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Key Technologies of New Type Comprehensive Assembly System

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Abstract: *Now, the leading domestic manufacturers follow the manual assembly mode introduced in the early technology, although some enterprises have only customized assembly tightening systems. There is a growing demand for comprehensive assembly system that can collect multi-type data. We present new type comprehensive assembly system, a system for enabling workers to collect multi-type data by combine multiple devices, including control station, tool cart, PDA, tightening equipment, measuring equipment, confirmation equipment. The system introduces a new solution that leverages common assembly systems and other type hardware to efficiently collect multi-type data, not only tightening data. For the convenience of the workers' operations, this system has two types of clients, running on the Android system and the Windows system respectively. One, running on the Windows system, install in control station to finish works nearby. Another one, running on the Android system, can work with a tool cart that carry different types of devices and can be moved easily to any places with workers. To support electric devices connection, the tool cart equips with a wireless router, connecting the electric devices in the cart. We have implemented the system and show that it (1) operates multiple type of process, tightening, measuring, photoing and verifying, (2) running on two kinds of operating system, Android system and Windows system, (3) can prevent equipments in the tool cart from disconnecting from server, and (4) Can handle any sudden and unexpected incidents that occur during the operation process.*

Keywords: *Railway Industry, comprehensive assembly system, tool cart, multiple types of data fusion, coexistence of multiple operating systems*

1. Introduction

Currently, the foremost domestic manufacturers adhere to the manual assembly method that was established with the initial technology. Though a few enterprises have adopted exclusively tailored assembly tightening systems only collecting tightening data [1]. Since many types of process in producing electric trains, there has been a growing demand to get the whole process data steadily in real-time. We refer to the system as new type comprehensive assembly system.

Four examples help illustrate some of the possibilities. First, new type comprehensive assembly system summarizes data from many different types of precision equipment such as tightening equipment and measuring equipment and record the real scene of the work site by using PDA [2]. Second, Some device drivers only support the Windows operating system, new type comprehensive assembly system implement client with same functions on different operating system. Third, after summarizing data, new type comprehensive assembly system makes it easy for management personnel to combine assembly records in a quality record table, which can complete traceability of process data and form a complete product resume. Fourth, new type comprehensive assembly system is not constrained by site boundaries and operational conditions, as well as factors like network signal blocking, and can flexibly cover scenarios such as in-train, on-top-of-train, or outdoor maintenance over long distances [3].

Although new type comprehensive assembly system has the potential to provide a powerful functionality, three essential challenges need to be addressed. First, workers can't carry a lot of electric equipment. The problem of transferring equipment to specified place should be solved. Second, the connection between PDA and Server is not affected. PDA and Server consume and produce a wide range of disparate input and output data, from a variety of sensor readings to rich picture media content. The connection may be disconnect if the location where workers carry electric tools to make equipment is far from the control station [4]. This problem will cause data loss. Good performance is essential for PDA saving data automatically when PDA software detect it can't connect to server across the network.

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Finally, clients running in different operating system should have same functions.

We introduce new type comprehensive assembly system, which can enable different type electric tools to be used in the real working without any data loss because of disconnecting exception between PDA and server. It is also not limited by the scope of the site and working conditions, and can flexibly cover remote operation scenarios such as inside the vehicle, on the roof, or outdoor maintenance. The system is based on one key observation. Although API for developing programs in different systems, like Windows and Android, are different, the functionality and data format can be same [5].

To solve these problems mentioned above, new type comprehensive assembly system builds on the observation and takes a novel approach: new type comprehensive assembly system introduces small, portable tool cart. It can play three roles during its use: first the tool cart can solve the problem of not being able to carry multiple tools for workers. Second, workers can press keys on the tool cart to avoid abnormal work steps and execute normal work steps. Third, this cart is also equipped with a router, so that the router on the tool cart and the router at the control station are bridged together. The tools and PDA on the tool cart can be connected to the control station through the router on the cart. This is possible to use common data formats in Windows's and Android's application. When PDA software detect it can't connect to server across the network, electric tools data will be temporarily saved in PDA until the connection between PDA and server is built. At last, all data will be summarized and sent to the server station.

We have implemented new type comprehensive assembly system and demonstrate it solve the problem mentioned above and provide functionality with low latency.

