Industry 4.0

The application of the Internet of Things (IoT), Big Data, and Analytics technologies to industrial automation is increasingly discussed worldwide since a couple of years. The general goal is to improve production line performance, lower operations costs, and to enable short response time to individual customer requirements. This will be a reversal paradigm shift to the centralized mass production introduced by Henry Ford (and actual still today) which lowered car prices significantly and enabled more people to buy and the market to expand. But now, as IT-based technologies such as IoT, Big Data and Analytics are becoming available, a change to manufacturing of inexpensive, personalized quantity-one orders seems to be possible.

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1. Introduction

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The start of the IoT-based manufacturing era is supported by a number of industry groups (such as Industry 4.0 originated in Germany) and many automation companies offer first products and solutions. First applications are of course supplements to existing machines and automation systems. This will, however, be only a small and first step compared to what is discussed as final "IoT-based lot-size 1" production concept. Both existing and new suppliers of the automation industry have to work hard on understanding the new manufacturing paradigm in all details and to provide the enabling hard- and software products.

2. The path to Industry 4.0

2.1 Industrial Revolutions change production basics

The world of today has been formed along the past 200 years by a number of major technological (industrial) revolutions:

The first Industrial Revolution, beginning in Great Britain at the end of the 18th century and ranging to the mid of 19th century, was driven by the invention of the steam engine and mechanization. It caused a shift away from agrarian economy to mechanical production with the help of water and steam power. It is also known as *Mechanical Revolution*.

The second Industrial Revolution began at the end of the 19th century and was characterized by the introduction of mass production based on the division of labor (Henry Ford´s assembly line) and increasing use of electrical energy. It started the age of affordable consumer products and is also known as *Electrical Revolution*.

The third Industrial Revolution started late in the 1960s through the use of electronics and IT in industrial processes. It opened the door to a new age of optimized and automated production and is also known as *Digital Revolution*.

The fourth industrial revolution has started just recently and announces to connect the two worlds of *manufacturing* and *networked connectivity* through the use of Cyber Physical Systems (CPS), Cyber Physical Production Systems (CPPS) and the Internet of Things (IoT). This revolution is characterized today by social media and M2M communication, will continue with smart products and autonomous transport systems and finally lead to fully integrated factories and Plug & Produce concepts.

