Symbiosis

www.symbiosisonline.org
www.symbiosisonlinepublishing.com

Review Article | International Journal of Advanced Robotics and Automation | Open Access

The 4th Industrial Revolution – A Smart Factory Implementation Guide

William Pagnon*

Freelance Robotics Pty Ltd, 17 Gary St Morningside, 4170 QLD, Australia

Received: May 05, 2017; Accepted: May 22, 2017; Published: June 06, 2017

***Corresponding author:** William Pagnon, Freelance Robotics Pty Ltd, 17 Gary St Morningside, 4170 QLD, Australia, E-mail: wpagnon@freelancerobotics.com.au*

Abstract

In this article, a method for factory automation from online ordering to product shipping without any human intervention is presented. Beyond the technical aspects, an off-the-shelf machinery example is used to illustrate the feasibility of smart factories; and we review the advantages of smart factories as well as current social trends. We find that factory automation has benefits for customers, the factory owner and the workforce. Future work is required to determine the most efficient process for moving existing plants to the smart factory model; and to ensure that the assumptions about the benefits of this model are being realized as more factories change.

Introduction

We are now in a time where the 4th industrial revolution has emerged and the way factories work will never be the same. From the development of computation and industrial robots, which was the heart of the 3rd industrial revolution, the 4th industrial revolution has evolved to combine superior processing power with massive real-time data analysis, producing smart machines capable of collaborating with each other and, thus, taking plant automation a step further [1, 2]. The 1st and 2nd industrial revolutions moved production from manual to machine methods, causing an evolution that changed the predominantly agrarian, rural society to an urban, industrial one. The 4th industrial revolution can be viewed as the fusion of a range of new technologies across the digital, physical and biological worlds that will potentially impact our economies and industries to the same extent.

In this article, a realistic way to automate the entire commercial process is presented. Starting with an online order we will track it through to delivery, describing here a new standard of single item, fully customised products that are issued from automated smart factories at a lower cost using high volume manufacturing.

Figure 1 illustrates the automated interaction between industries in the commercial process, where orders, bank payments, update notifications, fabrication, and product delivery are automatically orchestrated and monitored.

Figure 1: Smart Factory Schematic Diagram [© Nils Ackermann]

We also examine the potential advantages of the 4th industrial revolution for both factory owners and broader society. While many believe that the increased use of automation will have negative effects for workers, we find this is not so. In the future, workers will no longer have to perform repetitive or dangerous tasks, and will instead be employed in a range of creative and challenging jobs, increasing job satisfaction and buying power as the cost of goods falls.

Online Ordering

Shopping using the internet is a now well established purchasing pathway. For our example, consider an e-commerce website that takes you through a wizard to customise your product's colour, size, shape, as well as various other options. The product customisation is increased by the combination factor of $\prod_{i=1}^{r} n_i$ where r is the number of product options and n is the number of choices per option. For instance, if a certain product has five customisable options with respectively 5, 2, 6, 2, 6 choices per option, this gives a possibility of 720 product variations. The more options and choices per option there are, the more product variations ensue. This amount can grow rapidly, thus providing the consumer with a highly personalised product [3]. In addition, certain options have an unlimited amount of choice, such as custom text or images that can be printed onto the product, making it look unique. Such e-commerce options are readily available, e.g., the WooCommerce plugin from Wordpress [4].

Order Processing

Once the order is placed online, data from the customer's recorded product options can be transferred to the factory via a secure internet connection. If images are part of the data set, .csv or .xml format are potentially suitable file types. Instead of using staff to process this order, an order processing computer using a queuing management system can send it to the manufacturing floor coordinator computer. This will orchestrate the processing instructions, determined by the customer selections, into the production machinery. Each order being processed is given a unique ID code affiliated with its specific meta data, including the customer's options, but also their name, delivery address, and so on [2].

Raw Material Processing

To manufacture a product, raw materials are essential. They need to be unloaded and then stored until they are required to be loaded into the related machinery material container. In an automated smart factory unloading is managed by an Automated Guided Vehicle (AGV) system such as the one provided by the NDC company [5]. Automated forklifts can unload pallets and store them on shelves without any human intervention. The forklift fleet operates via management software that can coordinate a complex set of operations and tasks. Pallet barcodes provide a range of information, such as the type of raw material, size and number of boxes and so forth, are used to automatically record storage location. Shelves can also be automated using pallet flow racking methods to maximise the use of storage space. Companies such as Vinarack provide these types of pallet solutions [6].