2. System design

2.1. System framework design

The system contains server, assembly cart with industrial windows computer, industrial mobile android PDA, tool cart and different type of workshop tools. The system network architecture mainly uses wireless (WiFi and Bluetooth) and wired networks to implement data communication. The system adopts the architecture shown in Figure 1.

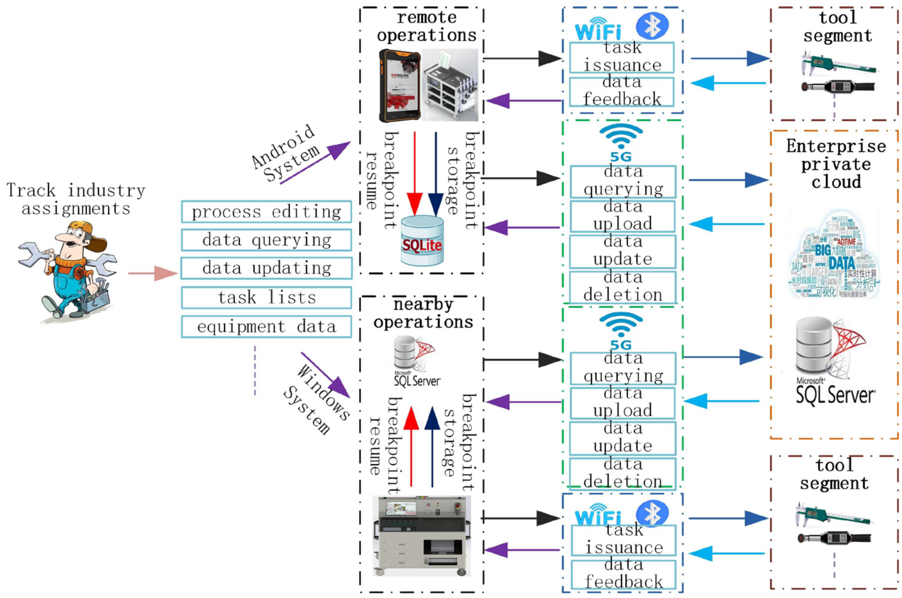

Figure 1: System functional framework diagram

The above diagram describes a highly integrated industrial automation and data management system, which utilizes advanced communication technology and computing platforms to achieve efficient on-site operations and data processing.

Mobile terminal (Android system): At the forefront, staff use Android mobile terminals equipped with SQLite database, combined with tool carts, to collect and deal with on-site work data. These mobile devices collect tool-side data via network connection, providing powerful data collection and

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preliminary processing capabilities.

Assembly vehicle (Windows system): The assembly vehicle integrates the functions of mobile terminals and tool carts, directly controlling on-site operating equipment on the Windows platform, and providing compatibility with device drivers. The local SQL Server can temporarily store data when the network is unavailable, ensuring data is not lost and serving as a powerful data storage and processing center.

Data transmission and communication links (5G and WiFi): The system's data transmission link ensures smooth and secure data flow between clients and central server. By adopting communication protocols such as 5G and WiFi, data can be seamlessly transmitted in various network environments and different operating systems, meeting the system's requirements for low latency and high bandwidth real-time data processing and remote control.

Enterprise private cloud: At the server level, the enterprise private cloud undertakes multiple tasks such as data aggregation, processing, and command distribution. Connected to multiple clients and APIs, the server is responsible for data synchronization, backup, and recovery, ensuring system performance and response speed in high data volume environments. In summary, the system is a comprehensive solution designed for modern industrial environments, combining mobile computing, traditional Windows systems, advanced communication technology, and enterprise-level cloud computing capabilities to support data-intensive on-site operations. Through powerful data collection, real-time processing, and intelligent analysis, the system can enhance operational efficiency, optimize production decisions, and ensure operational continuity.

