DIGITALIZATION, MONITORING AND PROCESS SURVEILLANCE

GRUNDFOS iSOLUTIONS

PUMP CLOUD SERVICES

INTRODUCTION

Digitalization is often described as something new and revolutionary that will change the world and our lives radically. But when it comes to digitalization in industry, it is something that started years ago and has developed along with the expanding possibilities in computer and communication technology.

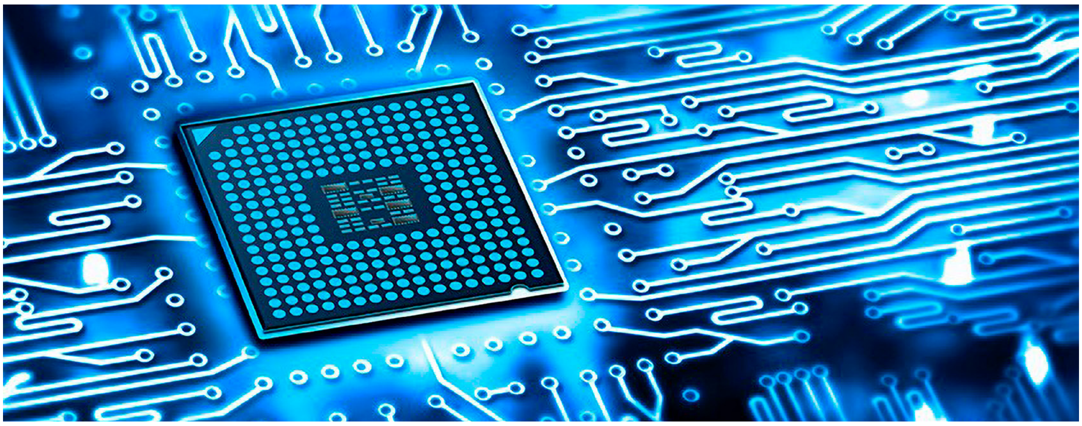
Industry has used process surveillance, data collection and advanced control equipment linked up via Bus communication to SCADA (Supervisory Control and Data Acquisition) systems since the end of the last century. With sensors, data communication, storage and computer power decreasing in price, advanced control systems are expanding to new parts of industry and used more widely – helped on the way by wireless communication and smart devices.

CONTENT

PURPOSE

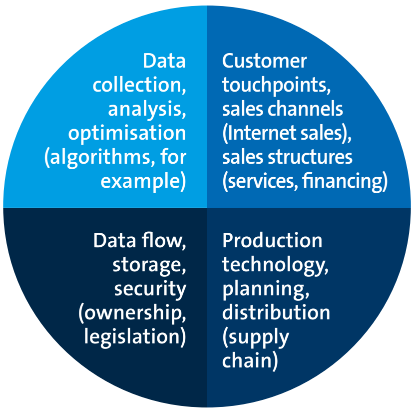
The purpose of this whitepaper is to present some of the key elements of digitalization that are related to industry. It will explain the benefits and options for using data and data processing, as well as the possibilities, limitations and obstacles that need to be considered when digitalization reaches industrial installations.

Digitalization can open doors to new areas of industrial applications and expand pump integration to the entire installation. This can be done by offering energy optimisation, monitoring, advanced system protection and pump control linked to process performance of the surrounding equipment.