When raw materials are required, the automated forklift can pick a pallet and drive it to a robotic station to remove the pallet wrapping, pick an individual box of raw material, and place it on a conveyor leading to a box opening station. Such a system is clearly illustrated by ABOT [7]. The box is cut and its lid automatically removed by a suction cap end effector robotics arm. As an aside, rubbish disposal AGV, such as Lynx from OMRON [8], carry storage waste (for instance the box lid) to a disposal bin to be unloaded into an outside rubbish bin collected regularly by a garbage truck. The raw materials then need to be extracted from the box. Depending on the type of raw material being handled, extraction methods differ. Loose, light items, such as powder or plastic pellets, can be vacuumed into a machinery container. Larger parts can be removed individually with a pick and place system and placed onto a conveyor where they may be stored in a distributor rack or a vibrator bowl. Alternatively they can be placed in a position configuration dependent on part size and function.

Product Manufacturing

Once the raw materials are loaded into the machineries, the product is ready to be made. According to the options selected by the customer, the machines receive commands to select the material required to build the ordered product. To illustrate, the commands could program selection of a colour powder and plastic pellets to vacuum form a part of the product. Given product variation, a self-cleaning procedure allows excess material from the product build to be flushed into a disposal bin handled by an Lynx OMRON prior to commencing the next order (automated waste disposal is as described previously) [8].

There is enormous versatility in automated product manufacturing [9]. Depending on the product, the production machines could select among different parts stored in racks as the next option for the product assembly, or send the partially made product to the next manufacturing station. Text or images may be printed according to the customer's file attachment, and so on. Once the product is complete, it is ready to be packed into boxes.

Packing is already a highly automated part of the manufacturing sector using longstanding 3rd industrial revolution technology, e.g. the FANUC robot application for box forming with pick and place application [10]. Note that in a smart factory the packing boxes are initially stored as raw materials, selected and moved by AGV, and then flat packs are shaped into boxes by a specialised machine. Once the finished product is boxed and addressed with the individual end user's customer details, it can be stored on another pallet with other customers' orders awaiting the courier. The initial pallet used to move the product is then returned to shelving as per raw materials storage (described previously).

Product Shipment

When the courier arrives at the loading bay, the automated forklift simply loads the pallets of addressed goods, which are then transported to the postal processing station. At this station, the product parcels are separated from the pallet and conveyed to the correct distribution area from where they are delivered to the customer. Upon delivery, our customer, who originally placed the order online, receives the custom manufactured product at their doorstep in a minimal amount of time.

Smart Factory Maintenance

Plant health is pivotal for running a quality smart factory. Moving machinery has wearing parts that need to be replaced or serviced periodically; additionally parts can wear faster than expected, e.g., because of environmental factors such as temperature variation, and need to be replaced out of cycle. Given that the machines are already connected to a computing system, using 4th industrial revolution principles, these machines can send real-time data about plant health to a central database. This data can be collected, analysed and stored without interrupting factory operation. Products such as Sysmac systems from OMRON are readily available to perform such tasks [11].

Data is used for a variety of applications, e.g., monitoring software can give a visual to the human controller of the overall operation of the system, or the repeatability of the data sent by specific machines can be checked for accuracy [12]. For instance, hose pressure data can indicate if there is an irregularity in an hydraulic system and notify the human controller to book a service prior to risk of failure occurring. Similarly, reading the intensity of a sensor could tell that the sensor needs cleaning. Tolerance in actuating part monitoring could indicate if there is a certain amount of wear that points to a part change at the next scheduled maintenance. Smart software, like the AEGIS iMonitor software, is increasingly common in the marketplace [13].

With data responsiveness, machines can operate according to real-time parameters and can therefore adapt to environmental modification, e.g. handling a part improperly oriented; using force feedback to detect if part lubrication is required; or to compensate for wear in a mechanism. The smart factory also reduces down time essentially by alerting the factory control system to preventative maintenance before the system becomes inoperable. Furthermore, the system could automatically send an email to the responsible contractor to arrange this maintenance at a given time; providing the maintenance provider a report containing job instructions. The contractor could use a dedicated app from the machine manufacturer that provides the maintenance procedure to follow. The factory control system could even manage different contractors with agreed scheduled time repair on a particular machine. A reduction in unexpected breakdowns reduces production losses – improving efficiency and saving money [14].

Production Feedback from the Smart Factory

Another great advantage of smart factories is the wealth of data developed and used in house via monitoring production. A great deal can be managed by the machines accounting for what is used, for example, raw materials can be automatically ordered from the provider when the tally falls below a certain pallet amount. Speed and efficiency can be calculated for each type of customised product [15]. Electricity consumption by the machinery can be monitored for each individual task [16]. Manufacturing costs can be automatically calculated for each order. Essentially, machine level data offers a highly accurate read on production costs without any human intervention. Many graphic and other analysis options can be automatically generated from this data ready to be reviewed by human executives who monitor the factory system in real time [17,18]. For example, marketing reports on trending product options can be compiled easily and accurately with marketing variables, such as seasonal periods that affect sales, clearly shown [19]. Existing software such as AEGIS iMonitor can assist with these tasks [13].

