The Industry 4.0 paradigm and the new Machine to Machine (M2M) and Industrial Internet of Things (IIoT) applications represent a new approach to goods and process monitoring in an industrial environment and allow for the development of new functions. This technology centres around a system of sensors which not only supply information to individual machines but are also interconnected, enabling them to send data to department supervision centres or to other machines, which in turn use the information to manage their own processes. The development of these technologies, coupled with the recent trend towards digitisation in industrial automation processes, opens up new potential for an activity that has always attracted the interest of technicians and process managers alike, namely predictive maintenance, otherwise known as “prognostics”.

Rather than a specific technique, instrument or certification, this term refers to the *concept of using the systems’ operating conditions and the data collected* during these stages of the production process to create a *data-based decision model* with the ultimate aim of improving quality, production and competitiveness.

There are two main approaches: one is *Data Driven*, in other words based on an analysis of the collected data, while the other is *Model Driven*, based on a physical model of the system. Both methods involve building a *mathematical model for the system* to serve as a performance benchmark. This model can either be created through data analysis and machine learning procedures or it can be based on a physical description of the system.

As an attempt at classification, we can identify the following four categories:

- **Process data**: these data include parameters such as temperature, pressure, electrical current, voltage, etc. and provide an indirect indication of failures.
- **Failure data**: these data provide a direct indication of system failures and include phenomena such as vibrations, noise, material wear, etc.
- **Analytical models**: established or estimated relationships between one or more independent variables (or explanatory variables) and one or more dependent variables (or explained variables).
- **Statistical models**: estimated relationships between one or more independent variables (or explanatory variables) obtained by extrapolating stochastic data.

Il paradigma dell’Industria 4.0 e le nuove applicazioni del Machine to Machine (M2M) e dell’industrial Internet of Things (IIoT) sono abilitanti per un nuovo modo di monitorare i beni e i processi in ambito industriale, rendendo possibili nuove funzionalità.

Al centro di tutto questo ci sono i sistemi di sensori, che non si limiteranno a fornire informazioni ai singoli macchinari, ma saranno connessi tra di loro al fine di inviare dati a centri dipartimentali di supervisione o ad altri macchinari in grado di sfruttare le informazioni per gestire i propri processi.

Lo sviluppo di queste tecnologie, abбинate alle recenti spinte di digitalizzazione dei processi di automazione industriale, apre nuove prospettive per un settore che ha sempre suscitato l’interesse tanto dei tecnici che dei gestori dei processi: la manutenzione predittiva, conosciuta anche come Prognostica.

Sotto questo nome non vi è la definizione di una tecnica, di uno strumento o di una certificazione: al contrario, si tratta di una filosofia che impiega le condizioni operative dei sistemi e i dati raccolti durante queste fasi del processo produttivo per creare un modello decisionale basato sui dati, con l’obiettivo ultimo di migliorare la qualità, la produzione e la competitività. Due sono gli approcci principali: uno è *Data Driven*, basato cioè sull’analisi del dato raccolto, e l’altro è *Model Driven*, basato su un modello fisico del sistema.

Il punto chiave di questi metodi è la realizzazione di un *modello matematico del sistema*, utile come benchmark delle prestazioni. Questo modello può essere ottenuto attraverso analisi del dato e procedura di machine learning, oppure attraverso la descrizione fisica del sistema.

Volendo fare oggi un tentativo di classificazione, quello che emerge è la possibilità di identificare quattro tipologie, descritte di seguito:

- **Process data**: (dati di processo); sono espressione diretta delle grandezze tipiche del processo (ed espressione indiretta dei guasti), co-
Data analysis is key to this process and merits further attention, once again with a focus on measurements. Many of the functions that need to be adopted require an ability to measure processes and machinery.

Intelligent sensors serve as the lens through which all aspects of the process are observed, but at the same time they are more than just data collectors. They are increasingly capable of understanding everything that takes place around them and to provide clear yet accurately filtered images of reality.

An intelligent sensor is required to collect, process and transmit data, with special emphasis on processing. Paradoxically, the greater the quantity of data available, the less we are able to observe what is happening within the machine or the process. In other words, our brains are particularly attentive to overall visions but get lost in a wealth of detail. Moreover, we cannot expect to change this by storing large quantities of data without any filtering operation. To help us perform this function we can use networks of sensors which are capable of filtering and aggregating data so as to transform them into transmissible information. Moreover, every sub-network performs an additional process of aggregation and passes on to the higher level only the information that is required for observation and decision making.

