How Democratized Artificial Intelligence Can Move Manufacturing to a New Evolution Pace

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INTRODUCTION

The convergence of manufacturing business disruption and digital technology disruption is making artificial intelligence move the manufacturing world to a new evolution pace!

The manufacturing world is originally a complex ecosystem built to industrialize and optimize the production of goods for a mass or large production at a best cost and the highest quality possible.

Today, we can say that a new generation of manufacturing practices and capabilities are still following this statement of producing more and better with less resources and tentatively less negative impacts. With this unique statement, we can already identify that the goal is to be smarter to produce goods and services, **addressing customer demands while optimizing resources and reducing harmful impacts (environmental, social…)**. This is also called the **Ideality indicator[1] or Ideal Final Result** in industry innovation practices.

THE MANUFACTURING WORLD IS DRASTICALLY CHANGING

The manufacturing business is not only a production business, but a part of a global value chain, surrounded by the many other activities and **new revenue streams** such as demand creation (sales & marketing), services [2] (from consulting to installation, maintenance, and analytics), innovation, finance, supply chain, supplier's management, etc.

The manufacturing revolution is a set of transformational trends impacting production capabilities and making the industrial live ecosystem more efficient and able to create more value. When we are mentioning Industry of the Future or Industry 4.0, it covers also the smart connected products; service monetization business (impacting business customers and original equipment manufacturers (OEMs)); new inbound and outbound supply chain for serving the factories and customers at the right time, with the right product, at the right place; changing financial and transactional practices to having more simplified, "real-time" and trustable relationship; reducing and making agile the innovation lifecycle by a continuous learning and improvement; producing products and services on demand and highly customizable; changing the sales and marketing practices to better understand and anticipate customers' needs. All of that, using real life data as source of truth to generate new revenue opportunities, with faster and proactive business decisions.

[1] Ideality: Innovation (perceived) benefits divided by the sum of cost and harm. (Darrell Mann – Hands on systematic innovation for business and management - ISBN 1_898546-73-8, pages 6-13

[2] Siemens Building Technologies leverages the Internet of Things to provide innovative analytics-based services (Capgemini - https://www.capgemini.com/consulting/industries/siemens-building-technologies-leverages-the-iot/)

Many transformations provide opportunities for manufacturing companies to differentiate themselves from the competition. Threats are introduced by opening the door to new entrants in businesses that had been considered strong fortresses for many years.

> **The current challenge facing operations across the globe can be summarized as follows:**
>
> ***Make an increasing variety of products, on shorter lead times with smaller runs, but with flawless quality. Improve our return on our investment by automating and introducing new technology in processes and materials so we can cut prices to meet local and foreign demand. Mechanize – but keep your schedules flexible, your inventories low, your capital costs minimal, and your work force contented.***
>
> **Dr. John Carrier, System Dynamics Group at the MIT Sloan School**

A few years ago, it was not imaginable to have new entrant in the aerospace market such as SpaceX[3]; and a new automaker entering from scratch in just a few years, as Tesla accomplished. But those technology and business successes and subsequent disruption already happened in other legacy industries including Amazon®, Google®, Netflix®, Easyjet®, Paypal®, Uber® and AirB&B®. Learning from large volumes of data captured from the field was a key driver of making those changes a success. **Manufacturing companies have to move fast to learn from data and adapt their pace of evolution to avoid having new entrants becoming leaders in their own industry domain (from 1955, only 12% of brick and mortar companies are still in the Fortune 500)[4].**

Artificial Intelligence is Becoming a Key Technology for Manufacturing

In the short introduction above, you have read some keywords: real-time, anticipation, simplification, trustable, connected, learning, data, fast, next best action.

That is where Artificial Intelligence (AI) and other emerging technologies are looking to help to achieve excellence. AI helps to adjust the execution level from awareness, to guided, to autonomous thinking and acting on, more and more, the operations that must be executed.

AI is a scientific domain historically preserved for researchers, data scientists, and large companies, and in most of the cases, very difficult to implement in real-life

[3] https://disruptionhub.com/disruption-aerospace-industry/

[4] http://www.aei.org/publication/fortune-500-firms-1955-v-2016-only-12-remain-thanks-to-the-creative-destruction-that-fuels-economic-prosperity/

due to their level of complexity. In the last 5 to 10 years, with the exponential evolution of computing power capabilities following the Moore's law[5], and now the Cloud[6] (a set of disruptive innovation for sharing digital capabilities) which is providing services across the world, AI is becoming a reality to use in day to day activities. Of course, this approach can be debatable, but most of the current manufacturing problems are still managed with spreadsheets and human discussions while "simple" and democratized AI tools make decisions more robust, logic, simplified, automated and scalable.

