Condition monitoring: why now?

As cost of operation reduces, condition monitoring is moving into new sectors and new applications

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Introducing condition monitoring

The idea of condition monitoring is not new. What has changed is that the availability of low cost, low power computing has made scalable condition monitoring systems practicable and viable in a variety of new sectors. Condition monitoring provides ongoing observation of and feedback about a system's welfare. It works by continuously monitoring specified system parameters and applying intelligence around the data to infer the condition of the system.

So condition monitoring is based on both sensing and on interpreting the data sensed. Those two areas are both key focuses at the moment. There is a lot of development activity around the sensory component itself – this could include the use of vibration/acoustic/ultrasonic sensing of rotating machinery. The second key area of focus is around the ability to interpret data and so there is a concentration of activity on the clever algorithms and analytics needed to carry out trend analysis.

Industries using condition monitoring

In an industrial setting, condition monitoring of rotating machines is commonplace and a variety of companies offer equipment for real time vibration analysis. Condition monitoring can be applied to many other areas too, such as:

Oil & gas

- Drill rigs
- Productions plants
- Down hole monitors

Medical

- Vital sign monitors (Heart rate, pulse oximeter, blood pressure)

Industrial

- Manufacturing equipment
- Rotation equipment

Automotive

- Tyres
- Drive shaft
- Lubrication condition

Aerospace

- Engine conditioning
- Vital systems' condition

Commercial

- White goods
- Washing machines
- Fridge compressors
- Central heating systems

Why condition monitoring?

The obvious reasons why organisations and individuals want to be able to monitor the health of their systems continuously, in real time, are cost and risk. Continuously monitored systems provide the following benefits:

- Minimisation of non-productive time (NPT)
- Greater maintenance schedule efficiencies
- Reduced risk of catastrophic plant failures
- Reduced cost by replacing equipment only when required
- Safety – personnel can be removed from potentially hazardous areas

The reasons why providers should want to include condition monitoring as a feature of their systems are more about deriving competitive advantage, for example:

- Improving competitive advantage for commodity products
- Retrofitting to existing systems to provide product differentiation
- Offering value added service to existing DCS and SCADA based systems

Condition monitoring should not be seen as just a periodic measurement made on a piece of equipment at the coal face of a system. Using advances in connectivity, sensor technology and business intelligence systems the condition monitoring process can be integrated into the entire equipment lifecycle. The key advantages of this approach enable the notification of when equipment needs replacing as well as providing valuable usage data to the designers of the equipment. This data can then be used to introduce improvements to the product being delivered; ideally, a continuous improvement cycle, see figure 1.

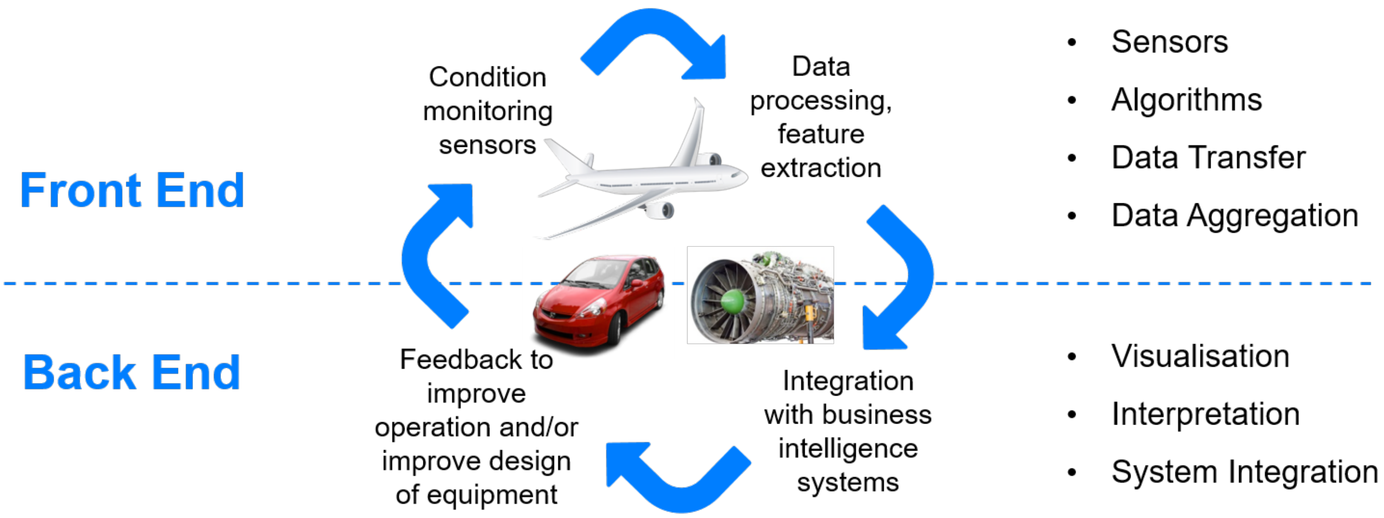


Figure 1 - Condition monitoring continuous improvement cycle

What are the key challenges in condition monitoring?