FUNDAMENTALS OF DIGITALIZATION

Digitalization can roughly be split into four areas:



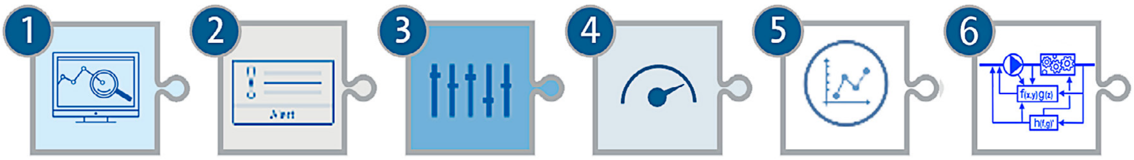
Each area may overlap with others; however, they retain strong ties to their individual parts of the organisation:

To meet the market trends and requirements, industry has allocated substantial resources to support these four areas. The challenge, however, is that this cannot be handled as a single large project. Because digitalization is scattered over a wide area of functions, processes and products, it requires a new mind-set, unallocated resources, fast response times and a willingness to take risks. It is expected that digitalization will grow organically in the organisation if the conditions are right and the organisation allows it, and we will see transformation at differing paces in different areas of the company.

This whitepaper primarily covers the first area noted above – Data collection, Analysis and Optimisation and then Protection and Response. This is often referred to as Condition Monitoring (CM) and is considered from a Grundfos industry perspective, although it applies to technical installations in general.

DIGITAL BUILDING BLOCKS

Grundfos has defined the following six Digital Building Blocks:



Monitoring **Alarms** **Remote control** **Optimization** **Fault prediction** **Intelligent response**

Monitoring

This covers measuring, data transfer, raw data processing, data storage and data presentation and can often depend on which other systems are installed such as SCADA (Supervisory Control and Data Acquisition) or other overall control structures. It is necessary to evaluate which data is needed and the quality – accuracy, measuring rate and time.

- Data transfer can be either analog or digital, wired or wireless, depending on what data usage, quality and amount are needed.
- Raw data processing is necessary for filtering, preconditioning, compensation and reducing the data amount before transfer and storage. It can be linearising, averaging and event-driven data packaging.
- Data storage can be in a local measuring device, in SCADA systems, local servers or in cloud-based storage facilities, either proprietary or hosted.
- Data presentation can be as simple dashboards, spreadsheets, CSV files, or other data-based formats.

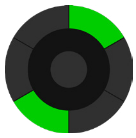
An example is a corresponding measurement of pressure, flow and power consumption, where actual value, sampled values over a time period, average, and minimum and maximum values can be used for creating a Load Profile, Efficiency calculation and Operating costs calculation.

Alarms

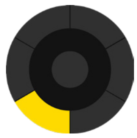
These can be direct digital on/off switches, equipment alarms, or measured values that exceed thresholds. These signals can either switch off equipment, start mitigating processes or be warnings about something deviating from normal conditions.

For easy overview and simplification, they are often presented by the colours Green, Yellow or Red, corresponding to Normal, Warning and Alarm and are either showed locally on the machinery, in the control room, on the SCADA system or relayed to remote monitoring equipment, surveillance or smart devices.

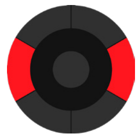
An example of these levels is for motor temperature:



Normal
=> No action



Exceeded motor temperature
=> Warning



High temperature alarm
=> Stop

Remote control

Allows for quick response to avoid the inconvenience, expense and resources of being physically onsite. This can be scaled from remote start/stop, change of setpoint and system reset to full access to the control system. This can include a change of configuration, sub-algorithms and firmware. These features are essential as enablers for Remote Service, Facility Management, Central Control Centers, third-party Service Providers and a lot of new services addressing unmanned automated operations.

An example of this is: Change of setpoint; Change of PI controller settings; Change of firmware; Remote fault analysis.

Optimisation

Improving on systems after commissioning requires analysis of data. This can be done manually by qualified operators; however, the biggest potential lies in automated optimisation.

Automatic improvements on a system require virtual models or representative algorithms that emulate the actual system, often referred to as Digital Twin. The quality of the model and precision of the data opens opportunities for improvement. The analysis can either suggest changes to the system or to actively change the parameter settings. Automatic optimisation is linked to Intelligent response, meaning that the system should be able and allowed to alter related parameters.

Examples of Optimisation: Autotune of PI controller; and Discharge pressure related to system load curve.