AI IS NOW A MATURE TECHNOLOGY FOR THE DIGITAL TECHNOLOGY DISRUPTION FOR MANUFACTURING

The AI disruption is not new. It already happens in some business domains such as banking, advertisement and marketing. A few years ago, the first large-scale, data capture disruption wave was the social network which brought a massive amount of data from people, their lives, their interests, their friend networks, their pictures and their movies.

All that data has been mixed with transactional data from retailers, credit cards providers and analyzed with AI algorithms to create profiles of interests[7], intents and behaviors. That also generated the need to create more affordable computing power for computing this massive amount of data shared across the world. This first disruption showed the value of AI and the democratization of the access to the AI outcomes to make business decisions smarter and more accurate. Marketing companies are now using Data Management Platform (DMP) [8] outcomes and consumer profiles to define their offering targets. They finally trust the work done by data scientists specialized in consumer classification to use the outcomes. Now, replacing the social network digital wave, the new digital revolution is coming from the Internet of Things (IOT) + AI and makes AI more relevant for the manufacturing domain.

1. **The Industrial IoT (IIoT)[9], the new data capture disruption wave** – Connecting

[5] ttps://www.intel.co.uk/content/www/uk/en/silicon-innovations/moores-law-technology.html

[6] https://en.wikipedia.org/wiki/Cloud_computing

[7] https://www.salesforce.com/blog/2017/09/use-ai-to-create-human-experiences.html

[8] Data Management Platform: It's a piece of software that sucks up, sorts and houses information, and spits it out in a way that's useful for marketers, publishers, and other businesses (digiday.com - https://digiday.com/media/what-is-a-dmp-data-management-platform/) .

[9] Algorithmically deriving insights from aggregated data, and/or applies machine learning to allow insights to bubble up, eliminating the inherent biases that algorithms entail (Forrester - https://reprints.forrester.com/#/assets/2/177/'RES136171'/reports)

devices and sensors for a cheap investment across networks and geographies is making the equipment data a gold mine to:

   a. Understand good, bad and changing usages of products
   b. Understand the relationship between equipment and their environments
   c. Identify some common, normal and abnormal patterns.

2. The mobile and high-speed communication networks are available for a cheap price (1Gbps at $158/month – Public Cloud pricing), making the cost of moving the data affordable to place it in cheap storage systems in the cloud (Data storage goes from $1M to 2 cents per gigabyte)[10]; almost 6 cents in the cloud (including the needed infrastructure for the storage system).

3. Cloud offers inexpensive elasticity with computing. There is no need to think about size of data or the size of computing power like it was necessary 10 years ago for on premise solutions, which were limited due to the inherent cost of infrastructure to run high performance computing. Right now, the cost versus the return on investment is becoming obvious in most cases.

4. The evolution of affordable multi-purpose robotics includes new operational technologies needing data to run, 3D printers that cannot run without files describing complex products and connected tools that need instructions on the fly to operate correctly. For example, a connected smart handheld drill[11] needs to get the right information to apply the right torque depending the part that must be assembled. High-speed camera controlling systems need to record and process high volumes of images to detect image pattern as fast as possible. This is now possible using AI in the cloud using TensorFlow® or Caffe® for instance.[12]

These digital and operational technology revolutions are starting and will provide enough data to use AI as an enterprise and on a large scale. Of course, AI can be used with only local data for specific and dedicated purpose. Large-scale data can train AI algorithms to build a next stage of learning analytics and make them affordable. These can then be used locally in a more accurate and efficient way to fix

[10]Computer World 2017: https://www.computerworld.com/article/3182207/data-storage/cw50-data-storage-goes-from-1m-to-2-cents-per-gigabyte.html?nsdr=true

[11] https://blog.bosch-si.com/categories/manufacturing/2016/02/airbus-factory-future/

[12] https://en.wikipedia.org/wiki/TensorFlow; http://caffe.berkeleyvision.org/ https://www.youtube.com/watch?v=cef7C2uiDTM (from 13:20 to 16:14)