- Gathering relevant data for effective condition monitoring
- Identifying key items of equipment and their failure mechanisms
- Collecting and processing large data streams
- Ensuring sensor network is robust to environment conditions (consider the environment of body implants or down hole O&G monitoring)
- Adding condition monitoring on top of existing distributed control systems
- Identifying power sources for sensor systems
- Relaying data from a multitude of different sensors to a central hub
- Providing non-invasive monitoring equipment suitable for existing systems
- Ensuring data security and availability

What's happening in condition monitoring?

Currently, there are two main areas of focus in condition monitoring. On the one hand, there is interest in the sensory component of condition monitoring – this could include the use of vibration/acoustic/ultrasonic sensing of rotating machinery. On the other hand, there are an increasing number of systems where data from control systems is already available and so clever algorithms and analytics are needed to carry out trend analysis while taking into account the operating mode of the equipment.

An example where both the sensory element and the data processing and interpretation element are required is in the aerospace industry. Rolls Royce has a system for Engine Condition Monitoring to check performance of its engine products throughout their lifecycle[1], including during flight. This requires real time telemetry as well as data centres for processing and detecting actionable events. Indeed, the airline industry is particularly forward-looking in this respect with airlines and manufacturers working together to gain early warning of issues before they reach fault status, allowing for corrective action to be taken.

Another industry at the forefront of condition monitoring is Formula 1 motor-racing. In order to ensure optimal vehicle conditions and gain a competitive edge a variety of systems are monitored. A typical Formula 1 monitoring

[1] Live monitoring helps engine manufacturers track performance (The Telegraph, 4 November 2010)

system remotely measures 130 parameters in real time and carries out around 15,000 different health checks on the vehicle. The data processing systems learn the normal operating conditions and automatically flag up warnings and faults.

In contrast to the very time-sensitive nature of Formula 1, condition monitoring can also enable the remote monitoring of long term degradation, for example, of buildings. This is advantageous in cases where long term effects, such as subsidence, need to be monitored. Rather than send a technician to take readings on a periodic basis, data can be captured remotely and monitored in real time and diagnoses made more quickly. This offers reassurance to the building owners, lowers cost, and speeds up insurance claims.

What is occurring in the industrial sector is also evident in healthcare. A patient has many vital signs whose parameters need to be monitored including heart rate, heart pressure, gas levels and respiration rate. There is already a mass market move to condition monitoring in the medical industry as an influx of connected health devices are coming to market. To complement the medical device monitoring equipment, there has been a push by telecommunications companies (e.g. Qualcomm, Verizon, AT&T) to implement infrastructure for capturing, analysing and disseminating data to stakeholders.

The use of data display and notification is also an area where technology advances can improve productivity. Cloud based services coupled with smart devices (mobile phones, tablets) enables data to be passed easily from sensors to engineers wherever they may be located.

The growth in the use of condition monitoring is so widespread that providers are also looking to retrofit existing equipment with condition monitoring capability. In these cases a non-invasive approach with a self-powered wireless sensor enables condition monitoring capability without the need to install additional local infrastructure, thus saving time and money.

The availability of low cost computing power advances in smart devices and the increasing number of scalable platforms for information gathering is generating a genuine uptake in condition monitoring.

What’s involved?

Condition monitoring systems typically involve several elements, illustrated in figure 2. Each of these areas are discussed below.