Figure 2 shows a schematic of the potential for currently available products to be used in a smart factory. The yellow section represents the factory floor. It this section, we find the robotic machines that undertake the production work, controlled by the automation controller. Supporting the machine functions are sensors, vision systems and motion actuators, whose signals are all filtered and processed via the I/O controller. In addition to controlling the robots, the automation controller processes and filters production data and monitors and records machine status. The green section of the figure 2 represents the industrial internet. At the factory, it provides the interface with the factory staff, allowing them to monitor and control the system; and is also the channel to data storage facilities and the broader community. The internet provides the link between the factory and its customers and suppliers, providing access to real-time data.

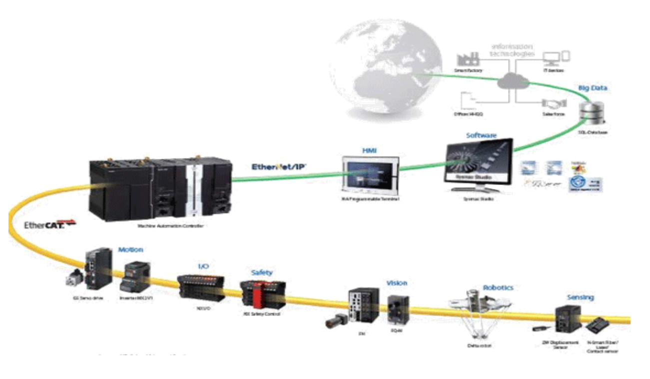

Figure 2: Smart Factory System (Image used courtesy of OMRON)

Smart Factory Advantages

There are clearly tremendous advantages to establishing a fully automated factory [1,14,19]. The 4th industrial revolution has arrived and those who invested early with innovative technology are moving quickly beyond their market competitors. Here is a short list highlighting why this is the case:

•Fast Return on Investment (ROI)

•Production of custom products at a cheaper cost than current mass manufacturing methods

•Increased competitiveness thanks to the production cost reduction in the world market

•Widening the market targeted by offering more product options

•Machinery breakdown prevention

•Removal of human error improves product quality. Humans do not excel in repetitive tasks, but machines do!

•Large reduction of injuries and increase in safety, as no humans interact with the machines apart from conducting maintenance

•Reduction of insurance costs for the company due to the safety improvements

•Reduction of labour cost, which is one of the main components of product cost

•Elimination of logistics and transport costs associated with human operators

•Direct to customer online sales eliminates middle men and retailers – this removes resale margins, thus creating savings from a one unit order

•Real time, traceable orders with almost no shelf time means a newer product arrives sooner.

Social Impact of Smart Factories

Smart factories are going to change the world as we know it, in an even more powerful way than the 3rd industrial revolution did. Labour intensive blue collar jobs are anticipated to largely disappear, with the role of humans moving on [20]. However, despite some concerns that there could be mass unemployment, in fact this change is an opportunity for job creation, workplace retraining and upskilling; and to experience a change in our collective attitude to the type of work we do.

Instead of manual labour, manufacturing staff will focus on machine monitoring, machine maintenance tasks, software application development, and so forth; increasing jobs in the third activity sector whilst the primary and second sectors of activity reduces [20]. Job creation is strongly predicted for information technology, creative space to develop and improve the customer services, marketing and managing of the smart factories. Manufacturers will likely look more like a service company focussing on the user experience. The IT sector and robotics will keep growing and be "banalised" (nicely explained by Avinash Meetoo in his TED talk [21]).

The bottom line - technological advancement is driving forward less hours of work per week for more money and more buying power, thanks to custom products becoming being available at a cheaper cost than what industries currently offer [3]. Quality of life and longevity are both expected to rise thanks to technological advances in the medical sector and personal transport. This video from TDC illustrates how automated cars are expected to hit the market by 2020, greatly reducing road accidents [22,23]. Energy dependence on fossil fuel will diminish towards cleaner energy that will allow us to restore the planet's ecological balance [24].

Our social patterns will change, education will change, jobs will change. Industry delocalisation will be part of the past. Transport will be the major cost of the product, expected to reduce over time as transport and fuel technology improves. Industry is predicted to come back to more regional production, rather than manufacturing in third world countries due to cheaper labour costs. Without the prohibitive costs of labour, it is the initial costs of the machines that matter most and with expected ROI rates this rapidly becomes a null issue. Essentially it will cost no more to produce goods in countries with high labour costs than it does elsewhere [25]. This shift is anticipated to vastly increase job creation in developed countries and drastically affect our current global economic dynamic.

