DESIGN AND IMPLEMENTATION OF WEARABLE DEVICES IN MACHINE TOOLS MONITORING SYSTEM

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ABSTRACT

The world's fourth industrial revolution has finally opened after the term Industry 4.0 was proposed by Germany at the Hannover Industrial Fair in 2011, which combined industrial production with an unmanned plant to perform automated production. With the rise of Internet of Things (IoT), cloud computing, and wearing computerized devices has brought more convenience to mankind with the immediate accessibility of the Internet and technology. For example, the development of mobile devices and network technology has inspired the rapid development of wearable devices on mobile devices. Thus, to enhance the current prospects of Taiwan's unmanned machinery factory's monitoring and maintenance capabilities, this paper studies the use of Google glass Machine Tools Monitoring system, GMTM system, to be implemented in Taiwan's machinery factories. GMTM system, via the Internet, monitors sensor tools to collect tool work data to be transferred to cloud computing for analysis, processing and show the actual working conditions of each machine tool. Furthermore, the proposed system uses the monitoring data in the database to inform the factory supervisors the working status of each machine to determine whether there is a need for machine tool maintenance. This system combines real-time monitoring of material with the presentation of Google Glass wearable devices and iBeacon interior space positioning technology. GMTM system can improve the quality of machine tool production and productivity as well as enhance Taiwan's industrial competitiveness.

Key Words: Industry 4.0, machine tools, wearable devices

1 INTRODUCTION

The rapid development of information and communication technology (ICT) has resulted in the integration of cloud computing, big data, the Internet of Things (IoT) and wearable computing through mobile phone and tablet computing. Wearable devices are well defined as mobile electronic devices that can be worn on the body or mounted on clothing and components by providing detection facilities, computing abilities, access to the Internet, and display capabilities.[1] Such devices can be applied in the

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fields of entertainment, fitness and wellness, payment, and fashion, and within the domains of the military or industry.

With the use of steam power had made mechanized production possible and resulted in the First Industrial Revolution. The Second Industrial Revolution was facilitated by electricity-powered mass production. The Third Industrial Revolution was the result of the information revolution, and the Fourth Industrial Revolution (was caused by the transformation), also called Industry 4.0, accompanied the shift from global manufacturing to intelligent manufacturing. The core of Industry 4.0 is to facilitate intelligent factories, which integrate Cyber-Physical Systems (CPSs) and intelligent sensor network infrastructure construction. Industry 4.0 allows the flow of developmental production with the implementation of monitors, actuators, communication, and networking to form automated intelligent factories with the ability to calculate, communicate, and control. Intelligent factories are in line to greatly change the current state of global commercial manufacturing.

Machine tools are the leading industry in commercial manufacturing. Such tools can produce metal machine parts for different industries, including automotive, astronautics, national defense, machinery, modeling, electronics, and power generation. Newly evolved high technologies, including semiconductors and panels, also require machine tools. Because of their widespread use, these tools are referred to as "the Mother of Industry." According to Gardner Research, the main producers of machine tools are South Korea, Japan, and China. The machine tool industry from South Korea and China is developing particularly rapidly. Thus, in Taiwan, maintaining worldwide competitiveness in machine tool industry is a priority.

A Google glass Machine Tools Monitoring (GMTM) system was developed to improve the digital marketing ability of machine tools as well as monitor the maintenance ability of automated factories in upgrading to intelligent factories. The GMTM system is composed of three layers, namely physical, machine tool monitoring and analysis, and machine tool presentation. The presentation layer uses the monitored machine tool data from the database and combines the data with wearable devices, such as Google Glass and mobile devices, to facilitate the monitoring and maintenance of factories. It also incorporates an indoor positioning model, iBeacon. When a manager is sufficiently close to a certain machine tool, he/she can see the related data from the machine tools via Google Glass. Data presentation and acquisition can be simple, convenient, and extremely fast, without manual operation. By equipping managers with wearable devices, such as Google Glass, product line managers can easily monitor and control the product line in real time to increase its effectiveness and efficiency.