Fault prediction

Reliably forecasting damage to systems and equipment breakdowns is a feature that is highly sought after by the industry to minimise downtime and scheduled maintenance.

Fault prediction requires large amounts of reference data, detailed analysis and deep knowledge about failure mechanisms and good algorithms and models of the equipment. This is expected to be developed and expanded with digitalization, due to faster and cheaper data transfer, storage, and computation power. However, it is highly dependent on the right data and resources for making prediction models.

This is especially true for fault prediction, where the use of Artificial Intelligence will in the future play a major role and requires large amounts of data combined with the need for pattern recognition.

An example of fault prediction is monitoring the development of wear in the pump by comparing measured hydraulic performance and electrical power, comparing the level of wear to previous breakdowns and forecasting expected time to critical service. Noise pattern development in ball bearings can foresee eventual breakdown.

Intelligent response

Knowing what conditions can damage equipment or when it will fail makes it possible to mitigate the damage. Changing operating conditions and activating protective measures automatically or by suggesting actions to operators can extend product lifetime. This creates savings on maintenance and costs related to unscheduled downtime. This again requires deep knowledge about the installation, application, the critical parameters and priorities, to keep operation running during protective measures.

An example:

- In a steam boiler system with a two-pump duty/standby configuration operating near cavitation, an automatic switching on of both pumps can take the system out of the cavitation zone.
- Detection of air in one pump in a multi-pump Booster system allows the other pumps to decrease speed while the air-filled pump increases flow to flush the air out.

SUMMARY – DIGITAL BUILDING BLOCKS

A quick assessment indicates that:

- Monitoring and Alarm handling are relatively easy to implement, and the market has done this for years.
- Remote control involves some technical and legal challenges unless the system is hooked up directly to a local Bus/SCADA system.
- Optimisation, Fault prediction and Intelligent response will require the right data, good models and skilled analysts with application knowledge.

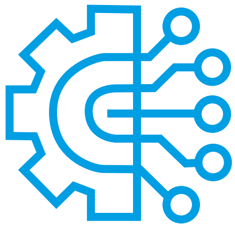
On top of this, Fault prediction also requires a huge amount of reference data on both operating and failing equipment, plus measurement and failure development analysis on systems from installation to breakdown.

IOT – THE INTERNET OF THINGS

The boost in digitalization is often mentioned in relation to three acronyms:

IoT – Internet of Things

IoP – Internet of People



IIoT – Industrial Internet of Things

IoT refers to the trend that more and more devices, such as everyday consumer objects and industrial equipment, have built-in connectivity, Ethernet, Bus, Wi-Fi, Bluetooth, and so on. That means that a large number of electrical devices now can be interconnected to share data and controlled easily by users and other equipment. It is this connectivity that is one of the enablers of digitalization.

IoP refers to the fact that people can connect to each other or to equipment almost anywhere. Telephone coverage and data connection have literally exploded since the turn of the century. Everyone is used to being online and able to be contacted or to get in contact with other people. Today most people worldwide carry a smart device that can connect to people, equipment and data storage, and more and more services are moving online – thereby changing the infrastructure of society.

IIoT refers to the above-mentioned trends and developments going on in industry.

It is important to understand that the Connectivity of equipment, Cloud-based data storage and Smart Device interfaces are not the basis of digitalization. They are merely practical Tools.