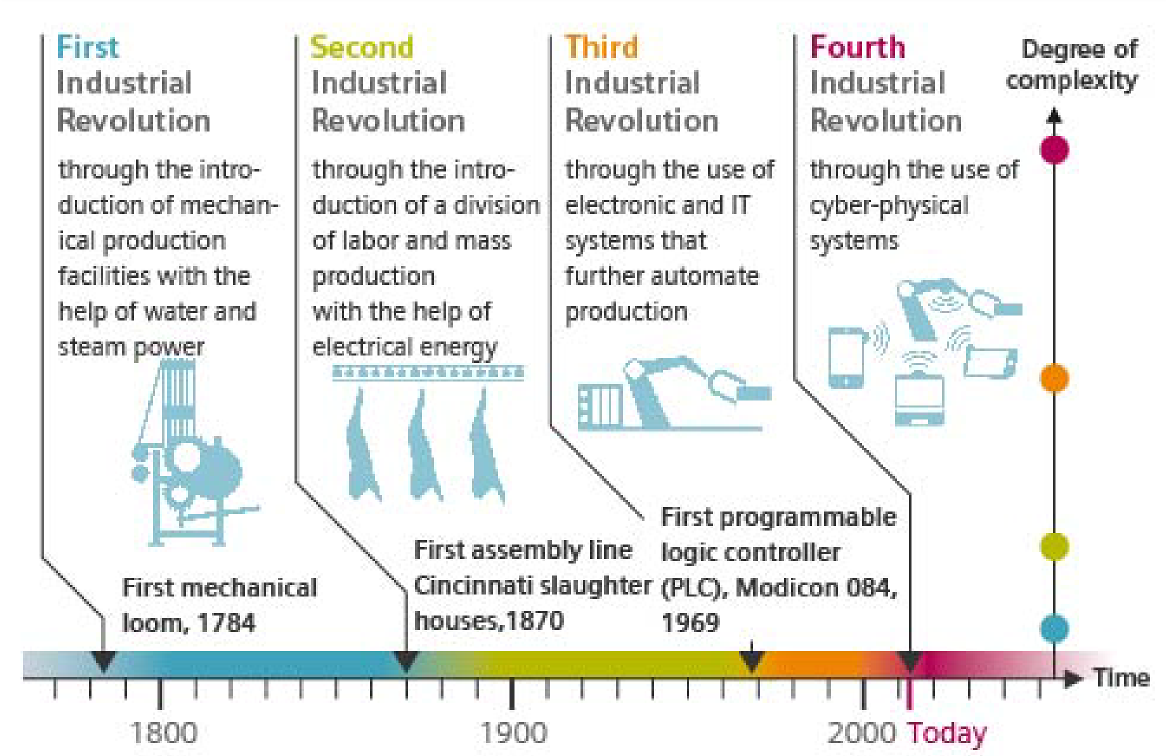

Figure 1: The path to Industry4.0（Sources: DFKI (2011)）

2.2 Industry 4.0, a high-tech strategy

The term "Industry 4.0" has been introduced first in 2011 in Germany at the Hanover fair as the designation of a high-tech strategy of the German government. The principle of Industry 4.0 is that by connecting machines, work pieces and systems, intelligent networks are created along the entire value chain that can control each other autonomously. This will cause a shift from the traditional 5-level Automation Pyramid (consisting of CNC, PLC, SCADA, MES and ERP) to a highly flexible connected cloud-based smart factory (fig 2).