2 RELATED WORKS

2.1 Industry 4.0

In line with the developmental trend of science and technology and the fierce competition in the global manufacturing industry, Germany first proposed the industrial 4.0 strategy in 2012. The purpose of this strategy was to strengthen the information and communication technology industry by linking the traditional industries with a new type of social digitalization. Furthermore, this strategy emphasizes the promotion and maintenance of manufacturing competitiveness, by improving the quality of manufacturing, cost savings, customer-oriented production, and creating product market segmentation and irreplaceability. This project affects the development of the country exponentially as a small national development that would lead to a big national strategy to enhance developmental improvement. The vision of this strategy for the development and construction of intelligent factories via the implementation of intelligent manufacturing can improve the manufacturing industry through smart production, green production, and urban production. This strategy will drive the world's fourth industrial revolution forward by changing the value creation chain, changing existing business models and services, and changing the existing division of labor.

The core technology of this strategy is to build a smart factory through the introduction of Cyber-Physical Systems information physical system so that production processes can work alongside with the sensors, actuators and communication networks, to become an intelligent production processing factory with computing, communication and control capabilities. This strategy can also change the traditional manufacturing process by accelerating the production process via integrating the product and its production system life cycle engineering integration by stressing the development of man-machine cooperation. The factory staff is then, converted from the operator in the production process, to the manager of the production decision controller and the process.

2.2 Wearable Devices

Wearable devices are a new type of computation that contains three features: 1. computation miniaturization, 2. customer mobility, and 3. customization. Several decades ago, personal computers have gone from being as large as an entire room to fitting on a tabletop. Today, to meet the requirements of high customer mobility, wearable devices have been developed to allow people to access the advantages of computation while moving. Compared to PCs and laptops, wearable devices can help users in a more sustained and smarter way.

There are many types of wearable devices that can be worn on different parts of the human body. In a variety of wear-style devices, this paper addresses that the type of monitoring system that should be used is the glasses-type headset device, as in Google's Google Glass. Google Glass as shown in Figure 1 is a non-single-mode system with several evenly distributed small units that consists of several components with different functions, including: motherboards, batteries, touch panels, and display elements.

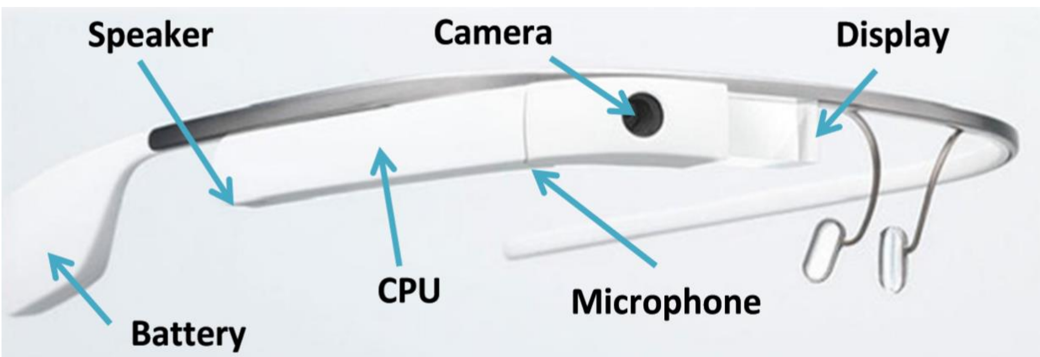

Fig. 1. Google Glass (Altw, 2013)

Google Glass is with a built-in Glassware app. Glassware uses the Google Mirror API to perform, publish, and sync updates; in which API is based on Representational State Transfer (REST) web services to help Google Glass communicate (Kuma, 2013). Google Glass's overall implementation architecture can be divided into three parts (Kuma, 2013), as shown in Figure 2.

1. Users subscribe to the developer's services: glassware developers develop applications and publish; in which, the general user to use OAuth 2.0 agreement to verify the identity and log on to the developer's website to download glassware related software.
2. Uses the mirror application interface to update Glassware: Developers use the mirror application interface to publish the application to the cloud.
3. Sync Google Glass: Once the developer's app is published to the cloud, the cloud will sync the application unto Google Glass.