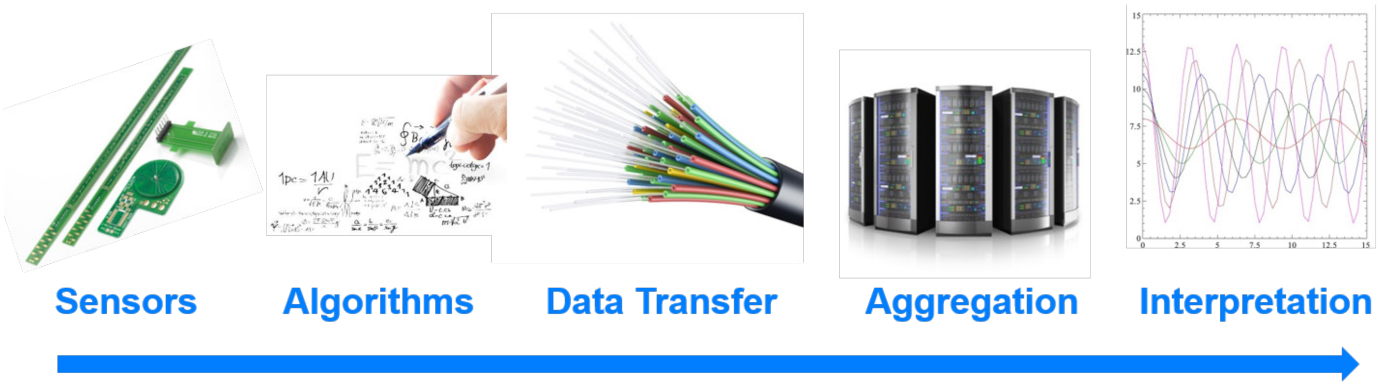
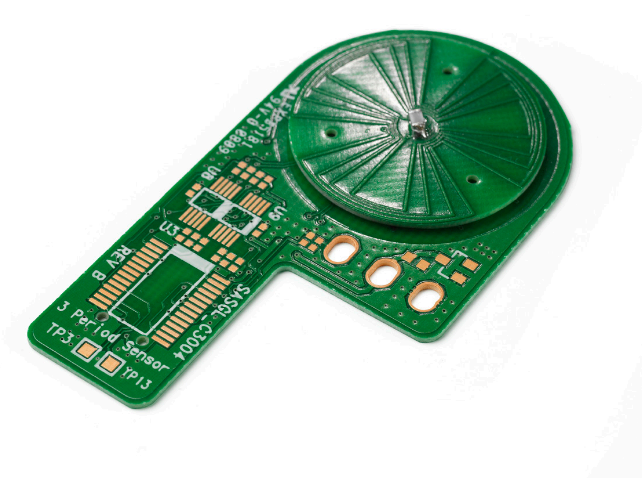


Figure 2 - Key processes in the condition monitoring flow

Sensors

A key part of any condition monitoring system is the deployment of sensors to measure parameters related to the UUM (unit under monitoring). Determining which parameters need to be measured depends on the particular condition you wish to monitor.

As well as providing sensors that monitor specific machines/devices, there is also the potential to monitor a plant by looking at derived quantities which are already part of the measurement process.



For example, monitoring flow rates and pressure into and out of a pump, as well as the electrical power input, gives information on pump efficiency which can then be used to indicate whether a pump is reaching its end of life as the efficiency goes down. Using these proxy measurements is commonplace in the medical arena and mathematical modelling and experimentation can be used to determine the correlation between the proxy variables and the condition being monitored.

Power sources for sensors are important in some applications. For example, in the built environment there may be many wirelessly connected sensors for monitoring the condition of a bridge. Batteries are one way to provide the power but for long term monitoring or for monitoring in extreme environments, energy harvesting is another option. Energy harvesting has been talked about for some time and we believe that now is the time when commercialisation of this technology is possible. The key drivers for wanting to use energy harvesting technology are where autonomous monitoring systems require ease of use (no need to replace batteries) or where the use of batteries is dangerous or prohibitively expensive.

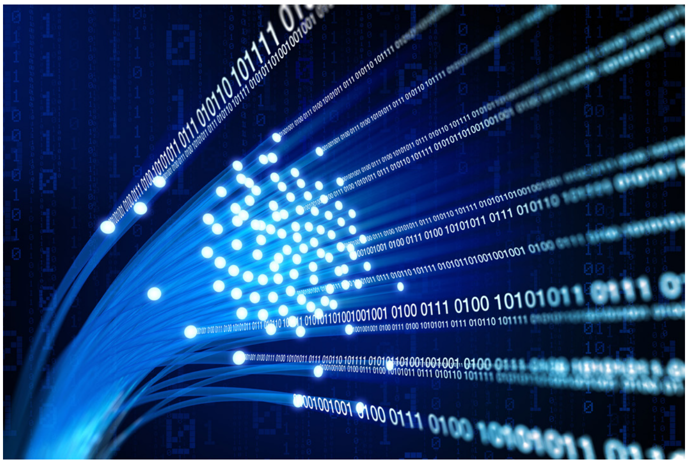
Low power electronic design is a key part of many systems and great advances have been made in the medical world where wearable devices and body implant devices are becoming more commonplace. The use of low power electronics is only half the story. There is also a need for compact and efficient algorithms and low bandwidth data transmission. Speed is directly related to power consumption. The slower you can undertake an operation the less power you will typically consume. So low bandwidth wireless data transfer and slow update rate measurements are key to maximising the life of an autonomous sensor.