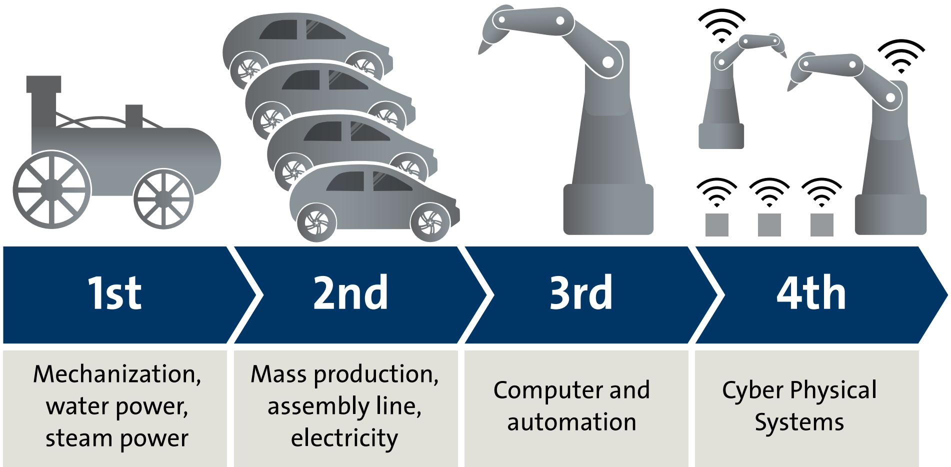
The growth of computer power, communication and data storage has developed with tremendous speed and has become less and less expensive, and we have seen new standards and platforms come and go over the last decade. This has so far limited global digitalization. Nothing so far has indicated that this technological development will slow down – rather the opposite. In order not to waste too many resources on this development potential, industry saw a dire need for a standardised development – a frame for how to manage the aspects of digitalization on a global scale for all interest groups and entities across borders.

Industry 4.0 – Standardisation of digitalization

Industry 4.0 is a European attempt initiated by German industry to try to set some standards and general guidelines for digitalization. In the US, a similar approach called Industrial Internet Consortium (IIC) is running in parallel, and China has also developed a frame called 'Made in China 2025'.

The acknowledgment is that individual initiatives and propriety standards are outdated because what thrives in this world is the wide distribution of data and information; the more access, the greater the viability. The more we can link to other systems and structures, the more we gain; we must follow the present standards, knowing that a new update is right around the corner.

Industry 4.0 refers to the major steps in the Industrial Revolution, where the 4th is digitalization



Digitalization, the Internet of Things and the globalisation of information are not something to be dealt with in the future, but something that we are in the middle of; it has already started and is all around us.

On the other hand, monitoring and process surveillance are not new to industry. Data collection, analysis, optimisation and response have developed gradually since we started to control machines and processes by computers. Gathering data electronically for analysis and optimisation has been done widely over the past decades through BMS, CTS and SCADA systems or local control systems.

What is changing is the amount of data, storage and availability that modern electronics and communication technology enables, as well as self-learning algorithms, vision systems and Artificial Intelligence.

GRUNDFOS AS A PLAYER IN THE DIGITAL WORLD

Digitalization is not new to Grundfos either; we started development of the Bus Communication Interface Modules, the CIM/CIU, at the beginning of the century. In 2008 we introduced Grundfos Remote Management (GRM) and the CR Monitor and thereby set the digitalization direction for the pump industry.

GRM is a communication platform that can relay alarms, operating data and do basic remote control on Grundfos pumps, motors and controls, to a proprietary Grundfos cloud or to a cell phone via SMS. The system could store data and present it to the customer, as well as see and present warnings and alarms if values were exceeding set limits. GRM covered Monitoring, Alarms and basic Remote control, which matches the Digital Building Blocks 1, 2 & 3.

CR Monitor was a device that could collect massive amounts of data, do advanced data analysis, derive conclusions and generate alarms, warnings and initiate preventive action. The CR Monitor used a self-learning system to detect a drop in efficiency, prevent dry run, avoid cavitation and detect operation outside the normal operating range. Alarms, Warnings and Data could be distributed to a local SCADA system or relayed via GRM to the Grundfos cloud service.

The key to rolling out digitalization in industry will be to follow the global standards for connectivity, data storage, availability and legislation, and to provide easy integration to other systems.

We believe that Grundfos can make a difference by utilising our proprietary pump and application know-how is in Remote Control, Optimisation and especially in Fault prediction and Intelligent response.