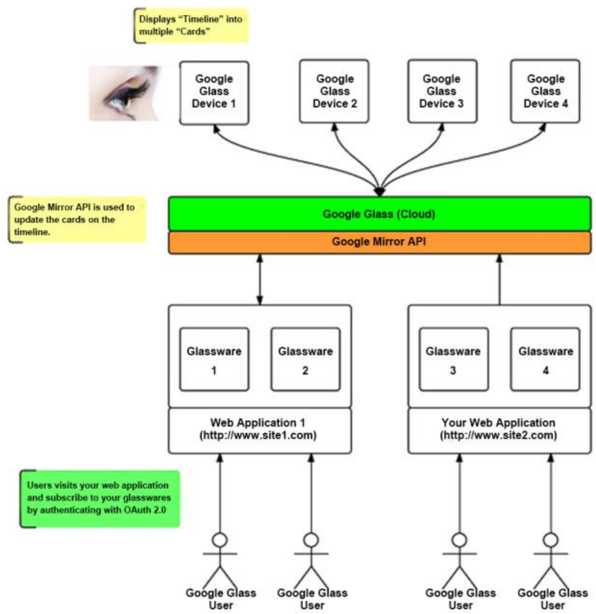

Fig. 2. Google Glass software framework (Kuma, 2013)

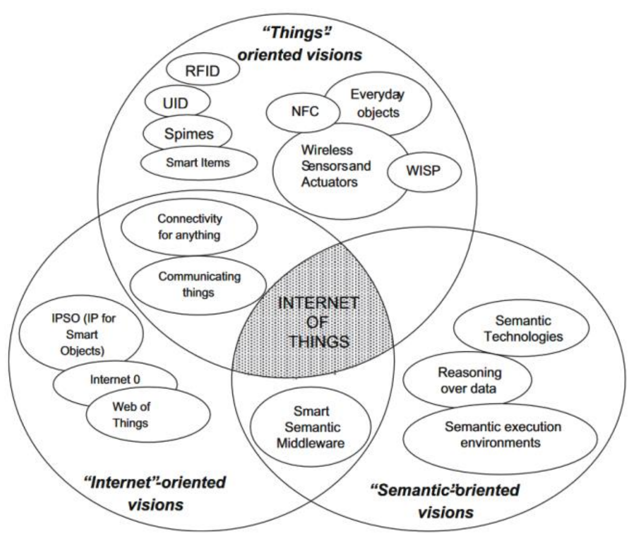

Fig. 3 IoT concept diagram (Atzo, 2010)

2.3 Internet of Things

IoT is an Internet-based, new network architecture that combines informational devices for all devices by providing a secure and reliable way to exchange information and shorten real-world objects and objects (Webe, 2010). Thus, objects can interact through the internet, access the state of the object and any relevant information, which is the ubiquitous basis of the Internet of things.

This concept integrates wireless technology, micro-electromechanical systems with the Internet, and exists in everyday objects such as sensors, actuators, radio frequency identification tags (RFID), mobile devices, and so on; these objects can be used through a special addressing mechanism, exchange information and cooperate together to achieve a common purpose, which is different from the past by humans or humans on the computer, but through the object of the object of computer-to-computer data exchange (Atzo, 2010). IoT concept diagram is shown in Figure 3.

2.4 iBeacon Bluetooth Agreement

iBeacon is a low-power, low-cost signal transmitter used for the interior space positioning system (Cava, 2014) that was proposed and formulated by Apple. iBeacon transmits a set of Universal Unique Identifier (UUID) to the aforementioned application via BLE proximity sensor, which is when the user uses any smartphone or device to perform signal detection within the sensed range of iBeacon. UUID detects the iBeacon signal strength and through this BLE standard technology, can make the device to be the current device in the room due to approximate distance and location. iBeacon technology has a micro-positioning and interactivity, which allows it to target the relative position of mobile devices in space, to promote useful information, and to offer many uses such as push ads, site navigation, and more. iBeacon hardware shown in Figure 4 shows a small circuit board with a small battery to maintain power supply and wireless signal transmission.