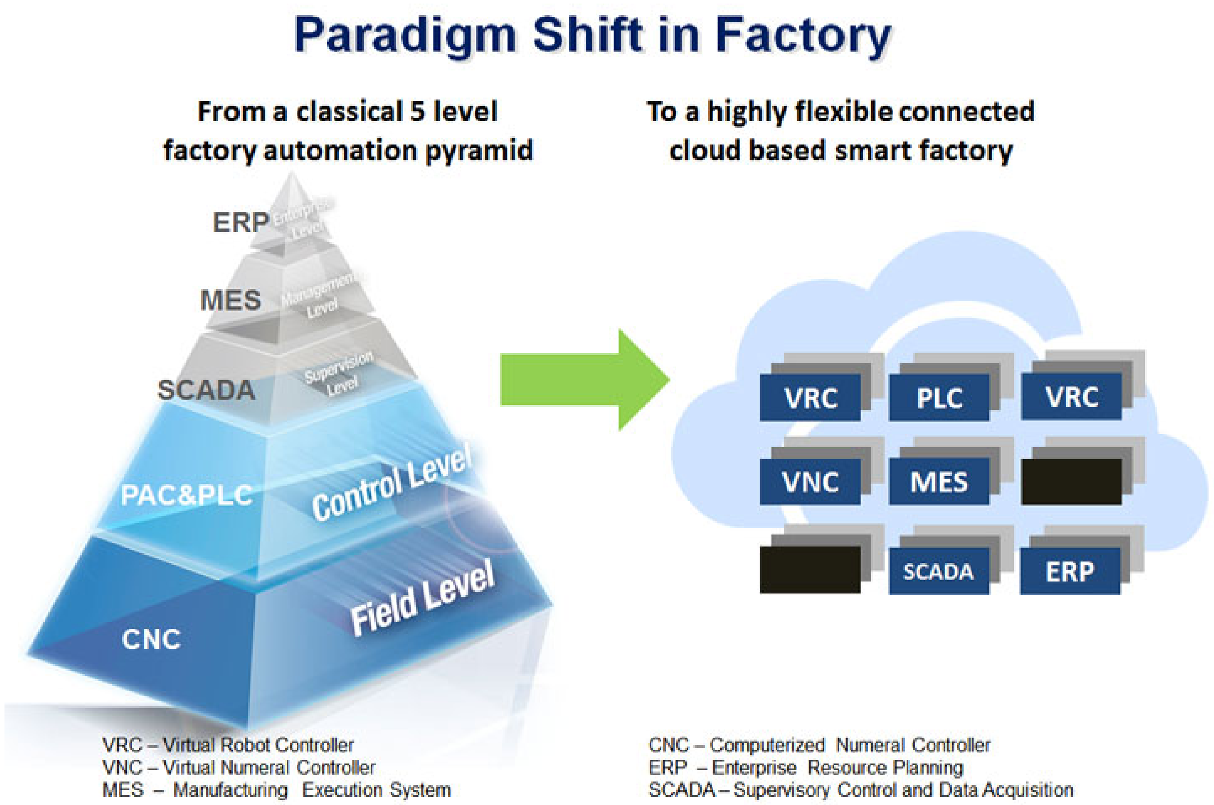

Figure 2: From centralized to networked structure

Networked machines and manufacturing systems are then capable of independently exchanging and responding to information to manage industrial production processes. Industry 4.0 represents a paradigm shift from "centralized" to "decentralized" production - made possible by technological advances which constitute a reversal of conventional production process logic. Industrial production machinery no longer simply "processes" the product, but the product communicates with the machinery to tell it exactly what to do.

This may lead to factories that operate similar as a single complex machine. Separate automated manufacturing devices will be connected as part of a complete manufacturing process. This process will use connected Cyber-Physical Production Systems (CPPS, real-time capable sensors, actuators and machines) which operate alongside an automated business process that controls materials flow and logistics. Connecting these iFactories (intelligent factories) to computer-based design programs will finally enable the manufacturing process to change as new products are introduced.

Although still at an early stage, Industry 4.0 relies on sophisticated software and machines that communicate with each other to optimize production. Smart connected machines will work together and interpret data while relying less on human intelligence. The computerization of manufacturing, the high levels of interconnectivity, the smarter factories and the communication between equipment, create a new era of automation, manufacturing technology and supply chain development: 'Industry 4.0'.

3. Cyber Physical Systems (CPS) and the Internet of Things (IoT)

Two major elements enable this changing manufacturing environment to what is called Industry 4.0: Machine-to-machine (M2M) communication in combination with the Internet of Things. **M2M communications** is used for automated data transmission and measurement between mechanical or electronic devices. Typical components of an M2M system are field-deployed wireless devices with embedded sensors or RFID-Wireless communication networks.

3.1 Cyber-Physical Systems (CPS)

According to Edward A. Lee (2008), Cyber-Physical Systems are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa. Cyber-physical systems are enabling technologies which bring the virtual and physical worlds together to create a truly networked world in which intelligent objects communicate and interact with each other. CPS in manufacturing industry e.g. includes all sorts of sensors, actors, devices and machinery that become interactive through embedded software and connectivity to a network to monitor and control physical processes with feedback loops. CPS collect, store and analyze sensor data through their local business logic to provide and use data and services. This kind of decentralized intelligence creates intelligent object networking and independent process management, with the interaction of the real and virtual worlds. This represents an entire new aspect of manufacturing and production processes.

CPS are not based on a new technology but use and combine existing technologies and established trends in an intelligent manner:

- Driven by the very innovative IT industry, communication technologies and the corresponding hard- and software will continue to get cheaper and more powerful year by year. This will be very much accepted by users in many industries because it enables them to get more and valuable information from their devices and machines and the relevant processes such as status, diagnosis, process parameters, etc.

- Because of the above, devices, systems and machines - as physical objects in the real world - will increasingly networked to each other in factory networks and also in the internet. Once existing in a network as “data points”, devices and machines will store more and more specific data of their own to build a “data object” in the network which will grow over time to a cyber-based second identity or “cyber objects” besides the physical existence of the device in the real world.

- The physical objects will continue to store data which may include specific know how, experiences etc. This will cause their cyber-based identity to get stepwise more intelligent (smart) and to some extend autonomous.

- Software services will be increasingly available to connect cyber objects to “cyber physical systems” with the objective to optimize certain processes. One simple, but famous example is to optimize the traffic flow by connecting the cyber objects of both the vehicles and the traffic light systems to a Cyber-Physical System, which then is enabled to optimize the traffic flow by providing "green waves".

In manufacturing, the CPS of a machine can be considered as a mirrored image of the real machine, which is able to continuously record and track machine condition during utilization. With the high connectivity offered by cloud computing technology, the mirrored model may provide e.g. better data for optimizing manufacturing than the real machine.

