Status of Smart Manufacturing in the United States

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***Abstract*—Programs in deploying Smart Manufacturing technologies have been under development in Germany, European Union, and Korea since 2011. This paper investigates the current status of Smart Manufacturing in the United States, and the trends in its technologies such as Industrial Internet of Things and artificial intelligence in standardized industrial robotics. In many other industrial countries, in particular, in East Asia, clear government policies and strategies exist that provide guidance and orient funding towards SM technologies, such as the "Made in China 2025" industrial policy and the Korean "Manufacturing Innovation 3.0" strategy. Although many efforts exist in the U.S. on the academic and industrial levels, that aim at increasing SM utilization, the efforts remain mostly isolated, and driven by the private sector without a clear guiding policy.**

Keywords—Smart Manufacturing, Industry 4.0, Intelligent Industrial Robots, Industrial Internet of Things

I. Introduction

In 2010, China, for the first time, surpassed the United States as the world's largest manufacturer and continues to widen its lead, according to current data (see **Table 1**) [1]. Furthermore, China fiercely takes the global lead in its push towards industrial robotics built with artificial intelligence, and places it as a priority for its growth in its industrial policy named "Made in China 2025" as stated by China's president Xi Jinping [2]. In the following years, the European Union and Germany adopted plans that largely rely on SM technologies to increase their national manufacturing production, and as a result, the new term "Industry 4.0" [3] [4] emerged to define the 4th Generation of industry [5]. *The Wall Street Journal* referred to it as the "New Industrial Revolution" in 2013, and *The Huffington Post* called it a leaving "bullet train" that will "propel the manufacturers that climb on board" [6]. In Korea, the Manufacturing Industry Innovation 3.0 strategy was launched in 2014 to introduce SM. In 2015, SM was first defined in the United States in Congressional Bill S.1054 as "a set of advanced sensing, instrumentation, monitoring, controls, and process optimization technologies and practices that merge information and communication technologies with the manufacturing environment for the real-time management of

TABLE I. Top 10 countries providing value-added manufacturing ranked by the percent of the world's manufacturing services provided [1].

1	China	23.2%		6	Italy	3.1%
2	United States	17.2%		7	France	2.4%
3	Japan	7.8%		8	Russia	2.4%
4	Germany	7.3%		9	Brazil	2.3%
5	Korea	6.3%		10	United Kingdom	2.1%

energy, productivity, and costs across factories and companies" [7].

The National Institute of Standards and Technology (NIST) defines SM as "fully-integrated, collaborative manufacturing systems that respond in real time to meet changing demands and conditions in the factory, in the supply network, and in customer needs" [8].

The Smart Manufacturing Leadership Coalition (SMLC) states that "SM is the ability to solve existing and future problems via an open infrastructure that allows solutions to be implemented at the speed of business while creating value-added results" [9].

From the definitions above, it can be concluded that the core of smart manufacturing includes:

- Technologies and practices
- Integration of manufacturing processes with information and communication technologies such as the utilization of wireless communication technologies and Industrial Internet of Things (IIoT) in manufacturing plants.
- Real-time adaptation

II. Technologies that Constitute Smart Manufacturing

The core of the state-of-the-art SM technologies [10] include:

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- **Industrial Internet of Things (IIoT) and Cyber-Physical Systems (CPS):** The interconnection of devices, machines, and equipment over a communication network [11]. As a result, IoT allows the machines, equipment, products and devices to be monitored and even controlled remotely over the communication network. Products can be improved, and large costs can be avoided. **CPS** systems are developed to achieve mass production with a high flexibility for customization in real-time [10]. **Table 2** shows some IIoT platforms and their sizes as of 2018 [12] [13]. It can be seen from the table that the number of connected devices and robots to the IIoT platforms increased dramatically within a short period of time. This trend is due to the increased improvement in reliability and reduced failure and downtime due to improved predictive maintenance.

