The interaction and convergence of IoT and AI at work

There are quite some forecasts and analyst papers regarding the combination of the Internet of Things *(IoT)* and artificial intelligence *(AI)*. This increasing focus on how both work together and why 'IoT needs AI' and often vice versa is in line with new evolutions but also somewhat surprising since IoT and AI have been used together in several business areas since quite some time. Yet, of course the rapid increase of several forms of AI across all levels of the IoT equation make it hard to keep up.

By 2019, 100% of all EFFECTIVE IoT efforts will be supported by cognitive/AI capabilities *(IDC)*

The leverage of machine learning, along with big data, as the combination to unlock the potential of and new opportunities in IoT was also already on the list of IoT predictions for 2017 whereby the shift to the edge and the advent of new data analytics streaming tools were mentioned as important steps "to feed machine-learning engines and more AI applications". Moreover, as Ovum stated, IoT and connected systems drive the adoption of AI as intelligent automation is needed to make sense of the big data that is generated from sensors.

Perhaps an overview of some examples where this is already the case might make it more tangible. Before starting let's point out two things. First, both IoT and AI are umbrella terms, not technologies. When looking under the hood of IoT and AI it isn't that hard to understand what both have in common: data turned into information into intelligence into decisions for meaningful purposes across several use cases. We also will look a bit deeper though, among others at some areas where AI is changing the various technologies and levels in the bigger IoT and Industrial IoT picture.

Secondly, if you look at the *(sets of)* technologies enabling digital transformation and Industry 4.0, as they are depicted in IDC's third platform, for instance, it's important to remember that they don't live in splendid isolation. Just take some typical technologies *(or rather technological areas)* in a scope of Industry 4.0: digital twins, virtual and augmented reality, cloud, big data, robotics, etc. It's relatively obvious that they all work side by side with, for instance IoT and AI. And it shows in the evolutions of IoT platforms and, in a scope of Industry 4.0, in the increasing role of AI engines and cognitive capabilities, as well as support for AR and digital twins in the space of Industrial IoT platforms.

Thirdly, on top of a combined view on IoT and AI *(whereby the use cases of course matter)*, there are far more combinations: IoT and blockchain, AI and robotics, IoT, blockchain AND AI; you can pretty much combine everything.

AI and IoT: a logical combination in perspective

The combination of IoT and AI shouldn't be that surprising when one looks at the essence and basic levels. Several forms of AI have been used for literally decades in, essentially, making sense of data, locating data and putting data at work, with a focus on the rise of unstructured data.

Just look at enterprise information management or even document capture where AI is anything but new. Or take contact center applications which aggregate various types of data from various types of sources in various types of formats and bring them to the contact center agent who can then really serve a customer with the key of service at his/her fingertips: end-to-end information and insights, possibly with a twist of, for instance, sentiment analysis, when social channels are brought into the equation.

> Acting as the body to AI's brain, IoT today provides both input (data) and output (action) for the smart computing and analytics function of a centralized AI system *(Maciej Kranz, Cisco)*

In fact, even in the scope of the difficult task to locate data across myriad locations there are AI solutions on the market, for instance in the context of personal data protection and compliance with the GDPR *(General Data Protection Regulation)* – in order to be compliant and respond to personal data subject rights requests or demands from data protection authorities you do need to know where personal data sits to begin with and what were the grounds on which you lawfully process the data next so, do bring in AI.