CLOSING COMMENTS

It is, of course, difficult to predict the future, but with the resources and focus directed towards Automation, Connectivity and Digitalization in all areas of consumer and industrial development and manufacturing, we can expect to make a huge impact at all levels.

Wherever this takes us, it is essential to focus on what can bring real value to the customers and us and to focus more on customer demands than on the new technology opportunities alone. Having the right products, understanding customer needs and application know-how (the cornerstones of Grundfos iSOLUTIONS) combined with Intelligent Connectivity, will ensure Grundfos a leading role for years to come.

APPENDIX:

ELEMENTS OF DIGITALIZATION EXPLAINED

Data transfer

On a small scale, data collection is usually done by wired connections. On a larger process and factory scale, data are mainly gathered in local bus systems; however, Wi-Fi and other wireless connections are expected to dominate the factory floor over the coming years.

Data are distributed between different parts of the company through closed and well-protected communication lines.

To respond on a global level, it is necessary to share data with other companies and entities, where the data content is restricted to protect our own business or interest. A lot of free data are available on a global scale, which can be combined with a company's own data and used to set direction, strategies and goals.

Cloud connection

A big contributor to the fast growth of digitalization is the development in transfer speed, data storage capability and price. We can expect that in the future, all data will be gathered in real-time by a cloud service; 5G is a big step in that direction. But for now, and in the immediate future, we will need local data processing and autonomous operation for critical equipment simply because of the price and technical limitations in central processing.

Collecting lots of data will be the key to analysis, auto-correction, trend development and failure prediction. But crunching large amounts of data in real-time and responding to it immediately requires local computer power. Vibration analysis on a failing ball bearing requires FFT (Fast Fourier Transmission) in a dedicated signal processor, which for now must be local; however, it can compare results or the noise pattern to a cloud-based reference.

A practical way to collect data for failure analysis could be to store a 10 second sequence of all relevant data every hour and deliver that to a central data storage facility where changes in operating conditions can be tracked over time, storing a data window 10 seconds before and after any alarm or deviating condition, or just storing data that exceeds certain limits; 'event logging with a heartbeat'. That way, we can record and learn damaging patterns and failure mechanisms on equipment and thereby develop prediction algorithms for critical components.

For now, cloud connections are mainly used to relay operating status, alarms and key operating data as well as simple remote control. A problem that needs to be solved currently is the ability to remote control; for now, it is not possible to push data through the cloud layer, but several companies are working on it. This will open a world of possibilities for remote service, control and upgrades.

Models

Data use is usually always based on a model derived from an understanding of how things work or interlink. The better the model is, and the more precise the data we add to it, the better we can perform.

With a constant-pressure-controlled pump, the PID (Proportional–Integral–Derivative) feedback controller is a simple model of the system; a good trim of the PID parameters is needed for it to work, and the faster and more precisely we can measure the pressure, the easier it is for the pump to keep the pressure constant. To compensate for external factors, extend the model using set-point influence or remote measuring.

If we want to control larger systems, we need more complex models with much more data. It takes huge insights to set up the model and gather the right data to succeed. Improving a system usually requires more complex models and larger amounts of data, plus increased processing capacity.

Good examples of this are weather forecasts. In the past they were local, often wrong and only forecasted a few days ahead, compared with today, where data from around the world is fed into finite element models and processed on supercomputers that can predict the weather with much higher precision.

Data and data quality

To get valuable information about a system, we need a model that can calculate the needed data, and for it to work we need to feed it with the right data input.

For measuring power consumption, we need corresponding measurements on current and voltage. If we measure flow and pressure before and after the pump, we can calculate the hydraulic output of the system. That enables us to calculate the efficiency of the system using a simple output/input relationship. This can be measured once a year to determine the figure for kW per m3/h. We can measure it every hour to get information on its efficiency during load changes. We can also measure it every second and compare it to the pump's performance data from when it was new, and we now get information on the wear-and-tear of the pump system, which can be used for predictive maintenance. If power consumption is combined with losses in the motor and drive, we can calculate shaft power, and shaft power combined with shaft rpm enables us to distinguish whether the losses are in the pump or in the motor.