Algorithms

There is a choice to be made as to where to place the algorithmic processing power; at the sensor to reduce the amount of data being transmitted, or at the aggregator where typically more processing power is available. This choice is very application specific and depends on the power available and the price point of the sensor. In a commercial dishwasher, an optical based system could be used to monitor performance of the washing system – i.e. check that rotors are rotating and water jets are clear from limescale. Here, a very low cost sensor is required as this is to be integrated into a cost sensitive device. Therefore great care must be taken to ensure the algorithm is as simple as possible so the computing requirements are low.

Data transfer

The data transmission component of a condition monitoring system is important. In some circumstances, condition monitoring systems can still be effective even if all data is not transferred at the same time. For example, equipment degradation takes place over long periods of time and doesn’t need the real time capabilities of Formula 1. This means that



condition monitoring systems can potentially piggy back on existing communications systems, utilising spare capacity when available. This is akin to the mobile phone industry where SMS messages were originally sent as low priority at times when there was spare network capacity. This means that existing or redundant infrastructure, whether wired or wireless could be reused for condition monitoring.

The use of wireless technology makes a lot of sense for systems where many additional sensors for condition monitoring need to be installed. Wireless protocols for reliable data transmission are becoming the norm and great strides have been taken in the commercial and medical worlds to ensure the integrity of wireless transmission systems.

Aggregation and data processing

The gathering of data from multiple sensors is no easy task. If data is available on an existing plant control system then it is possible to carry out some level of data processing on proxy variables as described earlier.

Key to operating an effective condition monitoring system is the algorithmic processing of the collected data. Of course it is possible to deliver a basic condition monitoring regime by individually monitoring items of equipment; however there are efficiencies to be made when you combine data from a variety of sensors spread over a range of equipment. For example, monitoring of several subsystems could allow you to infer information about the state of multiple items even if they are not being monitored. In order to do this, skills in mathematical modelling, physics and engineering are required.

To reduce false-positives it is important to understand the potential failure modes of the system being monitored as well as its intended operating mode.

There are two distinct methodologies which can be used to generate algorithms for condition monitoring:

1. Trend analysis

Collect real life sensor data for extended periods of time and wait for failures to occur. Analysis of this data can then be used to identify trends or features which correspond to particular failures. This is time consuming and is not guaranteed to capture all failure modes. However, this long term data is useful for helping to validate any algorithms developed by other methods.

2. Modelling

Mathematical and physical modelling can be used to help predict failure modes and their effect on measured parameters. In this way an algorithm can be developed from first principles. Validation of the algorithm can then be achieved through a combination of real life data and/or by deliberately introducing faults in the system (however this becomes cumbersome for expensive, large pieces of equipment).

Interpretation and integration

Once the data has been processed and information about device/system condition has been established it is important to display the data in a user friendly format and notify the correct personnel of impending failures so that corrective action can be taken. In Industrial and Oil & Gas processes, links into business intelligence systems allow the automation of maintenance schedules and the automatic generation of work orders. This is similar to the systems which are utilised in the healthcare industry for transferring information from body sensors via smart devices to a cloud server. Here the telecoms industry has taken a lead by providing a platform for medical monitoring companies which is certified to stringent standards to meet FDA regulations.

Interoperability

With the advent of inexpensive, readily available processing power and wireless connectivity the number of devices/systems which will be condition monitored is expected to increase. Some estimates put the expected expenditure in condition monitoring of machines at $2.1B by 2015[2]. With a variety of industries and vendors using condition monitoring equipment, is it time for an interoperability group to provide advice and enable collaboration between operators, vendors and developers? A good example of this in the medical industry is the Continua Health Alliance whose mission is to establish interoperable personal telehealth solutions. This is achieved by providing a set of guidelines to developers and integrators of medically connected devices to work together.

Conclusion

Condition monitoring is advantageous in many sectors. The concept of monitoring condition is not a new one however. With advances in technology and the significant commercial advantages of condition monitoring the time has come to integrate condition monitoring in a variety of environments. There has been a host of technology developments in the aerospace, automotive and medical sensing arena over the last ten years (wireless comms, low power electronics, energy scavenging) all of which can be used to help proliferate the use of condition monitoring which ultimately will save costs, reduce risk and improve the reliability of systems. Improvements can also be expected in the user experience as condition monitoring outputs are fed back to enable improved equipment design.

[2] This market forecast is from “Machine Condition Monitoring Equipment: A Global Strategic Business Report” by Global Industry Analysts Inc, published in 2014

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