We see following reasons why the combination of AI and IoT might be seen as 'novel' and probably gets more attention now:

- The fact that in many industries and for many organizations IoT and AI are still relatively new, whereas in others they are not.
- The different requirements for IoT and AI to work hand in hand across several use cases and actual deployments whereby there are use cases and *purposes (e.g. proactive and predictive maintenance instead of reactive)* that only apply to a limited number of companies.
- A potential misunderstanding of the essence of IoT and the reference architectures and purposes of frameworks as we find them in, among others Industry 4.0 and "smart logistics" *(the latter especially but not solely being an area where also blockchain comes in)*.
- The differences between how IoT and AI are de facto used in combination today and more future-oriented approaches in which more 'advanced' forms of AI and machine learning fit with an increasing focus on 'autonomous' intelligence.
- The evolutions in the IoT market whereby especially in Industrial IoT there is a growing, yet logical, increase in the focus on AI-powered IoT solutions and platforms.
- A limited knowledge of the algorithm and API economy whereby we would recommend readers to take a look at the evolutions in information management in the broadest sense on the level of, among others, microservices.
- The fact that thus far IoT has mainly been deployed in industrial environments in the broadest sense with specific benefits and low-hanging fruit in the scope of maintenance, predictive analytics and connected operations in sectors such as logistics, oil and gas, pharma, buildings, aviation, security, utilities and healthcare where AI and IoT led organizations to reap the benefits.
- A perhaps too slowly growing realization that the combination of AI and IoT *(and often other technologies)* make all the difference on the application level which matters most but also is radically changing existing business applications.
- Too much focus on various sets of technologies instead of on the actual examples how they are de facto used, often even with goals and benefits that can – literally – save lives.
- Our never-ending human desire to understand things by giving them names, even if they cover multiple underlying realities, rather than thinking from a holistic perspective and connecting dots on a deeper level.
- The mentioned rapid evolutions across all levels that make it very hard to keep up.

Let's take a look at the essence in some of these main reasons and then list examples of how IoT and AI are leveraged together today.

AI and the essence of IoT

IoT essentially is the network of connected things, sensors, actuators and communication technologies with specific hardware, software and architectural approaches to get data from myriad possible devices for a large number of use cases, purposes, enhancements and innovations.

On top of the things and the embedded electronics *(e.g. the sensors)* that enable capturing a broad range of types of 'condition and contextual state' data and communicating that data within the device environment it consists of IoT gateways, IoT platforms, IoT communication technologies, hardware and software where aggregation and analysis happens, the actual applications built upon it, potentially architectures such as fog computing and so forth.

Text analytics can generate new insights from a variety of data sources that in the past had little analytical value. In seconds we can process thousands of documents, both internal data but also public data like research articles. In addition to the generation of insight and knowledge, analytics will also improve the efficiency of our business processes. We can automate those processes using algorithms that are continuously improved using Machine Learning *(Herman De Prins, CIO, UCB)*

The essence of IoT is about getting data from connected devices and leveraging that data for a valuable reason which includes enabling people and connected devices to take an action based upon the analyzed and visualized data. So, it works in two directions from the 'physical' device (machine, actuator etc.) perspective: from data to intelligent action *(which could also be research or any form of human action)* and typically from actionable data to action within or by a 'thing'. Moreover, IoT data in many use cases do not stand on their own, they get leveraged along with 'other' data as we'll see next.

Without these element there is little sense in connecting things of course. And with big data analytics and visualization we are already de facto getting in artificial intelligence in more complex environments and applications. If you can't make sense of the data there is no sense in getting it and making sense of *(lots of combined)* data is really a matter of AI. The 'convergence of big data, IoT and AI, isn't just a reality in several use cases, it's also driving new, next gen applications in areas such as visualization technology and in brain computing interfaces as covered previously.

IoT and AI in the context of Industry 4.0

Smart industry and smart logistics as described in the reference architectures of, among others, Industry 4.0 and Logistics 4.0, essentially revolve around the integration of IT and OT, IoT and cyber-physical, end-to-end 'deep' data models and a move towards semi-autonomous and autonomous decisions.

Top achievers capture all forms of data from a variety of interconnected devices and use AI-based applications to plumb that data to reach new levels

of operational and financial proficiency *(Karen Butner)*

It's a gradual movement from automation to autonomy on the level of specific assets in manufacturing IoT and beyond: smart buildings, home automation, oil and gas operations, supply chains, robotics, the list goes on. This is an area where IoT and AI are already being used for several use cases as we'll see. Of course it takes a gradual approach and it's a matter of combining human control/decisions and autonomous decisions on levels where it makes most sense but it's key.