This last example opens a lot of opportunities, but the model is useless if we don't have the measurements at exactly the same time or if one measurement falls out or is corrupted.

Usually, most analysis on pump performance is related to flow, and if we do not have a precise flow measurement, we only have limited possibilities for using gathered data for system optimisation, predictive maintenance and other services. We can use other data for alarms, warnings and surveillance to protect the system and installation and withdraw valuable information (using virtual sensors), but this is currently a state-of-the-art feature.

Getting the right data at the right time is essential.

Connectivity and Big Data

Digitalization and Industry 4.0 are very much about gathering lots of data and using it in various ways. Selling data, developing models, selling processed data and related services are areas where many new companies and consultants thrive through digitalization. The battles of the future will likely be fought around ownership of data and models and what is considered a commodity and embedded in the products and systems versus what can be sold as an extra value.

In Industry, data are often considered private property, and industry only makes their data available in limited amounts for others to manage and use. Selling models and algorithms for incorporation into industrial systems and equipment that are compatible with their system and models, also means selling the right pumps, sensors and algorithms that can deliver the needed data. In that context, connectivity to all Bus systems, wireless, and so on is important; whether the data is transferred through the Internet is a secondary point.

IoT – Internet of Things

A lot of the foreseen development in digitalization, Industry 4.0 and Big Data, is based on freely available data, new models, and new uses and combinations of data. We have seen interesting examples of that already, especially in areas like medical diagnostics and lately on the spread and development of infectious diseases. However, just having enough data is not creating value, but with the right data and the right models, the algorithms can change everything.

Data flow, storage and data security

In industrial digitalization, data and dataflow is essential; however, with higher integration in the supply chain and closer cross border co-operation and globalisation, a series of questions must be addressed. Especially questions regarding:

- Who owns the data?
- Where is the data stored?
- Who has access to data?

These are essential questions, but we also need to answer:

- What data should be stored?
- How do we get the data?
- How often should the data be stored?

Let's have a look at the data and where it is generated. During the production process, a large amount of data is required. Some data carries the order information, and other data is generated through the production, including results from testing equipment and other types of production equipment, data showing that the production is in control, and so on. This means that there is an enormous amount of data available.

The way to capture the data in Industry 4.0 is to focus on IoT (Internet of Things), which means that future products must be connected to the Internet. However, it makes no sense to simply store all available data; it is one thing to store the data needed to control a production, and it is something completely different to store data for analysis later on.

Let's consider an example: running constant pressure in the pump during production. The actual pressure is measured every 2 minutes and the control acts accordingly. However, it is highly unlikely that an analysis of the production requires data every 2 minutes – it might be sufficient with data every minute or every 5 to 10 minutes.

The demand for data changes over a product lifecycle. Typically, more data and a higher frequency of data are required during the run-in of production compared to a production that has been running for a long period at a stable rate. It requires a careful analysis to find the right data and the proper data storage frequency, and to find the keys that connect the different data to each other. What is relevant in one application might not be in another.

The data analytic capabilities within a company or a supply chain are essential when talking about Industry 4.0. Data is just data if not used for anything; the real value lies in applying the analysed data. Analytic skills are critical to Industry 4.0 and companies must work to cultivate these skills to succeed.

Artificial Intelligence

When working with Digitalization and Big Data, we are challenged by the amount of data that needs to be processed, which is way beyond what human ability and resources can manage. That requires algorithms that can do pattern recognition and find trends, anomalies and coincidences in huge amounts of data, where they are obviously related and also more elusive influences. This needs to be combined with application knowledge about the actual surroundings to move towards valuable conclusions. For example, combining data like low inlet pressure, high liquid temperature, high flow, fluid acceleration, liquid boiling point and specific noise patterns can predict and conclude cavitation in a pump and explain the root cause.