Conclusion

This article summarised a concrete way to fully automate a smart factory, from the customer order to product delivery, all with readily available technology. Machine manufacturer examples were purposely included to demonstrate that smart technology is mature and can be put into practice now. We described how the machines can be maintained and the interconnectivity between the data and the central office can be used to extract valuable production information. Finally, smart factory advantages were highlighted, which links directly to the social impact the 4th industrial revolution will make on the global economy as well as day to day life, particularly from the manufacturing staff's point of view. The 4th industrial revolution is here, we are at the cusp, and it will affect us beyond manufacturing related areas. Market competition is already driving change forward at an immense pace. We are facing an imminent change in the way goods are produced, opening the door to service-centred, customised, safer and higher quality products. This is truly an exciting time to develop and innovate manufacturing processes.

References

1. Lucke D, Constantinescu C, Westkämper E. Smart Factory - A Step towards the Next Generation of Manufacturing. Manufacturing Systems and Technologies for the New Frontier. 2008:115-118. DOI: 10.1007/978-1-84800-267-8_23
2. Wang S, Wan J, Li D, Zhang C. Implementing Smart Factory of Industrie 4.0: An Outlook. International Journal of Distributed Sensor Networks. 2016. DOI: 10.1155/2016/3159805
3. Simão JM, Stadzisz PC, Morel G. Manufacturing Execution Systems for Customised Production. J Mater Process Technol. 2006;179(1–3):268-275.
4. WooCommerce. WooCommerce – eCommerce for WordPress. WooCommerce. WooCommerce. Web. 2017.
5. NDC Automation. Welcome to NDC Automation. NDC Automation. NDC Automation. Web. 2017.
6. Pham Tung. Warehouse Storage Solutions, Suppliers of Standard Pallet Racking, Very Narrow Aisle Pallet Racking. YouTube. 2017.
7. CASI Frisco. ABOT – Automatic Box Opening Technology. YouTube. 2017.
8. Smart RobotX. Mobile Transportlösung von smart robotX. YouTube. 2017.
9. Radziwon A, Bilberg A, Bogers M, Madsen ES. The Smart Factory: Exploring Adaptive and Flexible Manufacturing Solutions. Procedia Engineering. , 2014;69:1184-1190.
10. FANUC America Corporation. Robotic Pick and Place Case Packing System - Delkor MSP-200 Case Packer. YouTube. 2017.
11. Sysmac Style – Industrial Automation. Sysmac – process improvement through integrated traceability, inspection, and direct database connec. YouTube. 2017.
12. Kaiser WJ, Pottie GJ, Srivastava M, Sukhatme GS, Villasenor J, Estrin D. Networked Infomechanical Systems (NIMS) for Ambient Intelligence. Ambient Intelligence. 2005.
13. Aegis Software. Aegis iMonitor 2.0 Redefines Real-Time Factory Monitoring. Aegis Software. 2017.
14. WEFUSA Report. Industrial Internet of Things: Unleashing the Potential of Connected Products and Services. 2015.
15. Wang S, Wan J, Zhang D, Li D, Zhang C. Towards Smart Factory for Industry 4.0: A Self-Organized Multi-Agent System with Big Data based Feedback and Coordination. Computer Networks. 2016;101:158-168.
16. Shrouf F, Ordieres J, Miragliotta G. Smart Factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm. 2014 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM). 2014: 697-701.
17. Jeschke S, Brecher C, Song H, Rawat D. Industrial Internet of Things: Cybermanufacturing Systems. 2016.

18. Rong W, Vanan GT, & Phillips M. The Internet of Things (IoT) and Transformation of the Smart Factory. IES. 2016:399-402.
19. Meredith JR. The Strategic Advantages of the Factory of the Future. California Management Review. 1987;29(3): 27-41
20. Smith A, Anderson J. AI, Robotics, and the Future of Jobs. Pew Research Center. 2014.
21. TEDx Talks. Jobs of the future and how we can prepare for them by Avinash Meetoo. YouTube. 2017.
22. The Daily Conversation. The Future of Driverless Cars. YouTube. 2017.
23. Litman T. Autonomous vehicle implementation predictions. Victoria Transport Policy Institute. 2014.
24. Walker B, Holling CS, Carpenter S, Kinzig, A. Resilience, adaptability and transformability in social–ecological systems. Ecology and Society. 2004;9(2):5.
25. Gold B. Robotics, Programmable Automation and International Competitiveness. IEEE Transactions on Engineering Management. 1982;EM-29(4):135-146.