Fig. 4. Estimote beacon (Esti, 2014)

Figure 4 is the Estimote Beacon designed and manufactured by Estimote. The iBeacon can be fixed at any location, and when a mobile device enters the Bluetooth detection range, the mobile device will detect the Beacon, in which it will indicate that the iBeacon will send at least 10 broadcast messages per second to the message range of mobile devices, as an update. Since each iBeacon has its own set of UUIDs, any mobile device can easily determine the various distinctions between any iBeacon (Figure 5).

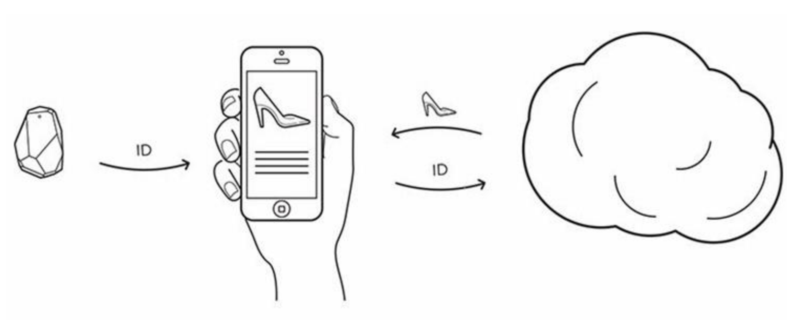

Fig. 5. iBeacon working concept diagram (Ibea, 2014)

iBeacon can be identified using four identification attributes (Dave, 2013), namely, universal unique identifier, internal identifier, primary identifier, and minor identifier. The developer can use four attribute identification symbols for micro-positioning. The iBeacon signal can be calculated using a fairly approximate and qualitative method (Cava, 2014); in particular, iBeacon can monitor three different distances, immediately (50cm or less), near (about 50 cm to 2/5 m), and far (2/5 m to 30/50).

3 GMTM SYSTEM ARCHITECTURE

3.1 System Architecture

As shown in Fig. 6, the GMTM system composed with Apache server, database and data server. The data server was developed with a three-layer architecture, including the physical components, machine tool monitoring and analysis, and machine tool presentation layers. The physical layer monitors the machine tool status via a network interface in real time and then, transmits data to the machine tool monitoring and analysis layer via a network, such as a TCP/IP network or a wireless network.

The monitored machine tool data are processed and saved to a database for future use in the presentation layer after being received by the machine tool monitoring and analysis layer. Finally, the machine tool presentation layer connects to the monitored data in the monitoring and analysis layer via real-time or message servers and receives data from each machine tool in real time. If the machine presentation layer is not connected to the monitored data via real-time or message servers, a 3D presentation of the machine tool architecture can still be performed with machine tool commercials and marketing applications. This section explains how real-time monitoring and presentation are achieved.

Fig. 6. The architecture of GMTM system

3.2 Data Collection Layer

This server (Figure 7) is used for collecting the monitoring data from various machine tools. Because of the different types of monitoring devices and motor-controlled chips from various machine tools, the monitoring data collected by several different machine tools are in different formats. Therefore, the collection of monitored data via an inner Data Collection Module (DCM) is based on a variety of machine tools can solve the data formatting problem. In this approach, whenever newly designed machine tools need to be integrated into the GMTM system, the addition of a DCM that corresponds to the new machines for easier system maintenance can solve the problem. The data collected by the DCM is then, transmitted to the Data Format Normalization (DFN) unit via the interface for the purpose of normalizing the data format. In order for data to be saved, processed data are transmitted back to the database DB module via the interface.

The data exchange interface receives the machine tool monitored data from the DCM and transmits the processed data back to the DFN unit. After data normalization, monitored data are sent to the DB module. Data transmission is conducted between the DB modules. The DFN unit receives and normalizes the monitored data from the DCM to generalize the data format. The DB module receives requests from the interface and sends normalized monitored data back to the database.