3.2 The Internet of Things (IoT)

Cyber physical systems need to be connected to a network to enable the intended information flow. This network is not limited to a factory or plant but can also be the internet which makes a CPS part of the Internet of Things (IoT). This is a network of physical objects or "things" embedded with electronics, software, sensors, and connectivity to enable it to exchange data with people (manufacturer, operator, maintenance specialist) and/or other connected devices in order to achieve greater value and instant support. Each "thing" is identifiable in the network through its embedded computing system and is able to interoperate within the entire Internet infrastructure. Because of its connectivity to all things in the internet, IoT offers more than the established machine-to-machine (M2M) communication. The interconnection of these embedded devices including intelligent (smart) objects is expected to support very much automation in many fields with versatile applications.

The Internet of Things is the current label for what automation professionals used to call machine-to-machine communications. SAP AG, the world's leading enterprise software manufacturer, defines the Internet of Things as, "a world where physical objects are seamlessly integrated into the information network, and where the physical objects can become active participants in business processes. Services are available to interact with these 'smart objects' over the Internet, query and change their state and any information associated with them, taking into account security and privacy issues."

The Internet of Things (IoT) is fundamentally reshaping business and technological requirements within the business landscape. Innovative solutions that intelligently monitor and control remote sensors and devices are revolutionizing enterprise computing. These next-generation intelligent systems are collecting, analyzing, and enabling organizations to act upon massive volumes of raw business data generated by vast numbers of endpoints, to improve business intelligence and auto- mate business processes. Your network and system architects will need to reorganize your IT infra- structure to accommodate and support the Internet of Things.

By using the IoT, the physical manufacturing devices become an active part of the manufacturing process and the real manufacturing world will change to a kind of information system. With sensors and actuators embedded in physical objects and linked through wired and wireless networks, factories will start to produce physical objects from commands and information. These new cyber-physical-systems need advanced embedded processor technologies and software that can support the new demands for real time connectivity and distributed control. See paragraph 6.

4. Connectivity and Smart Factory

Connectivity is a conceptual development for the Internet that would allow consumer as well as industrial objects to have or get connectivity, enabling them to send or receive data over a network. In fact, anything and any object that can be fitted with a transponder, can be assigned an IP address and connected to the network. This implies that all devices will need an IP address as unique identifier. Because of the new Internet Protocol IPv6 with an address length of 128 bit as many as 3.4×10^{38} Internet addresses will be available. Connectivity brings together people, things, processes, and Data to make networked connections more valuable and tuning information into actions that create new capabilities and opportunities for businesses and private life style.

4.1 Connected devices

Connectivity, in context of this document, comprises all kind of smart devices sharing relevant data. The existing Internet of connected *humans* (by social media) is extending fast to an internet of connected *things (IoT) and processes*. Sources predict around 30 billion of devices connected in 2020 thus outnumbering the earth's population by far. Therefore, the future Internet will be primarily the Internet of Things – or more likely the Internet of Everything (IoE). Technology of connectivity is most closely associated with the established "smart" machine to machine (M2M) technology. The connected devices have embedded intelligence that enables them to monitor and analyze data and take action without human intervention, although humans monitor and control these networks. Machine intelligence makes connected systems much more efficient by performing operations that can be done more quickly, consistently, and reliably than systems that require humans to sample, analyze, and act on information.

Implementations are typically based on wireless sensor networks that connect to the Internet and to send for analyses. With increasing intelligence and processing power, sensors will be able to perform high-speed data collections, processing, and communication, which bring cloud-based computing to the IoT. The cloud provides scalable storage for the massive quantities of data provided by the sensor nodes as well as the analytical tools required by the users to make sense of all that data. The cloud can provide the necessary computing resources and services to manage large IoT networks. Cloud-based software-as-a service (SaaS) is key to scaling IoT applications. data

4.2 Use cases

Use Cases range from urban transport to medical monitoring, from household devices to the manufacturing industry, from energy supply to traffic control and many more. Applications are classified into categories such as smart home, smart city, smart manufacturing, smart environment, and smart enterprise and will deal mainly with management of heat, electricity, energy, manufacturing and transportation. Regarding security, home alarm systems could have greater capacity to notify property owners when there has been a suspected breach, while simultaneously contacting the appropriate authorities and letting the homeowner control various aspects of their system from a smartphone.

In business and industry, there are many different potential applications, including improved asset tracking, inventory control, optimized manufacturing etc.

