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Smart Manufacturing

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Abstract

Manufacturing accounts for a quarter of worldwide employment. Employees of this sector earn higher than the median income of a country. Manufacturing contributes up to twenty percent of Gross Domestic Product, GDP of countries. Moreover it has multiplier effect on business services jobs. Manufacturing is vital to country's economic growth and ability to innovate. Hence countries such as Singapore, China, USA, Germany, India, UK, Korea, and Japan have embarked on substantially funded national programs to strengthen manufacturing. Singapore's nineteen billion dollars Research, Innovation and Enterprise plan known as RIE2020 has a major emphasis on Advanced Manufacturing and Engineering, AME. Automation and robots have been part of manufacturing innovation. The following discusses what are on the horizon that will shape the future of manufacturing.

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Keywords:

Digital Manufacturing

The terms "digital manufacturing" or 'smart manufacturing' or 'intelligent manufacturing' refer to communication and computing technologies which enable all players in the value chain of products at the supply chain, enterprise and shop floor levels to be digitally connected and data analytics-driven, thus achieving intelligent coordination for demand and supply matching, faster time to market, mass customization and cost benefits. Engineers are developing Manufacturing Control Tower (MCT) for this purpose. Maintenance of machinery is an

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area of focus. For example, company General Electric, GE reported that at one of its plants, use of Predix software platform connected to sensors led to the detection of gas leakage and preventive measures led to savings of $350,000 per year. Another example, consider cutter tool wear in a CNC milling machine. After each cut, photos from a high fidelity stereomicroscope can be taken to measure the wear of the cutting tool. Measurements from sensors such as vibration sensor and force dynamometer are sampled using data acquisition cards and the data are stored on computers. After data acquisition, the sensor readings are used for feature extraction and selection. These selected features can be used to train and cross-validate advanced neural network (NN) or Hidden Markov Model (HMM) models of the tool wear, e.g. via an offline computing platform away from the machine. When the models are trained and cross-validated, they can be used for: (a) diagnostics where the degree of tool wear in the current time step can be determined from the model given the current and past sensor readings, and (b) prognostics so that the tool wear is predicted. These predictions enable maintenance to be scheduled when necessary, thus reducing downtime while increasing reliability.

Smart Sensors and Processors

Success of digital manufacturing is contingent on the availability of robust, power efficient and cost effective smart sensors and processors, and wireless networking interfaces. For this purpose nanotechnology and 3D Printing enabled next generation flexible sensors, electronic skins, self-powered, and disposable sensors are being developed. More over the smart manufacturing requires a variety of processors from small low end cores for sensors and actuators to more compact and power efficient for robots and intelligent devices to highest performance cores for servers. Various processors could be grouped into two blocks. The powerful but complex and expensive Intel processors, and the low cost and low end ARM cores. At the very low end side of processors a multitude of non-compatible devices exists usually focused on certain specific tasks. Intel processors have been combined with specialized graphics processors GPUs and FPGAs to increase both processing performance and power efficiency. ARM processor cores are combined with a number of accelerator units to reach acceptable overall performance. Yet, they lag in meeting the demands of smart manufacturing. Other requirements include easy connectivity and integration with overall system, cost, size and cooling budget. Even more demanding requirement is the homogenous software system so as to interact intelligently and lower the risk of failure. This requires a processor architecture which scales from small low end cores to very powerful high end processors. Such an architecture requires rethinking of traditional processor architecture from the scratch. For example, Hyperion-Core, a tech start-up is proposing polymorphous architectures (2). They are based on a data-processing array capable of emulating FPGA and GPU like data processing. They also process efficiently emerging Artificial Intelligence Algorithms while fully compatible with different programming environments and codes. Such developments are leading towards a single processor platform and a single open source software platform for the complex manufacturing system.

Internet of Things (IoT) or Industrial Internet of Things (IIoT)

Based on the aforementioned technology advances it is feasible to digitally connect many physical objects and equipment in what has come to be known as the Internet of Things (IoT). The pervasive connectivity provides many benefits such as information sharing and coordination leading to new functions and services that were previously not feasible, as well as greater equipment reliability since their status can be queried on a regular basis. These benefits have far-reaching implications for manufacturing as they have the potential to make manufacturing more agile and responsive, reduce equipment downtime and achieve greater efficiencies in operations leading to reduced costs. They also enable better matching of demand and supply, and can potentially increase revenue as well. Engineering companies as well as aerospace companies are betting on IoT. It is estimated that more than 50 billion machines will be connected by 2020.