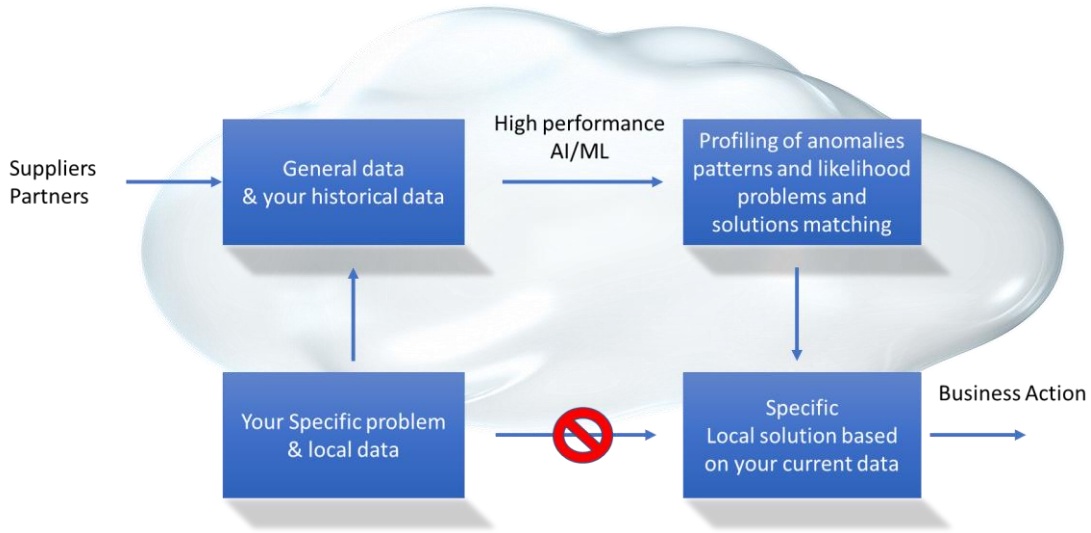

Figure 1: Move your data to the cloud for large scale multi sources of data and intensive AI and ML computing then use the outcomes locally to improve your business behaviors in your specific context

specific issues and potentially reach the target of autonomous system maturity level.

In fact, **the next data capture disruption wave can potentially be the blockchain** to get a massive capture of transactions, contract and ownership behaviors data.

Four Major AI Topics are Key for Manufacturing Companies

1. **The predictive analytics (or time machine)** is now starting to be embedded in business applications (predictive maintenance, production monitoring, demand & production & supply planning and financial planning). This approach is using a small or medium set of historical data mixed with current data, correlated together in a business context to define a potential future situation against a timeline. Let's take the case of predictive maintenance: The wish is not to get an alert when the system fails, but anticipate the alert of a potential failure of a system within a timeframe – such as within the next 15 minutes or 10 hours.

   That gives information to the asset manager or a machine itself to take a counter-action decision in advance. What changed from previous reporting and forecasting method? Now, we are showing potential futures in real-time. Leveraging the new computing power capability, we are now able to process a large source of data streamed together, correlate them in real-time, compare with historical data, then **forecast and show the future, all of that in real-time**. Of course, we can apply this on **predictive maintenance**, but also in **production trends**, sales trends, financial trends and many other individual or consolidated indicators. Another case could be, you are a plant manager, and you want to know in real-time your actuals and your potential production trends for the next hours.

Then you will be able to **adjust your production planning** and slow down or accelerate for the next production period based on your targets of overall efficiency, costs, quality and demand satisfaction indicators. In manufacturing some tools are using, for instance, simple linear regression[13] and ARIMA[14].

2. **Machine learning (ML)** is the second AI area also embedded in manufacturing business applications (predictive maintenance, production monitoring, human resources, finance, supply chain, marketing and sales). This technology is using a large set of historical data to **identify abnormal behaviors and patterns in a set of data qualified as normal data** thru mostly two approaches, supervised and unsupervised models[15]. The purpose of these approaches is to detect a repeatable and non-repeatable, unexpected, undesirable behavior hidden in an expected, normal behavior. This AI domain is now also included in the Digital twins[16] approach for Assets and Process.

Let's go back to our predictive maintenance case; you already know and set up your monitoring thresholds for a