- **Cloud Computing:** A computing system that is based on the Internet, in which computational resources and data are provided to the pool of users. Cloud computing can increase production efficiency by allowing simultaneous access of data to users.

- **Sustainable Manufacturing:** The U.S. Environmental Protection Agency defines sustainable manufacturing as "the creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources" [14].

- **Additive Manufacturing (AM):** This layer-by-layer production technology is rapidly finding an increased number of applications. Initially, AM saw applications in rapid prototyping, altering production lines and adding a high level of flexibility to manufacturing processes [10], part repair, and direct manufacturing of parts as well [11] [15] [16].

TABLE II. Common Industrial Internet of Things platforms and their sizes as of 2018

IIoT platform	Owner	Year launched	Size as of 2018
Ability	ABB Robotics	2017	7000 robots
FIELD	FANUC Robotics	2016	Not reported.
Conium	Kuka Robotics	2016	One million devices
Predix	General Electric	2016	Not reported. The largest IIoT platform in the world.
MindSphere	Siemens	2017	More than 30 million devices.

- **Incorporation of Wireless Transmitters for Continuous Improvement:** Significant cost cuts can be achieved. For example, truck engines have recently been equipped with wireless transmitters that relay engine performance and oil temperature to manufacturers and owners, who in turn, can avoid costly recalls and repairs [17].

- **Machine Intelligence:** These technologies have undergone significant progress in the recent years, employing methods that primarily rely on algorithms based on neural networks. They can simplify troubleshooting processes and reduce costs significantly for manufacturers. For example, the ability of intelligent robotics to self-learn the optimal process and solve problems, rather than needing a technician to teach them every step in the process can result in improvements in the process after the machine self-learns as much as a "**million fold**" [18]. Also, optical scanners with the proper image processing algorithms may be used to troubleshoot faults in printed circuit boards [17] [19].

III. Smart Manufacturing in the United States

In the United States, medium- and small-sized manufacturers typically do not have the financial resources and expertise needed to adopt the efficient SM technologies [20][21]. U.S. Senator Geanne Shaheen states that annual electrical energy consumption can be cut by $25 billion [21] by providing SM technologies to small- and medium-sized manufacturers. Furthermore, the global gross domestic product can be increased by $15 trillion over the next two decades by the utilization of SM [21]. In response to this need in SM technologies, the United States Department of Energy (DOE) created Industrial Assessment Centers (IAC) to provide targeted manufacturers with free energy and waste management assessment [22].

However, the effort provided by the IACs addresses only the manufacturers that contact the DOE to request an assessment, and it only targets companies that have fewer than 500 employees and annual gross sales of less than $100 million [7]. Furthermore, it does not provide a workforce pool that is trained to utilize and perform SM technologies and techniques.

To answer the need for a pool of skilled workforce, Smart Manufacturing for America's Technological Transformation ($SMART^2$) was initiated. This project includes educational and on-ground modules offered to community and technical college educators, and an online platform with practices and applications of SM in industry to link the educational institutions with manufacturers.

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IV. CONCLUSION

Technologies and practices that constitute SM include Industrial Internet of Things, Cloud Computing, Sustainable Manufacturing, Wireless communication networks, Additive Manufacturing, and Artificial Intelligence. Smart Manufacturing was officially defined in the U.S. in 2015, and is based on the Industry 4.0 paradigm, which officially came to existence in 2011.

Although many efforts exist in the U.S. on the academic and industrial levels, that aim at increasing SM utilization, the efforts remain mostly isolated, and driven by the private sector without a clear guiding policy. In many other industrial countries, in particular, in East Asia, clear government policies and strategies exist that provide guidance and orient funding towards SM technologies, such as the "Made in China 2025" industrial policy and the Korean "Manufacturing Innovation 3.0" strategy. Some current efforts in the U.S. to increase utilization of SM include those that directly target small and medium-sized manufacturers such as the Industrial Assessment Centers created by the U.S. Department of Energy, and those that target technical education in community and technical colleges such as the SMART^2 project funded by the National Science Foundation.

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