Data Analytics in the Cloud

Smart manufacturing depends on the ability to perform real-time analytics on large data gathered at various points in the value chain. Under the umbrella of Apache Software Foundation, the open source community has developed many techniques and tools for big data analytics such as Hadoop for MapReduce operations and Spark for in-memory large scale data processing. Closely related to data analytics, machine learning libraries such as Mahout and MLlib have been developed for these platforms. While these tools and features can be deployed on clusters of computers on premise, popular cloud service providers such as Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform have incorporated many of these tools and features and made them easier to use for big data analytics in a fee-based subscription manner. They also provide facilities, e.g. AWS IoT, Azure IoT Suite and Google IoT Solutions, to receive data streams via IoT gateways using a protocol like MQTT and performing simple operations like alerting and visualization on real-time dashboards. However, these platforms do not yet support complex data analytics and machine learning operations like clustering, regression and classification. GE's Predix platform is interfaced with Microsoft Azure could. An issue is the delay or latency associated with transmitting voluminous sensor data streams to be stored and processed on the cloud, and for any necessary action to be transmitted back to the place where the machine is located or where the physical process is taking place. Efforts are being made to develop edge analytics technologies to process sensor data streams and construct advanced models in situ where machines are located, while being connected to the cloud, thus reaping the benefits of cloud computing without its concomitant shortcomings.

Materials Informatics

Manufacturing innovations are critically dependent on the availability of suitable materials and data on invertible structure-processing-property-performance-life cycle linkages of materials. Material development cycle generally exceeds the product development cycle. Hence, there is need to accelerate the materials innovation. This is a major challenge considering the hundreds of thousands of materials and processes, and millions of materials information and data on microstructure, composition, properties, and functional, environmental, and economic performance. Emerging field of Materials Informatics computationally mines and analyses large ensembles of experimental and modelling datasets efficiently and delivers core materials knowledge in user friendly way via web based platforms to the designers so as to accelerate materials, products and manufacturing innovations (3).

Zero-Waste Manufacturing

Zero-waste manufacturing involves designing products and processes such that no trash is sent to landfills or incinerators. One approach is to redesign products and materials selection suitable for reuse. Another approach is to conserve and recover resources from the used products, and use them in manufacturing of new products. An emerging trend is remanufacturing or reconditioning. Closed-cycle manufacturing or circular economy is aimed at enhanced product life span, more efficient use of resources, and elimination of waste and pollution during the manufacturing process as well as life of the product. Life Cycle Engineering, LCE approach aims at waste prevention as opposed to the end-of-life waste management. It is a whole system approach that aims to change the way resources flow during the full life cycle of the product thus resulting in zero waste. In the future a web enabled collaboration platform can envisioned via which data and knowledge about whether a particular waste is recyclable or transformable into a useful resource can be shared among the manufacturing companies, recyclers, and product designers. Using such web based platform the manufacturing wastes or by-products are physically exchanged between different companies from within and across industries thereby waste-to-resource matching is dynamically facilitated. Moreover decisions can be made based on the economic and environmental viability of the exchanges. Challenges for this development include codifying the vast and growing amount of tacit knowledge on multitude of manufacturing wastes and resources. Industrial Symbiosis devised by International Synergies Limited, UK is one such example.

3D Printing or Additive Manufacturing

Recently popular 3D printing method involves direct making of products by layer by layer disposition of materials using digital data from a 3D model. It has been promoted as a zero waste manufacturing method as opposed to conventional subtraction ways of manufacturing which generate waste. It is particularly suitable for customized manufacturing of low volume products. Further efforts are necessary in terms of materials options, manufacturing speed, and engineering performance so that this method could be applied to high volume, engineering products.

Cyber Security for Smart Manufacturing

The aforementioned complex, integrated system increases the security requirements of the manufacturing companies by adding both, more points of attack and more data points available for the attacker. Advanced internet security tools use artificial intelligence for detecting behavioral pattern of malware and viruses and for isolating and terminating threats. As the manufacturing systems grow, the future networks require built-in intelligence for detecting intruders and autonomously fighting back with adequate measures.

International Standards

Smart manufacturing is contingent on the collection, analysis, and secure exchange of quality data. International standards are necessary for this purpose. They are in nascent stage given the newness of smart manufacturing. For example, ISO/IEC 27000 standard information security management system is for general purpose enterprise system. It is difficult to fulfill all the necessary requirements of manufacturing control systems. ISO28000 is related to the security aspects of supply chain. It needs to be adopted to the manufacturing supply chains. Standards organizations need to cooperate and put efforts to study gaps and areas of smart manufacturing where specialized committees may contribute additional needed standards.

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Conclusion

Manufacturing is changing from large monolithic production floors to geographically distributed, internet-connected, medium scale, smart factories. Benefits of smart manufacturing include improved productivity, cost savings, product customization to the markets, resources efficiency, and mitigating manufacturing's negative environmental impact. According to the United Nations Environment Program, UNEP manufacturing is responsible for 20 percent of global CO_2 emissions.

Engineering education is not keeping pace with the technology advances in manufacturing. Curriculum is to be updated so as to train engineers with knowledge and skills related to sensors, data analytics, algorithms, IoT, machine learning, artificial intelligence, and smart manufacturing.

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