Let's take a look at some use cases and areas where AI and IoT de facto are and increasingly get used in combination on several levels and layers. As a reminder: the IoT stack consists of several layers and AI is increasingly being applied to all layers, from embedded AI in IoT to AI in architectures such as the mentioned fog computing or in edge computing and related software, hardware and communication services overall. It's especially here that embedded AI will become paramount as the goal of both edge computing and fog computing *(not the same)* essentially is to make sense of the data at the edge, close to the device.

AI and IoT in facility optimization

In building management, intelligence *(AI)* is moving to the edge at various levels. Entirely in alignment with the overall move to the edge the intelligence is moving further and further in the field, away from the central part where all the data is stored and analyzed, which enables to learn how the building is operating as Martin Feder explained in an interview on BMS system trends where autonomous decisions at that field level are also tackled.

IoT provides the data AI needs in order to make smart decisions…in return, some of these insights and decisions can then be acted upon by IoT and end devices such as robots, drones and industrial machines *(Maciej Kranz, Cisco)*

However, in the overall picture of facility optimization the combined usage of AI and IoT stretches even further whereby predictive optimization and predictive analytics with pro-active maintenance of critical building assets are among the essential use cases and machine learning is used to inform a facility operator that issues are about to happen within specific building areas or pieces of equipment. In fact, AI and IoT are poised to become cornerstones in the whole emerging facility optimization software notion.

From a building perspective do note that also in smart homes and in workplaces *(e.g. smart offices)* AI and IoT are increasingly used in a 'converged' way as well.

AI and IoT in healthcare

Healthcare is obviously an extremely broad field. So it's not a surprise that AI and IoT are leveraged together in many healthcare areas. IoT already plays a

big role in healthcare. You can read some examples in our piece on IoT in healthcare. The exact same thing goes for AI.

There is for instance a growing role for AI in healthcare delivery *(e.g. computer aided diagnosis)*, AI is playing an essential role in healthcare facilities and hospitals as well and does it need to be said that both AI and IoT play a significant role in the pharmaceutical industry?

In an interview conducted in the Spring of 2017, Herman De Prins, CIO at Belgian biopharma company UCB, explained how research data increasingly include data generated by *wearables (connected devices)*, patient data captured by clinicians and genetic data, on top of clinical trial data. The consequence? As ever more data are incorporated, volumes exponentially increase. It's not hard to guess what De Prins saw as the future of the company. Data analytics and artificial intelligence indeed.

AI and IoT work together in the scope of the interoperability and data exchange between all healthcare facility centers, enabling facility operators to have a clear concise view of what is happening within the facility in real-time – and act upon it *(Christopher Roberts, Schneider Electric)*

The role of IoT, AI and the 'converging' usage of both however doesn't stop with finding new cures, even as the first smart pills are getting approved. AI and IoT are finding their place in integrated electronic health records, medical equipment and both the facility and healthcare assets in hospitals. With a focus on patient-centricity, access to healthcare, cost of healthcare *(both for patients and delivery)* and healthcare quality, measured on patient outcomes and 'population health' as Schneider Electric's Lead Healthcare Solution Architect Christopher Roberts sums up the priorities, AI and IoT already work together in the scope of the interoperability and data exchange between all healthcare facility centers, enabling facility operators to have a clear concise view of what is happening within the facility in real-time – and act upon it.

Moreover, healthcare facilities have problems with their maintenance backlog where AI and IoT again enter the predictive maintenance and downtime reduction sphere. Also from the perspective of the improvement of clinical workflows for clinical staff AI and IoT are being used so staff can spend more time with patients.

These are just a few examples of IoT and AI in healthcare but most of them are already there today, which is part of the point we want to make. It's clear that with RTHS *(Real-time Health Systems)*, the increasing usage of robotics in healthcare, smart beds in smart hospitals, remote healthcare and so forth the combined usage of AI and IoT in the digital transformation of healthcare will only grow.