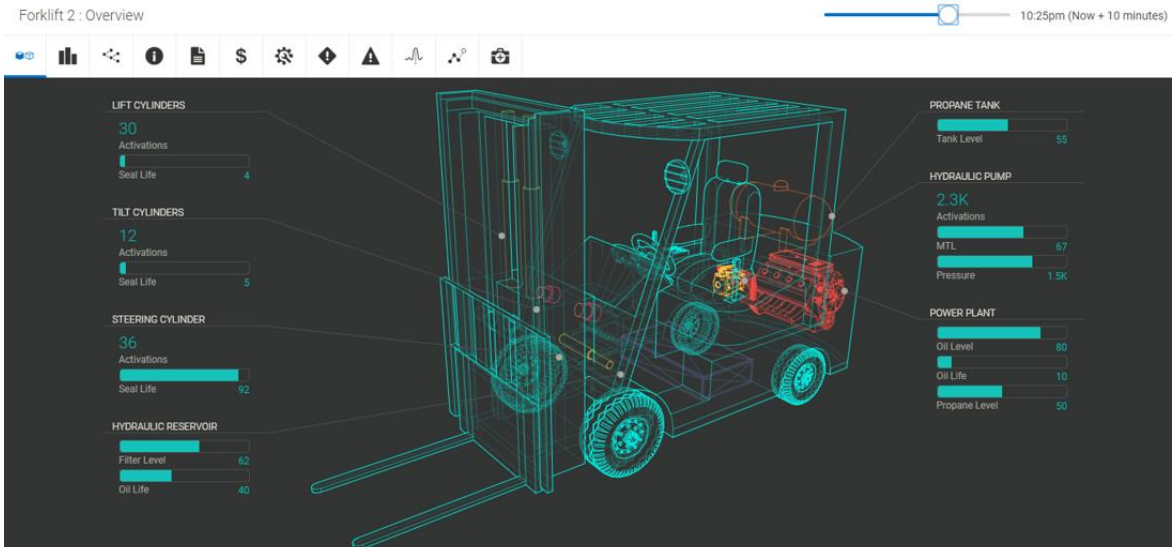

Figure 2: Example of now + 10 minutes data prediction approach

[13] https://en.wikipedia.org/wiki/Linear_regression

[14] https://en.wikipedia.org/wiki/Autoregressive_integrated_moving_average

[15] https://blog.clearbrain.com/posts/the-two-types-of-machine-learning

[16] Digital twin refers to a digital replica of physical assets, processes and systems that can be used for various purposes. The digital representation provides both the elements and the dynamics of how an Internet of Things device operates and lives throughout its life cycle.
http://innovate.fit.edu/plm/documents/doc_mgr/912/1411.0_Digital_Twin_White_Paper_Dr_Grieves.pdf;
http://research3.fit.edu/camid/documents/doc_mgr/1221/Origin%20and%20Types%20of%20the%20Digital%20Twin.pdf

specific machine on high and low temperature, vibration and humidity indicators (by the way, you can now anticipate the future of them using AI predictive tools).

But it is not enough if you want to detect potential issues: You may have to detect a repetitive temperature and humidity fluctuation hidden in the normal behavior of the equipment which could have an impact on your production efficiency and quality. The aim is to automatically detect this *unknown* repetitive pattern to understand why and correlate this abnormal behavior with the potential side effects, using techniques like Grubb's test[17], SAX (Symbolic Aggregate approximation) [18] or LOF (Local Outlier Factor)[19]. The most important is that business applications embedding AI are helping based on the business and application domain and by computing, in parallel, different algorithms to provide different probabilities of selecting of the best AI algorithm which fit to the data and helping to eliminate non-relevant data from the dataset; mostly in case of supervised AI models.

The second case could be to detect, for instance, one small fluctuation: While usually the temperature fluctuation is medium, a small fluctuation should generate at least a warning to investigate and take a corrective action. The same as predictive AI, the new real-time capability provided by new Information Technology (IT) technologies (Graphics Processing Unit (GPU), In-Memory, Cloud and High-performance communication) is making this feature available to make fast decisions in day-to-day activities. Of course, this technology can be used for many topics like operator mistake detection, raw material or

Figure 3: Example of anomaly detection application for industrial equipment

[17] https://en.wikipedia.org/wiki/Grubbs%27_test_for_outliers

[18] https://jmotif.github.io/sax-vsm_site/morea/algorithm/SAX.html ; http://www.cs.ucr.edu/~eamonn/SAX.htm

[19] http://scikit-learn.org/stable/auto_examples/neighbors/plot_lof.html

final product quality issue detection, production performance fluctuation detection, safety and security issue detections and help you to react as soon as possible before having a worse situation to manage. For those two detections of AI technologies, it is important to understand that we must change our usual way to capture and record data from real-life. The usual way, currently implemented in Manufacturing Execution Systems, is to filter the raw data to record only the abnormal behaviors detected by predefined engineering models and set up thresholds on filtered indicators that you want to monitor. This approach was implemented to reduce the cost of data communication and storage and emphasized the limited computing power which was not able to process large amounts of data to provide useful insights.

Now, with new technologies of cheap data capture, communication and recording, associated with an almost "unlimited" capability to process and analyze the data, it makes the historic data management approach obsolete and dangerous. Dangerous, because it is not giving the new Predictive and Machine Learning AI the opportunity to provide their power and valuable outcomes. And dangerous because the new manufacturing world of introducing new high-quality products quickly to the market – produced on new equipment, with new worker skillset, new raw materials and new suppliers – cannot wait to meet and identify all potential issues at a *"human" ramp up speed*, to know and place them under control. Now, we must continuously learn, predict and react at a *digital speed* to constantly adjust the excellence practices to achieve our short-term and long-term goals. If you want to setup a new production line, you now have a few months to deliver your product and optimize your costs. While before now, you had a few years.