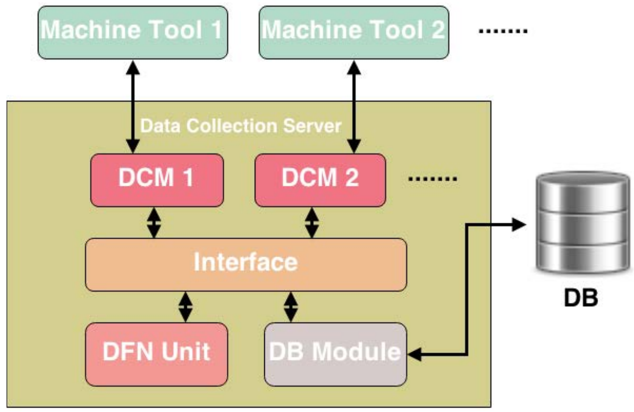

Fig. 7. Data Collection Server architecture

This real time server (Figure 8) is used for collecting monitored data from machine tools in real time, transmitting monitored data to the database, and sending the real-time monitored data to the requesting devices. A real-time DCM retrieves data from the specific machine tool that it belongs to; thus, the appearance of new machine tools only requires the additional mapping of real-time DCM. The data interface receives the monitored data from the machine tools via the real-time DCM, which it then sends to the DFN unit. The DFN unit monitors real-time alarm data from the real-time DCM and broadcasts it to the devices for warning purposes. The DB module receives requests from the interface and sends the normalized monitored data back to the database. The network module is used for receiving data requirements from each device and sends requests to the DB module of the monitored data from the machine tools. The received monitored data are transmitted to each device that has sent a request for maintenance or repair.

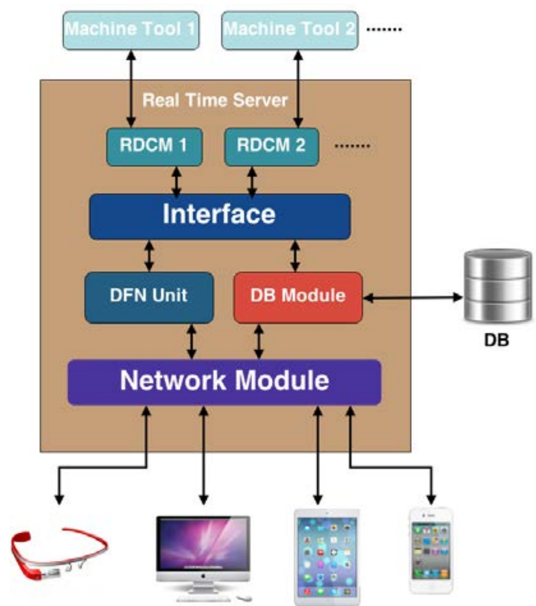

Fig. 8. Real Time Server architecture

This message server (Figure 9) is used for receiving data requests from each device and transmitting data to each device. Due to different data transmission platforms and user privileges are involved in the data transmission, the units in this message module are used for defining user privileges, acquiring the OS and connection information of each device, and the transmission of data to each device based on this information. The authority unit is used for receiving the user registration information from the register unit. This information is used for classifying user privileges. Eventually, the user privilege levels and data are sent to the DB module.

The register unit is used for receiving user registration requests, processing registration, and sending the registered data to the authority unit; in addition, it also processes user requests for the monitored machine tools. First, a request is sent to the DB module for user privilege information. Then, based on the user privilege level, the register unit informs the message broadcast unit of the privilege level-classified broadcast.

The DB module receives permission information from the authority unit and transmits data to be saved in the database. After receiving requests from the register unit for the user privilege information, a request is sent to the database asking for this information. The message broadcast unit sends a request for the monitored data from the machine tools. After receiving the user privilege information, the requested data are transmitted. The message broadcast unit sends a real-time alarming data to devices that meet the authority privacy requirements.

The main task of the message server is to receive the data requirements from each device and to request and return the Real Time Server. First, the Authority Unit is a rights control unit that accepts user data from the registration unit and classifies each user's data to the database unit according to the classification of the rights. The Register Unit is a registration unit that accepts a request from a user to receive the data and send it to the Authority Unit to send the permission data to the DB Module. Processing the user's machine tool to monitor the data request, and inform the message broadcasting unit of the permission level classification according to the user's permission level. DB Module accepts the request from the Authority Unit, sends the data to the database store; accepts the request from the Register Unit, performs the database search, retrieves the data, returns the request from the message broadcast unit, searches the database. The information is then, sent back to the message broadcast unit.