We tackled some examples from 2017 research from IDC, among others putting AI and IoT in a context of the increasing use of robots for medication delivery *(there are already plenty of automated guided vehicles in hospitals as Christopher Roberts reminds)*, the

shift from passive to active patient engagement and care plan adjustments in real time with AI using data from wearable devices, to name a few.

Last but not least IDC also forecasted that by 2019, 60% of healthcare applications would collect real-time location data and clinical IoT device data and embed AI to discover patterns, freeing up 30% of clinicians' time.

AI and IoT in manufacturing and beyond: robots and cobots

Although there are ample more industries and use cases where AI and IoT de facto are already converged or converging and there certainly is a lot more to be said on the level of technological aspects, including challenges of bringing AI to the edge, we look at a final area before summing up some main cross-industry use cases.

> Analytics, machine intelligence and automation capabilities will be an integral part of future networks, substantiating innovation from network operation to new business opportunities within the IoT *(Erik Ekudden, Group CTO Ericsson)*

We're not going to zoom in on the usage of AI and IoT in manufacturing overall since it's a broad area and there are overlaps with several areas we touched upon but focusing on robots and cobots *(collaborative robots)* which already really are de facto cross-industry examples *(manufacturing, warehouses and logistics but also, for instance, the agricultural sector)*.

Depending on the precise functions of cobots *(and robots)* they already use IoT and AI, deep learning, facial recognition and overall awareness and recognition of patterns, behavior, movement and more, for example leveraging machine vision.

Given the many aspects to take into account when deploying cobots *(you don't want accidents)*, certainly but not solely in production environments *(the used materials, the human-machine interface, the acceptance in factories, the avoiding of dangerous movements and far more)* advanced manufacturing cobots have a bunch of sensors, IoT technologies and AI on board.

> Today the main use cases of the combination of AI and IoT are mainly in avoiding downtime through predictive capabilities, the improvement of operational efficiency and making sense of ever more IoT data

In order to let cobots and robots do similar tasks with slightly different settings deep learning is also already used, in combination with machine vision. An example which we described in our article on 'turning AI, deep learning and robots from children into

responsible citizens' is that of Belgian company Robovision that uses AI-based image processing and deep learning in the automated rooting of plants using robots which is already done in several agricultural companies across the globe.

The company was also involved in a cobot project in the Audi manufacturing plant in Brussels a few years ago which was part of a research project and leveraged several of the mentioned IoT and AI technologies.

Obviously cobots are already in use in several areas. Just think about Amazon's warehouses. And of course 'intelligent' robots and smart machines are used in manufacturing as well, just as we see more and more smart sensors.

AI and IoT: the brain and the body

Taking into account several other applications where AI and IoT work together, whether it's in practice as we saw or in more future-oriented autonomous contexts *(e.g. autonomous cars)*, whether it's in the scope of augmented intelligence or autonomous intelligence and whether it's in the mentioned industries and applications or in oil and gas, the smart home, aviation, transport, industrial drone applications, security, utilities or several wearable applications: AI and IoT are obvious companions whereby Industrial IoT deployments increasingly leverage AI but AI also in a way needs IoT.