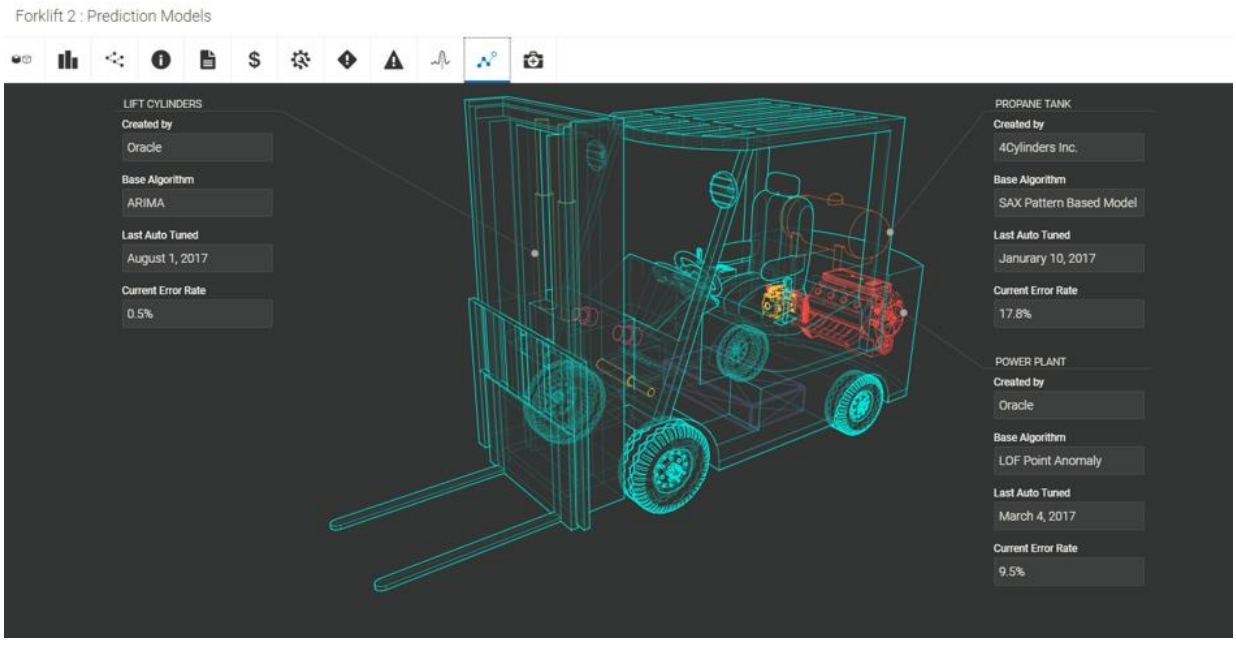

Figure 4: Example of prediction and machine learning analytics embedded in an Asset Monitoring platform

3. **The guided next best action/decision** is the third AI topic available for many business areas. This AI technology **helps to identify the usual and best patterns for selecting the right next best action** based on well-known decision trees and new decision trees built on-the-fly from smart analytics. Those decision trees help to **follow a path of logical decision-making based on guided questions, assumptions and recommendations** identified by the consolidation and correlation of historical behaviors. Those tools are, for instance, using a mix of NLP (Natural Language Programming)[20] and Machine Learning algorithms to analyze questions and identify likely answers based on existing documentation, previous answers or text describing a solution. This is the case for digital robot tools, aka chatbots,[21] for example.

In the case of potential failure of my industrial equipment which has been detected by predictive AI and confirmed by an abnormal machine learning pattern detection, the question becomes: Must I stop my production line right now to fix the issue or can I keep it running until the end of my production batch? What if the potential failure is happening at 90% in 3 hours and my production series will be completed in 1 hour? The AI next best action will guide me to consider several parameters from production plan, maintenance scheduling, potential failure and historical fixing behaviors to help me to decide to wait and update my maintenance plan instead of stopping my production line immediately as the equipment alert is suggesting. Then, AI will recommend I anticipate spare parts ordering and