The solution to analysis and pattern recognition in large amounts of data is usually linked to Self-learning systems and Artificial Intelligence. But unfortunately, it is not enough to just feed random data into a large computer and wait for a result. The algorithms need to be tailored towards the application with defined boundaries, and the system needs continuous feedback on whether it is on the right track or needs to correct during the learning process and afterward. Setting up the system needs good knowledge and a deep understanding of the process, influential factors, mechanisms and possible outcomes.

Self-learning systems and AI needs large amounts of the right data to come to useful conclusions. And as mentioned earlier, Failure Prediction needs reference data measured from commissioning to breakdown, which puts a significant time factor into the system: we need data over a time span, with both primary and influencing parameters, to get reliable prediction.

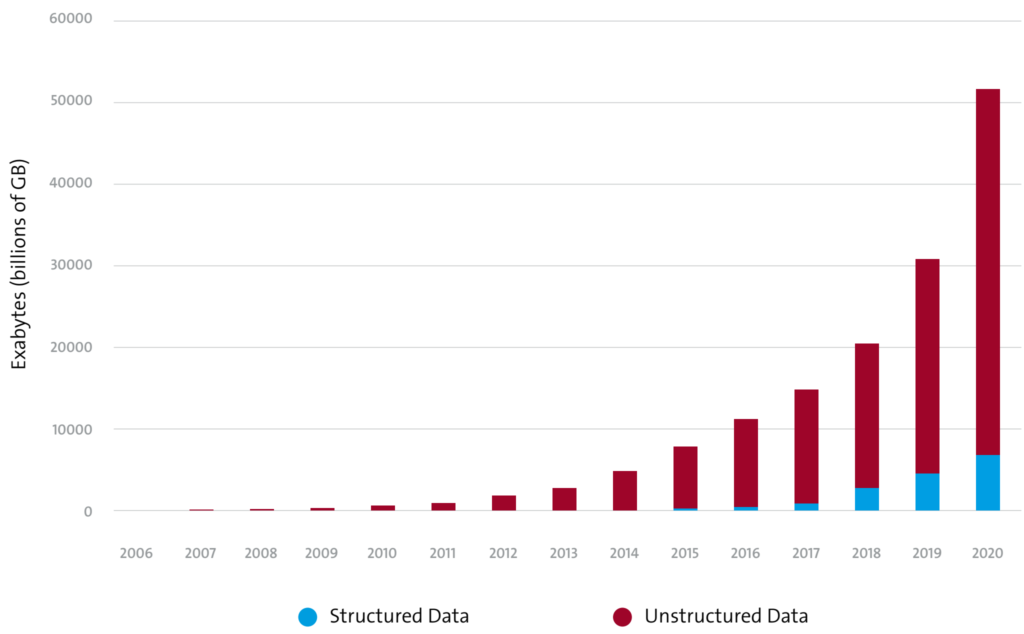
We will probably soon see new computers systems that can automatically seek, access and process relevant data for new tasks and problems. The first attempts, like IBM's Watson – a medical diagnostic system – still tends to generalise.

Large amounts of data

Gathering, processing and storing data has become easy and inexpensive in recent years, which makes it possible to collect useful data that can be utilised for improving efficiency, process optimisation, asset management, reducing maintenance and service costs, and much else. However, it must be done with care and consideration because gathering, processing and storing data comes with a downside on resource use and environmental impact.

Analysis of data collection and usage during 2020 reveals that:

- Half the data in the world was created over the past two years
- 20% is structured (processed and accessible)
- Only 6% of the data has been used
- Data centers consume about 2% of the world's electricity, but that's expected to reach 8% by 2030
- Internet use accounts for 3.7% of global emissions, which is the equivalent of all air traffic in the world (before Corona)



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