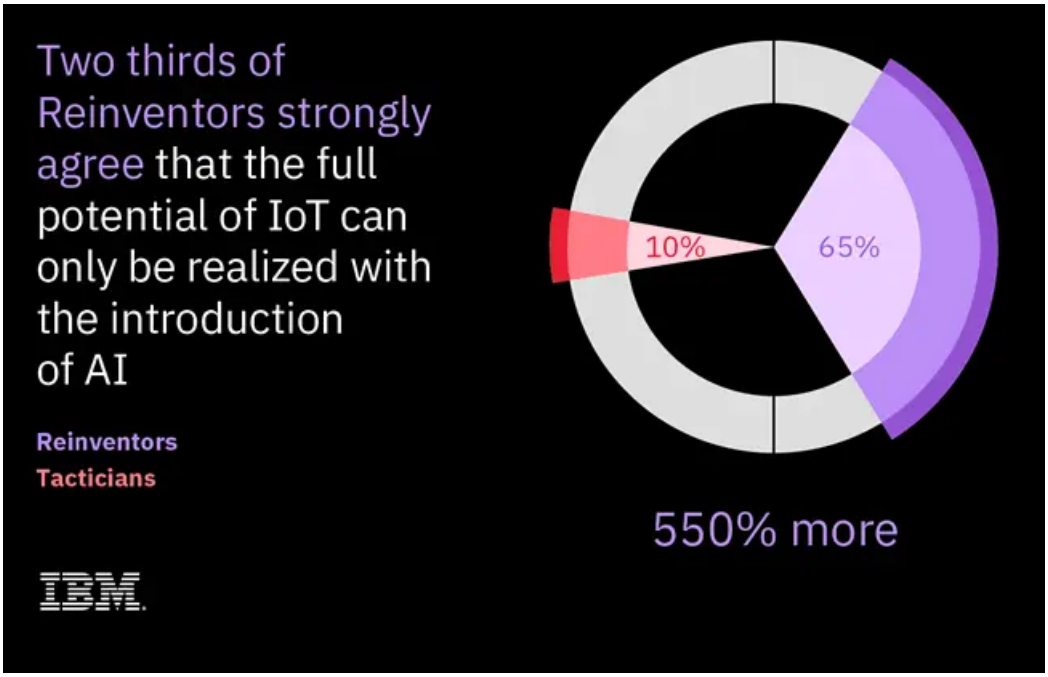
The full potentional of IoT can only be realized with the introduction of AI
(IBM Institute for Business Value)

Today the main use cases of the combination of AI and IoT may be mainly found in avoiding downtime through predictive capabilities, the improvement of operational efficiency, making sense of ever more IoT data in ever larger IoT projects, and ever more data, including IoT data, in research as the biopharma example showed and so forth.

Referring back to IDC: as written before in a context of the DX economy, the research firm already predicted in 2016 that by 2019 100% of all effective IoT efforts – would be supported by cognitive/AI capabilities. While that percentage seems high *(do note the word 'effective' however)*. The question is not if and why IoT and AI simply need each other but where the most meaningful purposes across industries and use cases, including the development of new services and, last but not least, customer, worker, operator and patient experiences.

For more examples *(e.g. Maersk in an IoT and AI supply chain strategy)*, use cases, business opportunities and customer value propositions you might want to take a look at this article from Cisco's Maciej Kranz *(who wrote "Building the Internet of Things")* where AI is called the brain and IoT the body.

Quote: "IoT is the body that gives AI's brain the ability to act. IoT also provides the data AI needs in order to make smart decisions…in return, some of these insights and decisions can then be acted upon by IoT and end devices such as robots, drones and industrial machines".



Reinventors agree that the full potentional of IoT can only be realized with the introduction of AI according to IBM – source and more info

Although they are certainly not the only ones, depending on the use cases and areas of combined application, of course IBM immediately comes to mind when using the words AI and IoT in one sentence *(and adding blockchain on top)*. Dear Watson indeed.

As it happens early 2018 IBM's Institute for Business Value released research on how IoT and AI can make a business smarter; we would add can deliver tangible value in so many useful areas. You can download the report here.

Quote from the blog announcing the research *(where the image above also comes from that shows what reinventors think about the combined benefits of AI and IoT; the blog explains what reinventors are with another image)*: top achievers capture all forms of data from a variety of interconnected devices and use AI-based applications to plumb that data to reach new levels of operational and financial proficiency.

AI and IoT: the many technological innovations and levels

In his overview of 2017 Technology Trends, Ericsson's CTO Erik Ekudden pointed out how the various technology components which underlie the evolution of the digital economy will rely on a 'symbiotic evolution in the software and hardware dimension'.