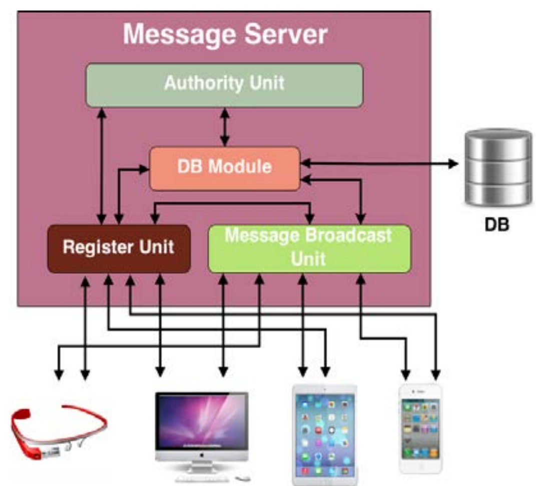

Fig. 9. Message Server architecture

3.3 Presentation Layer

For the purpose of monitoring, the display of machine tool data is displayed in a synchronized manner, combined with the wearing device. The advantage of Google Glass is that it can lessen the burden of the monitoring staff or maintenance personnel of the machine tool via automation of operating the maintenance tool hands-free. Maintenance personnel would be able to use the information and technical manuals that by touching the Google Glass viewing machine with one’s fingers when needed to inquire about the relevant monitoring data. In addition to improving efficiency, the reduction the error of personnel operation would increase dramatically.

3.4 GMTM System Design and Planning

This paper combines the concept of Internet of Things and Industry 4.0 with the wearable device Google Glass to solve the inconvenience and difficulty of operating and managing in the machine industry. For example, the maintenance personnel of the machine tool often need to switch each machine on and off at multiple times of the day, in order to obtain the work status of each machine tool, which leads to inefficiency and decrease in productivity. However, with the implementation of wearing a device, like Google Glass, and integrating the iBeacon indoor space positioning technology, the difficulties of this field would be solved. The following is the explanation of system architecture and planning:

- Design ideas for Google Glass cardware.

Google Glass is mainly for the time-line. The interface is 640x360 pixel card with static card and live card presentation, plus voice trigger to operate Google Glass, as shown in Figure 10.

There are two types of cards, namely live and static. Users can control the cards of the past, present, and future with touch pad scrolling or voice commands. The first page card is the center of the timeline. The newest card is positioned on the left-hand side of the first page card, and the old cards are positioned on the right-hand side. The GMTM system is combined with an app called Machine Tool app (MTapp) for Google Glass. MTapp combined with the indoor positioning model iBeacon can be used for monitoring and managing product lines.

MTapp requires an iBeacon model for each machine tool factory workshop. By using Google Glass with MTapp to supervise factory workshops, managers can obtain clear information regarding a particular workshop, including the workshop number, the total number of machine tools, the last visit date, and the number of machine tools receiving maintenance. Then, other iBeacon models are set up on each machine tool station, which allows Google Glass to access Bluetooth signals to find the closest iBeacon. Therefore, when a machine tool operator with Google Glass is at a distance of less than 1m from a machine tool, the machine tool status and operation information can be displayed on the Google Glass. At the same time, operating information regarding utilization rate, spindle temperature increase status, spindle (X/Y/Z) axis travel, working status (Busy, Idle, Alarm, or Off), tool status, pressure system, cutting coolant information, lubrication system, heat-exchanging system, and spindle coolant system is always stored in the timeline card so that operators can check it with any voice or touch controls.

Fig. 10. Execution concept diagram of GMTM system

- Machine Tool Factory Supervising Planning

Machine tool operators and supervising managers wearing Google Glass can operate the GMTM system. First, they start MTapp and determine the workshop in which the staff is currently located. Then, the staff chooses either the supervising or the operating mode. These two modes can be explained as followed.