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These are the basic principles of predictive maintenance: predicting failure conditions, evaluating the falloff in machinery performance and estimating its remaining lifetime.

Machines, systems and components are not subject solely to malfunctions but are increasingly likely to operate correctly over their entire life cycle. Two issues therefore arise. The first is to determine this life cycle, which owing to wear is very different from the theoretical duration. Knowing the remaining useful lifetime of a component will certainly help us plan the various stages in the process in order to predict the point at which action will need to be taken to restore its original performance. Moreover, developing a good predictive maintenance system certainly helps in determining the life cycle. Another important issue concerns the possibility of planning the efficiency of the process in terms of production, consumption and waste. This is closely related to the falloff in system performance. Company process engineers and energy managers are keen to be able to predict how the efficiency of systems will change over time. For this reason the concept of predictive maintenance is often associated with that of Condition Monitoring. Condition Monitoring is increasingly described as one of the pillars of Industry 4.0 due to its ability to serve not just as a useful diagnostic tool but also as a way of developing and proposing new services.

This new industrial concept involves digitising the factory and its sensors as well as developing new products that incorporate all the benefits of collectable and shareable information. Condition monitoring exploits this data collection potential to create a set of information that can be used in different decision-making stages and not just for maintenance. An effective approach to Automation 4.0 makes all this information available and enables it to be used to define an increasing number of services. Digitisation is the backbone of this process and serves to create an increasingly efficient and competitive new production methodology.

do un’enfasi particolare sull’elaborare.

Paradosso, infatti, più sono i dati a disposizione e più siamo ciechi a quanto accade nella macchina o nel processo: il nostro cervello è particolarmente attento alle visioni di insieme e si perde nel mondo dei dettagli. Né possiamo pensare di cambiare questa natura immagazzinando grandi moli di dati senza nessuna operazione di filtro. A svolgere questa funzione ci vengono in aiuto le reti di sensori, in grado di filtrare e aggregare dati trasformandoli in informazioni da trasmettere. Inoltre, ogni sottorete ne aggrega sempre di più, trasmettendo al livello superiore solo le informazioni che gli competono per osservare e decidere.

Tutto questo rappresenta le fondamentali dei principi di manutenzione predittiva: prevedere le condizioni di guasto, valutare il degrado delle prestazioni del macchinario e stimare la sua vita residua. Macchine, sistemi e componenti non sono, infatti, soggetti solo a guasti: sempre di più sono destinati a funzionare in maniera corretta durante tutto il loro ciclo di vita. Intervengono allora due questioni. La prima è determinare tale ciclo di vita che, a causa dell’usura, si discosta molto da quello teorico; poter sapere quanto vita utile rimane ad un componente aiuta sicuramente a pianificare le varie fasi del processo al fine di prevedere quale dovrà essere il momento di intervenire per ripristinare le performance originarie. Definire un buon sistema di manutenzione predittiva aiuta sicuramente anche nella determinazione del ciclo di vita.

Altra questione particolarmente sensibile è la possibilità di pianificare l’efficienza del processo sia in termini di produzione che di consumi e scarti. Questo è legato strettamente alla degradazione delle performance del sistema. Poter prevedere come cambia l’efficienza di questi sistemi sta a cuore a tutti gli ingegneri di processo e agli Energy manager aziendali. Per questo il termine di manutenzione predittiva molto spesso è legato al concetto di Condition Monitoring (monitoraggio delle condizioni) il Condition Monitoring è sempre di più indicato come uno dei pilastri dell’Industria 4.0 proprio per la sua capacità non solo di essere uno strumento utile di diagnosi, ma anche perché offre la possibilità di sviluppare e proporre nuovi servizi. Questa nuova concezione dell’industria non passa, infatti, solo dalla digitalizzazione della fabbrica e della sua sensorizzazione, ma anche attraverso lo sviluppo di nuovi prodotti che portino in sé tutti i benefici derivanti dalle informazioni raccogliibili e condivisibili. Il Condition Monitoring sfrutta proprio queste potenzialità di raccolta del dato per creare un insieme di informazioni utili in diverse fasi decisionali, e non solo per la manutenzione.

L’implementazione di un corretto approccio di Automazione 4.0 permette infatti di avere a disposizione tutte queste informazioni utilizzabili per definire sempre più servizi. La digitalizzazione è lo scheletro di questo processo, su cui costruire una nuova metodologia produttiva sempre più efficiente e competitiva.
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