Massive data collection from, for example, IoT sensors will drive the need for new predictive software algorithms that also take advantage of the increasingly parallel computational power says Ericsson CTO Erik Ekudden – source and more info

In the many areas and evolutions he touches upon, machine intelligence *(an Ericsson term combining AI and machine intelligence methods as mentioned below)*, IoT, and other technologies are present on several levels:

- **More advanced architectural structures** in transistor technology, non-volatile memory *(with embedded NVM enhancing the performance of IoT devices)* integrated silicon photonics *(there are integrated silicon photonic neuromorphic chips, NVIDIA GPUs and GPU-accelerated databases converge machine learning and OLAP and enable to boost throughput for IoT, not to forget IBM, Intel, AMD and so forth).*
- **New predictive algorithms** for the IoT sensor data deluge, which can take advantage of the increasingly parallel computational power *(part of what the previous point is about)* and algorithms in software design *(e.g. deep learning)*.
- **AI within networks and the communication level** as networks become more complex, among others in the scope of 5G and IoT whereby Ekudden mentions the area of beamforming in future 5G networks.
- **What Ericsson calls 'true machine intelligence'**, whereby that machine intelligences as said combines AI and machine learning methods, leading to new environments in, among others, the context of human and machine 'training and mentoring'.

There is far more, among others on the level of the Industrial IoT, security in IoT and semantic interoperability, semantic applications, augmented knowledge, an extended distributed IoT network, identity, analytics and so forth. A highly recommended overview.

IoT and AI and all the rest

The growing number of areas *(applications and use cases),* as well as the increasing number of layers where artificial intelligence gets 'applied and injected into IoT' in order to have it reach its full potential as said doesn't stand on its own.

What we are seeing is an increasing combined usage of IoT with several technologies at the same time. And it's certainly not unexpected. Executives have understood this evolution although of course not all possibilities are seen yet. On the level of the leverage of AI and IoT, in the edition 2017-2018 of its IoT Barometer Vodafone reported that 79 percent of respondents agreed that in the period until 2022 more than half of organizations will use AI and machine learning to make sense of IoT data which is really the main use case today as said but only the tip of the iceberg too.

When IDC looked at the market of AI and cognitive in September 2017, the company's research director David Schubmehl stated that cognitive and AI technology and solutions are weaving into an ever broader and wider array of applications and use cases as mentioned in our IoT guide. This definitely goes for IoT as well.

Yet, looking at all those integrations there is far more to mention. IoT, AI and blockchain is becoming an increasingly obvious one and is a card that's played by some vendors.

79% of IoT adopters think that more than half of enterprises will be using AI and machine learning to make sense of their IoT data by 2022 *(Vodafone IoT Barometer 2017-2018)*

However there is more: next-gen security, robotics, advanced forms of AI (which remains that umbrella term) such as deep learning, the evolving architectures in the scope of cloud, fog and edge, new chips with ever more embedded functions allowing for higher performance, operational technologies *(AI is changing virtually all applications in industrial environments, from PLC, HMI/SCADA software and manufacturing execution systems to ERP as well, the latter in combination with blockchain and IoT)*, machine vision, advanced data analytics, new data management approaches, some newer forms of connectivity whereby the fog computing ecosystem looks at 5G, the list is sheer endless – and as always depending on context and use case.

When analyzing the main use cases for IoT and distributed ledger technology and presenting the result early 2018 in a report we previously tackled, Kaleido Insights put it this way: "A kaleidoscope of emerging technologies is advancing alongside blockchain technologies and they will no doubt influence and be influenced by one another. From computer vision to deep learning, from 3D printing to high performance embedded chips, many of these will see uptake prior to and alongside mainstream blockchain adoption. Others, such as quantum computing and more yet to be named, may shift development paradigms as well."

And so it is. And you can certainly add more.

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