4.3 Connected processes and business

A connected ("smart") city is a system of interconnected processes, including employment, health care, retail and entertainment, public services, energy distribution, and transportation. Such a system of systems is tied together by information and communications technologies that transmit and process data about all sorts of activities within the city. All transportation that helps make a city smart is "connected transportation" where vehicles, travelers, and infrastructures communicate with each other through various data streams. This data can optimize city processes and improve the delivery of urban services and the management of infrastructure.

If a company is deploying a large number of assets, these deployments have to be tightly integrated with the enterprise's business processes. This starts with asset-specific production, sales, and commissioning processes, wherefore the asset needs to register itself with the IoT. During operation, the assets must be able to interact with a variety of backend processes, e.g. for managing condition changes, handling alert events, etc. Large amounts of data coming from the asset must be efficiently analyzed, and it is essential to provide mapping to backend processes that can react to the results of this analysis. Similarly, business processes must be able to reach out to devices, for example to re-configure a device based on the outcomes of a process.

To form a *Connected Business,* an integrated environment is required which accelerates interactions inside and outside the organization, reduces interaction friction and increases productivity. An *Integrated Business* needs integrated business data, processes, rules, services and capabilities between internal and external IT assets in an environment which optimizes business interactions inside, outside, and across organizational boundaries. Self-service applications have to enable customers to connect and view available products, inventory, and transaction status. Published APIs expose data and enable connection, deliver automated notifications based on business activity.

4.4 Smart Factory

The merging of the virtual and physical worlds through CPS and the resulting fusion of technical and business processes lead to a new manufacturing concept named "smart factory". Smart factory products, resources and processes provide – compared to earlier production methods - significant real-time quality together with time and cost advantages. The smart factory is designed according to sustainable and service-oriented business practices. These include flexibility, self-adaptability and learning characteristics, fault tolerance, and risk management.

High levels of automation are established as standard in the smart factory by a flexible network of CPS-based production systems which, to a large extent, automatically oversee production processes. Flexible production systems which are able to respond in almost real-time conditions allow in-house production processes to be radically optimized. Production advantages are not limited solely to one-off production conditions, but can also be optimized according to a global network of adaptive and self-organizing production units belonging to more than one operator

5. Advantech´s Approach to Industry 4.0

Advantech´s Industrial Automation Group declared 2015 to be the "Year of Industry 4.0". Founded in 1983, Advantech, with its headquarter located in Taiwan, is a global leader in providing innovative embedded and automation hardware and software products and solutions including system integration, customer-centric design services, and global logistics support. The company`s current mission is to enable an intelligent planet with Automation and Embedded Computing products and solutions that empower the development of smarter working and living.

Advantech´s approach to Industry 4.0 is structured as a 3-layer architecture, enabling Intelligent machines and robots (Layer 1), Connected iFactory Solutions (Layer 2), and the "Internet of Services" (Layer 3). Through integration of information, quick response and flexible manufacturing, the overall effectiveness and efficiency of manufacturing processes will be highly improved. This 3-Layer concept is combined with an intensive cultivation of vertical markets.

5.1 Enabling intelligent machines and robots (Layer 1)

For intelligent machines and robotics, Advantech offers a complete range of products and technologies including controller, motion control, machine vision, automation computing and integrated machine tool and robot controller (Fig. 3). With these advanced instrumentation and technologies, traditional machines will become more intelligent (smart) equipment**.** Advantech´s goal is to make machines become cyber-physical systems.

Figure 3: Complete range of products

5.2 iFactory solutions (Layer 2)

In an Industry 4.0 environment, all machines and equipment are networked and continuously provide the machine status and production information to the process control system. Thus, the system can perform immediate analysis (Fig. 4) and quickly take the necessary actions. Furthermore, the information can be integrated into big enterprise systems such as Manufacturing Execution Systems (MES) and Enterprise Resource Planning (ERP) System.

In order to reach the aforementioned goals, Advantech provides solutions to enable a fully networked connected iFactory. Advantech´s WebAccess Integrated IoT Software Suite and Solution Platform, together with products such as gateways can connect machines, robots and equipment to the factory network and integrate with systems such as MES and ERP system.

Figure 4: Wide range of analysis

5.3 Internet of Services (Layer 3)

Another goal is to enable the Internet of Services. The service sector has become one of the biggest and fastest-growing business sectors in the world. Services should become more widely and easily available and should also yield higher productivity. This new vision for next-generation services provided via the Internet is known as the Internet of Services. Here, innovative technological developments enable new delivery channels for services and entirely new business models (Fig. 5). The creation of these services is facilitated by open platforms and interface architectures.