Supervising mode: Once the user chooses the supervising mode in the system, he can obtain a set of UUID through iBeacon at the plant entrance and communicate via the WiFi or mobile network with the message server to communicate the upload and receive the unique identification code. Then, the supervisor will be able to obtain information about the state of the plant, including productivity, power, machine tool status and other general information, as well as use the chart to map the data in the Google Glass display as shown in Figure 11.

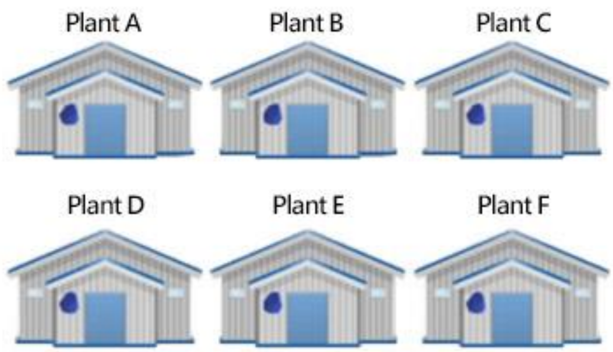

Fig. 11. Schematic diagram of plant with iBeacon

Operating mode: When an operator chooses the operating mode, the closest machine tool to the operator is identified by using the distance between the machine tool and the iBeacon models. Then, the iBeacon model for this machine tool sends a UUID code from which Google Glass can acquire the related working status, manuals, and abnormal signals via Wi-Fi and then, display this information on the screen, as shown in Fig. 12. Operators can use voice controls to select the file to be displayed while operating on the machine tool station with two hands, which enhances both efficiency and convenience.

Fig. 12. Schematic diagram of machine tools with iBeacon

4 RESULT AND VERIFICATION

GMTM system is an application developed on the wearing device Google Glass, in which the main purpose is to enhance the efficiency of intelligent factory supervisors by reducing work errors and provide monitoring personnel to query the technical manual and seek the help function to solve the current factory issues for resolution. The application of the research and development of this paper has now been completed, the system execution mode and operation mode display architecture shown in Figure 13.