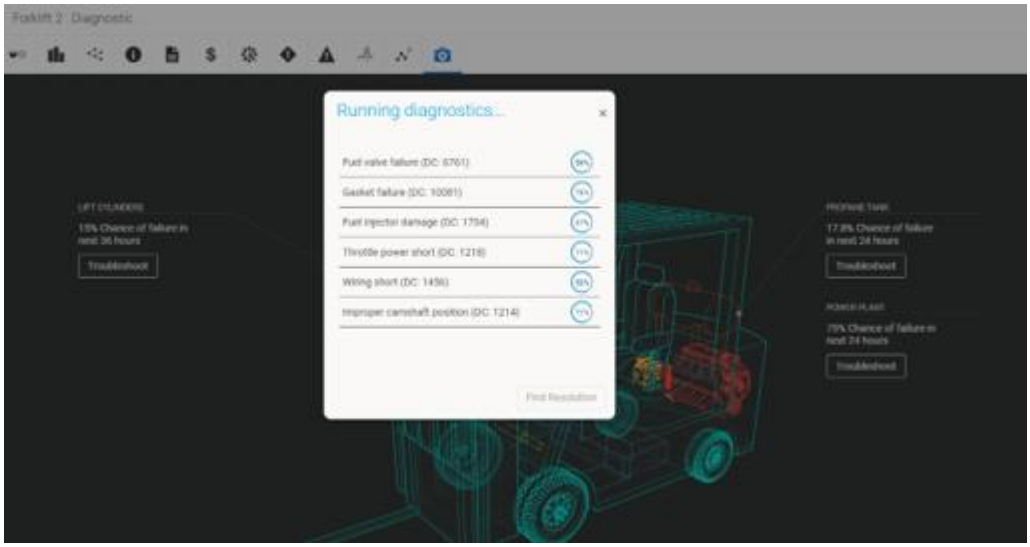

Figure 5: Example of guided decision based on AI in asset issue fixing

[20] https://en.wikipedia.org/wiki/Natural_language_processing

[21] https://blogs.oracle.com/mobile/getting-started-with-chatbots-v2

resources booking to perform the maintenance operation. This is a type of question that the "Adaptive" Intelligence helps to solve by adapting your behaviors from a large set of parameters to focus you on the few best actions learned from the history of practices suggested by complex logics and insights from others (in your company, consulting firms, suppliers, etc.). This technique can also help if you have employee churn issues. This technology can help you to augment your new employees' capabilities to make them immediately efficient and better at making the best decisions.

Tied to the next best actions, the complex interaction with human is also using AI to emulate human interactions like voice, chat, images and sensing to provide a natural and fast way to interact with humans. Two of the most common technologies are voice recognition and chatbot. A chatbot helps to understand human expressions by not only understanding the words, but also understanding the intent, the actions, the questions and the sentiments. All those understanding techniques are learned from a massive amount of data captured around the world, including culture, languages and practices, to be used as a source of human interaction understanding. Let's say you are a maintenance technician who wants to get access to the next best action to fix a potential failure raised by a machine. Why not chat with a chatbot to get recommendations about the next action to do, and requesting to this chatbot to reboot the machine? To do so, the chatbot must recognize you individually and recognize your questions, your intent and the action. It must potentially check your intent and sentiment versus an abnormal behavior described above to avoid you making the wrong decision in a stressful situation. This use case is not science fiction.

4. Finally, the Autonomous AI capability is consolidating all the technologies above to make a physical or digital system able to take its own decisions to optimize its behavior based on its sub-systems monitoring and external parameters from human and digital. Some machines can automatically resolve their own issues and make the decision to follow a specific route by themselves to optimize their activities[22]. This is the case of some collaborative robots (Rethink robotics[23]) and Automated Guided Vehicles (AGV). This intelligence is usually a mix of industrial real-time embedded intelligence mixed with preprocessed best practices data pulled from the cloud. In this case, the cloud runs massive and complex analytics on large-scale historical, current, predictive data and benchmarked behaviors to identify the best practices useful in the current

[22] See Nexen tire factory: http://nexentire-nfera.com/en/factory/

[23] http://www.rethinkrobotics.com/

context of the machine, as Tesla is doing with the fully autonomous car or Oracle are doing with the fully autonomous databases system. Software vendors such as Oracle with its 18C and cloud-based autonomous solutions – as well as many other software vendors – are building fully autonomous software solutions to store and manage data across a broad spectrum of use cases. This system is providing an unmatched reliability and performance at half the cost of classical systems; no human labor, database automatically upgrades, patches and it tunes itself while running; automates security updates with no downtime window required; no human error; a Service-Level Agreement (SLA) guarantees 99.995% reliability and availability, which minimizes costly planned and unplanned downtime; no manual performance tuning; databases consume less storage because of machine learning and automatic compression.

Four AI Trends Can be Applied at Different Layers of Systems

1. **At the machine or device layer itself**, if computing power is embedded: A robot or an AGV can recognize a face, a part, a situation, and take the best action based on abnormal constraints that it can meet during its operation (changing its route for an AGV or changing the movement of its arm for a smart collaborative robot). It can also be applied at a wearable device level if a worker uses a tablet, a smart watch or Virtual Reality/Augmented Reality (AR) glasses. At this small machine level, the embedded capabilities are limited to short term (seconds, minutes), low

