former General Manager of the professional organization representing major electronic hardware equipment manufacturers and suppliers in France, AFNUM, he has been involved in developing regulations for this sector for over 20 years and has mastered their procedures.

Since 2018, he has been helping hardware companies (startups, SMEs/SMIs, large groups) meet their sectoral regulatory obligations.

In 2022, he co-created the Hardware France association with Guillaume Gourdin, hardware entrepreneur, founder of Prisme Technologies and Prisme Studio.

CHARLY HAMY

CTO of Rtone

X-Telecom, specialized in IoT architecture for nearly 15 years, Charly cut his teeth as a developer and then cloud technical leader at Orange, architecting end-to-end solutions for industry, health, transport, including the Live Objects group IoT platform.

He joined the Rtone product studio in 2018, putting his skills to work on projects combining software and hardware on behalf of SME/ETI clients and large French groups.

As CTO since 2020, he ensures the animation and coordination of the many Rtone professions in the continuous improvement of skills, tools and processes, and guiding strategic and technological monitoring.

ANNEX 3 – ABOUT HARDWARE FRANCE AND RTONE

HARDWARE FRANCE

Hardware France is an association created in 2021 that brings together French hardware product manufacturers and their ecosystem. It now has around forty members. Its objective is to bring together this profession, develop mutualizations, promote and increase the attractiveness of the profession.

RTONE

Rtone is a French product development studio that relies on a team of more than 100 engineers with multiple specialties to offer a tailor-made and comprehensive offer.

Rtone supports its customers in the study, design, industrialization, production and maintenance of innovative, intelligent and connected solutions. It is notably a member of Hardware France.

By bringing together key expertise internally, such as mechanics, hardware, firmware, cloud, cybersecurity, mobile and R&D, Rtone offers a global approach to realize its customers' vision, with a single objective: to bring their product to life and meet the expectations of its users.

ACKNOWLEDGMENTS