The continuously produced status of plant equipment and production information can be used through big data analysis and the development of the Internet of services. The endless stream of information is an excellent source to develop new applications and creative services. For example, traditional machine maintenance relies on human judgment which is not very precise. With the big data analysis of information, such as the vibration of the machine tool bearings, we can configure the model for failure occurrence and thus develop a predictive maintenance system. By doing so, the maintenance action can be performed during non-operational times, and it won't affect the regular operation and the operational efficiency is also effectively improved. Other services include product serialization, manufacturing execution or mass customization.

Figure 5: Industry 4.0 solutions (Internet Services)

5.4 Business Model Innovation for Industry 4.0

To cultivate different vertical markets, Advantech intensively promotes the WebAccess+ IoT Solution Alliance program (Fig. 6). WebAccess+ is an Integrated IoT Software Suite & Solution Platform which is the core software platform of Internet of Things solutions. As an equipment provider, Advantech developed this open software platform in order to support system integrator partners to integrate various applications. The platform (1) combines the smart HMI/SCADA software, remote device management software, intelligent video software and (2) connects industrial cloud platform, and (3) analyzes and manages large amounts of data, video and voice data. Thus, the platform provides critical information anytime, anywhere for management decisions of industrial customers, effectively realizing the vision of Industry 4.0.

Figure 6: WebAccess+ Alliance Program for Industry 4.0 solutions

6. WebAccess (Overview)

WebAccess + Integrated Software Suite and Solution Platform is an Integrated IoT Software Suite & Solution Platform, which is the core of Advantech´s Internet or IoT solutions. It combines four software packages WebAccess/SCADA, WebAccess/NMS, WebAccess+IVS and WebAccess+IMM in one suite. (Fig. 7)

WebAccess/SCADA is the core of all Advantech IoT solutions. It is an 100% smart web-based HMI/SCADA software with powerful networking capabilities and open architecture for versatile vertical application implementation. As main features, it (1) can support the cross-browser business intelligence dashboard or remote data analytic service, is (2) easy to connect to and control a variety of IoT devices and (3) supports ample protocols and over 200 device drivers which makes it flexible and suitable for every automation projects. For data acquisition, analysis and display, the greatest advantage of WebAccess/SCADA is the HTML5-based Business Intelligence Dashboard. Users can configure the dashboard by dragging and dropping the built-in widget library.

WebAccess/NMS is a Network Management Software designed for managing and monitoring industrial device networks. It includes various advanced network management functions, such as visual management, ring topology support, hierarchical architecture, automatic generated topologies and Google map integration. Those functions can provide more on-time, more user friendly management experience beyond general network management. If management systems can't generate the correct topology for users, they have to draw the connection from device to device one by one. WebAccess/NMS can generate the topology automatically which can help avoid the hard work necessary to draw the device connections manually. WebAccess/NMS uses 100% web-based design. Users can just install NMS on a single server PC, and manages the entire global network. Users can also access the NMS using the browser on a PAD or tablet.

WebAccess+IVS is an intelligent Video Software and offers an intelligent video software platform which can support real time monitoring, flexible event action plans, multiple backup modes, quick searching for event logs and powerful IE browser monitoring and much more. WebAccess+IVS is bundled with diverse intelligent video analytics (IVA) modules, such as, face detection, people counting, forbidden zones, motion detection, dwell time & loitering and more. Using this modular SDK Software Development Kit), system integrators can easily integrate WebAccess+IVS to their central management system and application software. This can apply to different application scenarios which help administrators or managers enhance the operating performance and understand the market trend by business intelligence.

WebAccess+IMM (Interactive Multiple Media) is an intelligent digital signage management platform. It possesses a server-client architecture where users can lay out, schedule and dispatch sign content on up to 500 displays via the Internet. It supports more than 30 types of media forms and applies to various Industries and vertical market applications.

Figure 7: WebAccess+ IoT Software Suite

Though Industry 4.0 is still in its initial stage, Advantech believes that the rapid pace of technological development will soon bring it to a turning point where the current landscape of manufacturing and other industries will be drastically changed. Advantech is devoting itself to accelerating the shift of paradigm and realizing the Industry 4.0 vision for the future world.