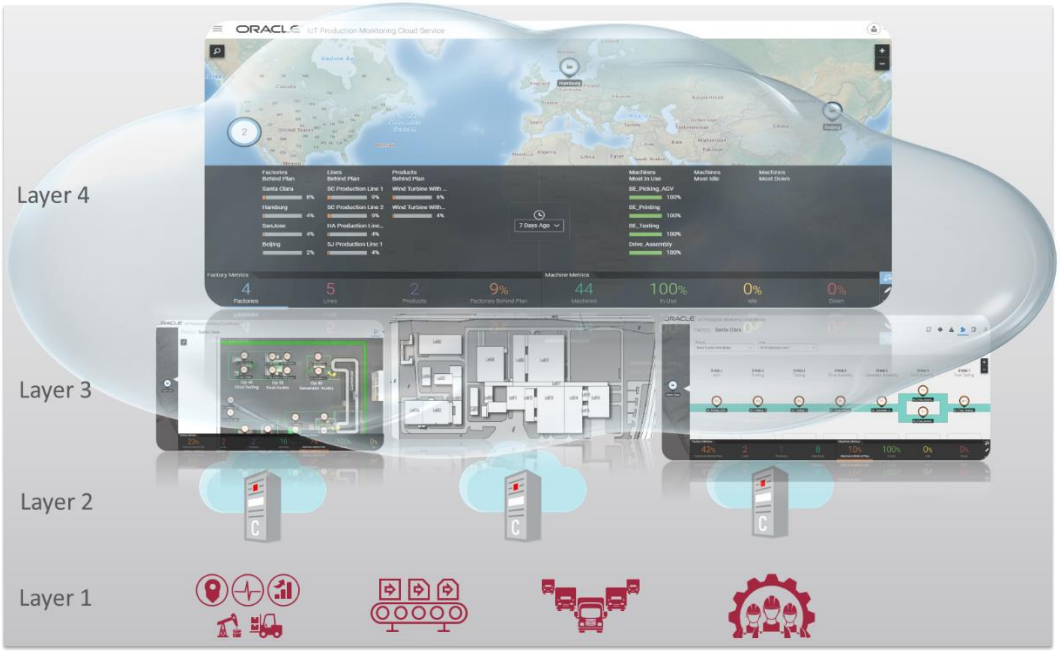

Figure 6:4 layers of AI implementation

correlation complexity and few device/sensors data consolidation due to small data storage size and computing power. Even if those technologies are innovating fast, the other issue that presents itself is the innovation upgrade (mostly hardware) which is limited by the complexity of deployment and maintenance at a large scale. New devices like smart watches, tablets, AR glasses, collaborative robots and 3D printers are now also able to extend their capabilities with a direct access to the cloud and hybrid cloud, using external computing power and services.

2. In case of brownfield or low computing power capability in the devices, **this intelligence can be hosted in the edge computing devices**, which are playing the role of automation controller (PLC, Programming Logic Controller[24]/Motion Logic Controller). They are now becoming intelligent controllers with a mix of industrial real-time functions, "human real-time" smart computing and cloud gateway capability to access external cloud computing power and services. This technology can also help to control and make smarter a group of machines and devices to automate actions and monitor a part of a manufacturing process in a specific location area. The limitations here are the silo scope and the limited local storage capability and analytics computing power.

3. The third level is **the plant level**, consolidating data from factory machines, humans, orders, warehouses, logistics, maintenance and quality to **better organize the activities** using cloud or hybrid cloud AI (hybrid cloud means hosting a part of the cloud on premise). The aim of this level is to leverage complex analytics to provide predictive alerts, machine learning and adaptive intelligence to help technicians, workers, managers and operational officers make the best decision in advance or in real-time to improve overall efficiency and excellence. As a plant manager, **I want to predict in real-time my future production achievement, my supply, logistic, worker and maintenance plans** based on the current situation and predicted situation, and **I want to be agile if the situation changes**. That is what Cloud/Hybrid Cloud AI is providing.

4. Finally, the last layer is **the ecosystem, regional or worldwide level**, consolidating data from your company, getting access to data from suppliers, benchmark data from partners, consulting firm and data suppliers to refine your horizontal and vertical AI analytics to make the best decision. Can I benchmark predictive failure of all my motors across my factories and OEM suppliers to identify specific (humidity, amperage fluctuation, vibration, etc.) patterns of failure in my conveyors, robot and elevators and avoid hard failure? How can I predict the impact of

[24] https://en.wikipedia.org/wiki/Programmable_logic_controller

a specific weather condition on my order dispatching across my factories? How can I build a new product with multiple options in one production line and learn from field data to make it efficient in the short term? How can I monetize or consume machines per hours of usage in contract manufacturing and make sure that it is 100% available when needed, with maintenance done at the right time to not impact my production? These are some questions on which AI is now able to help you solve in an **agile and fast way to make your business more flexible, proactive, reactive and reliable**.

How Can I Start This AI Journey?

Let's first identify where you are in terms of maturity. The first level you need to achieve is to get data from the business area where you want to apply AI.