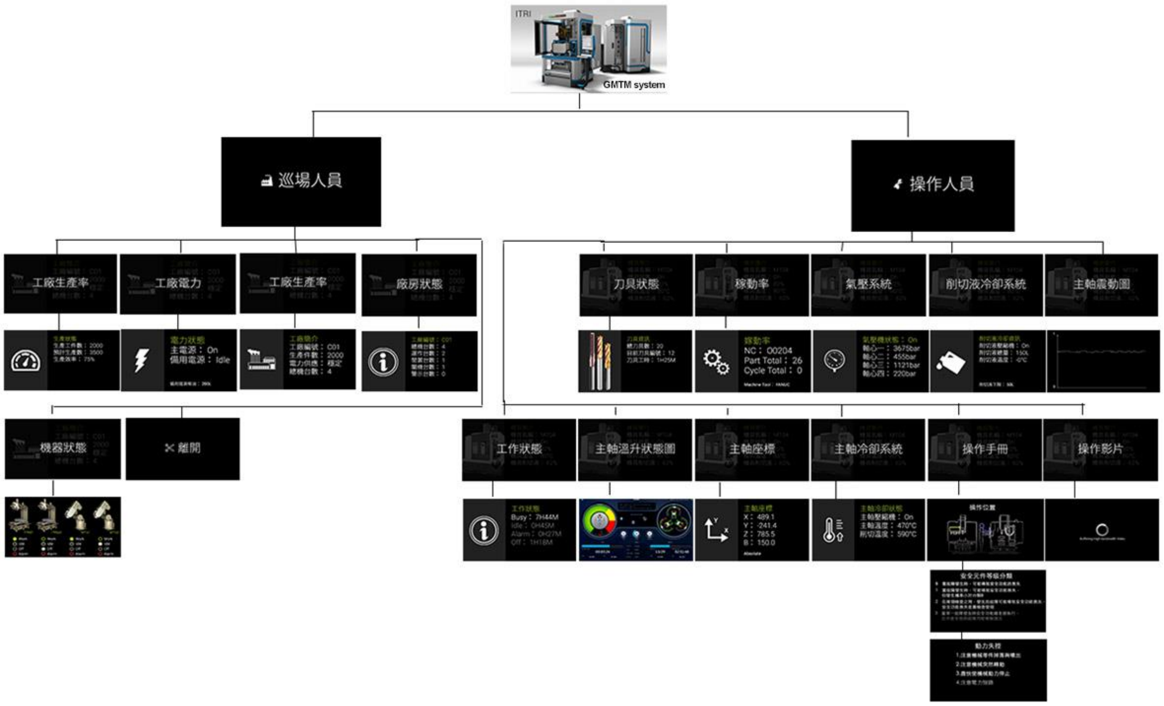

Fig. 13. Card display architecture of GMTM system

Operating mode, as shown in the right branch of Figure 13, eleven main cards are developed: load rate, spindle temperature rise state, spindle coordinate, spindle cooling state, tool working state, tool status, air pressure state, cutting fluid cooling information, spindle shake, operator's manual and operating instructional film so that supervisors can operate the machine based on the current data in the application; five cards are developed in the tour mode: factory profile, factory status, supervisor mode status, the factory power information and the state of the factory equipment. Thus, monitoring staff can enter into the factory entrance without ever needing to manually check the status of the plant by knowing the details of the working conditions and tools of the work of the machine to improve efficiency and simplify the tour process via the use of GMTM.

As shown in Figure 13, start the application and enter the home page, click on the right frame of the touchpad to select the operating mode. By entering the operating mode, it will scan the closest iBeacon and machine tool and automatically upload the generic unique identification code of the device to the server side to obtain the data. The supervisor can click into the next layer interface and slide the card to inquire the information needed to be viewed. After entering the tour mode, it can scan the closest iBeacon and jump to the plant profile page, which can monitor the demand point to enter the next level of interface information required. Through this GMTM monitoring factory real-time system, Taiwan has entered the industrial 4.0 era, towards the innovation of factory development and efficiency.

5 CONCLUSION AND FUTURE WORK

Instrumental to the technology revolution, the integration of new technology will redefine the workin g styles and the lifestyle of humans in the near future. The development of the machine tool industry is an important index of the industrial manufacturing power of a country. With the rapid development of ICT, t he machine tool industry has evolved from three-axle machine tool equipment manufacturing to an ICT-in tegrated sophisticated industry. Since the introduction of Industry 4.0, the use of automated intelligent fact ories that integrate IoT, cloud computing, big data, and wearable devices has become an important trend i n the global industrial development. The rapid integration of new technologies is an extremely important i ssue for the industrial competitiveness of each country.

The GMTM system is composed of a three-layer architecture that includes the physical, machine tool monitoring and analysis, and presentation layers. This system has the potential to become the new architecture for Taiwanese machine tool manufacturing companies by facilitating the integration of machine tool system monitoring and marketing. With the GMTM system, these companies can systematically convert the current machine tool manufacturing facilities to large-scale unmanned factories. By using the product line monitoring architecture of the GMTM system, factory personnel become the decision makers and managers of product processing instead of being machine operators. In the future, we intend to integrate the GMTM system with IOT, cloud computing, and big data analyses.

In recent years can be said that Augmented Reality (AR), Virtual Reality (VR) has vastly enlightened the technology world year after year, as each company has pursued the implementation for one these application into their current products, including HTC's HTC Vive, Oculus VR company. The launch of Oculus Rift, Microsoft's launch of HoloLens, especially Microsoft's HoloLens is expected to combine penetrating screen (See Through), infrared scene depth detection, which can lead to be an innovative breakthrough in the mixed reality (Mixed Reality, MR), as well as greatly enhance the wear-type device in the application of the functionality of strengthening and plasticity.

In this paper, the GMTM system will be transplanted to a more powerful wearable device in the future. As a vast amount of data continues to be obtained from the concept of Internet of Things, it will be presented with a huge amount of technical analysis to achieve a more mature, complete and accurate system. It will demonstrate how the increase of efficiency of factory staff and machinery can enhance Taiwan's machine tool industry as an international competitor.

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