Once the second step is raised, **the next steps from 3 to 7 are quite easy to achieve** if you are using modern cloud solutions. The cloud software vendor companies are making a huge effort to simplify the access to those technologies. Now most of the AI capabilities are natively embedded in business solutions. To start, there is no mandatory need for in-house data scientists' expertise or heavy investments; find your scalable use case, your AI platform partners, connect your data and equipment, subscribe to AI services and activate the capabilities. At the first stage, if you want to monitor and make visible multiple sources of data, predict trends and detect abnormal behavior, start step-by-step, looking for solutions that provide no coding capabilities and proof-of-concept platform environment. For more advanced analytics, the AI platforms must be also open to host

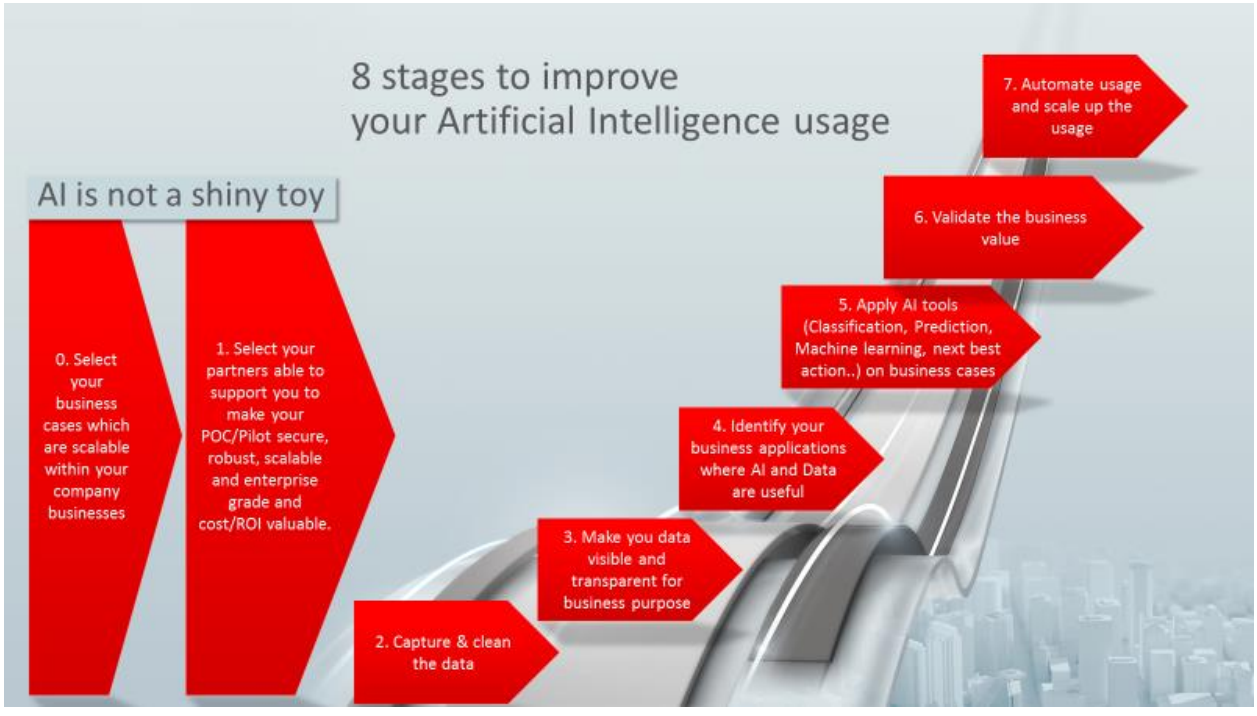

Figure 7: How to start your AI journey to impact your businesses in the short term while preparing for the long road ahead

specific algorithms built by researchers, suppliers, consulting firms, engineers and data scientists supporting open source languages like R[25] and Spark MLib [26]. Those experts must have access to user-friendly environments to focus on business outcomes instead of IT programming activities. The point here is not to explain that you will never need any data scientist, but more to focus your effort on business usages of AI and trust the pre-packaged AI solutions and infrastructures built by data scientists and IT experts.

Don't wait, it's the right time to start your journey to investigate and test how AI will make your business more efficient. If you don't start, your competitors will. Don't be scared by the approach, in most of the cases, it is non-intrusive and applied more as a business helper until it proves its value and has been integrated in the core business processes. One of the major values of cloud solutions is providing a *business try and test* environment on the edge of your core systems and business processes to validate the business cases at low cost. If you are a new entrant, the mandatory step is making sure that you are embedding those capabilities natively in your core processes and solutions.

AI and ML can provide you differentiating advantages, but those advantages will be fully successful only if you work with partners who can help you to generate business value rather than asking you to waste your time and money on technical prerequisites and standalone experiments. This AI is moving forward to purpose-built solutions within a framework that makes sense for your business.

The democratization of the AI for manufacturing business is just at the beginning. Keep in your monitoring radar what is currently happening in the near future on monetizing manufacturing IOT data with AI analytics, to provide cooperative AI solutions for partners and *coopetitors* to improve their businesses. This is what is happened using AI in Marketing and there is no reason to not see the same in the manufacturing world: Having a Business Oriented Manufacturing DMP (Data Management Platform) in the future, like Skywise [27] is doing in Aeronautics the industry.

[25] https://www.r-project.org/

[26] https://spark.apache.org/

[27] http://www.airbus.com/newsroom/press-releases/en/2017/06/airbus-launches-new-open-aviation-data-platform--skywise--to-sup.html

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