2.2. System Process Design

This system can divide the operation equipment into two combinations, classifying them as nearby operation positions and remote operation positions with the assembly vehicle location as the center. For nearby process operation positions, workers only need to operate the client software on the assembly vehicle. According to the process requirements issued by the server, they respectively pick up tightening tools, measuring tools, cameras, etc. The operation data will be sent to the assembly vehicle first, and then transmitted to the server. The system also has an exception handling mechanism. After the operator logs into the system, they can check whether there are any abnormal tasks in the abnormal management module. If some exceptions occurs, they can click the exception handling button to submit the abnormal tasks. When all conditions are met for processing exceptions, the operator will handle the abnormal tasks. For remote operation positions, workers need to place the operation tools and Android-based assembly system hardware (PDA) on the tool cart. Push the tool cart to the designated operation position, and select the relevant operation tools according to the process operation requirements displayed on the PDA. The operation data will first be transmitted to the PDA and temporarily saved. At this time, the PDA will first determine whether the network is connected. If there is no network problem, the data in the PDA will be transmitted to the server. During the operation process, workers first select the tasks assigned by the team leader. Each task may contain multiple types of steps. The system also has an exception handling mechanism. After the operator logs into the system, they can check whether there are any abnormal tasks in the abnormal management module. If there are any, they can click the exception handling button on the tool cart to submit the corresponding abnormal tasks. When all conditions are met for processing exceptions, the on-site operator will handle the abnormal tasks. The operation process is shown in Figure 2.

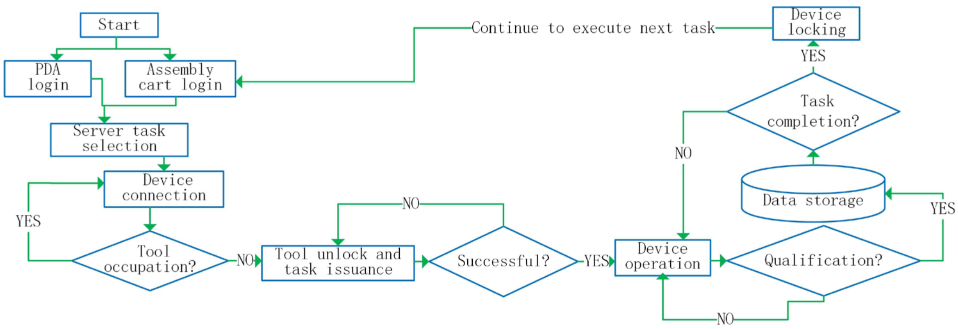

Figure 2: Design of the System Process

3. System hardware design

3.1. Assembly Cart

The assembly vehicle is suitable for online fixed workstations, especially in environments where the operating area is relatively stable. It demonstrates excellent applicability, suitable for conditions where it is placed and no longer moved, serving as a fixed operation vehicle mode. The assembly vehicle is equipped not only with key equipment such as operation lights, industrial control computers, network devices, alarm lights, barcode scanners, card readers, printers, etc., but also with a series of operation tools, fully realizing the close binding of workstation operation tools, personnel, and data, thereby optimizing the workflow and improving operational efficiency. Through this highly integrated design, the intelligent assembly vehicle can provide operators with a comprehensive, efficient, and convenient working environment, greatly reducing the complexity of equipment management. Assembly vehicle is shown in Figure 3.

Figure 3: Design of Intelligent Assembly Vehicle

For certain device drivers that are only compatible with Windows systems, this assembly vehicle can accommodate them well, ensuring smooth compatibility between devices and operating systems, allowing users to enjoy a seamless and efficient user experience even in a diverse hardware environment. Additionally, the design of this assembly vehicle takes into account the scalability of future technologies, providing convenience for updating and upgrading device drivers, thereby ensuring long-term compatibility and performance sustainability.

3.2. Tool Cart

The tool cart is suitable for mobile workstations, especially in environments where the operating area is relatively uncertain. It is a mobile operation vehicle designed to assist operators in transporting tools and improve network performance and stability. The tool cart is equipped with a series of key equipment, including mobile power supplies, control buttons, work lights, network devices, alarm lights, routers, printers, and PDAs, among others. Additionally, the tool cart carries various operating tools.

The tool cart needs to be used in conjunction with a PDA. The PDA controls the devices on the tool cart and transmits the resulting data back to the server via the router on the tool cart. The router on the tool cart is bridged with on-site network devices, which can change the network topology to make data transmission more efficient. In bridge mode, the router on the tool cart no longer performs Network Address Translation (NAT) but forwards data packets directly to the target device, thereby improving network performance and stability. The tool cart is shown in figure 4.

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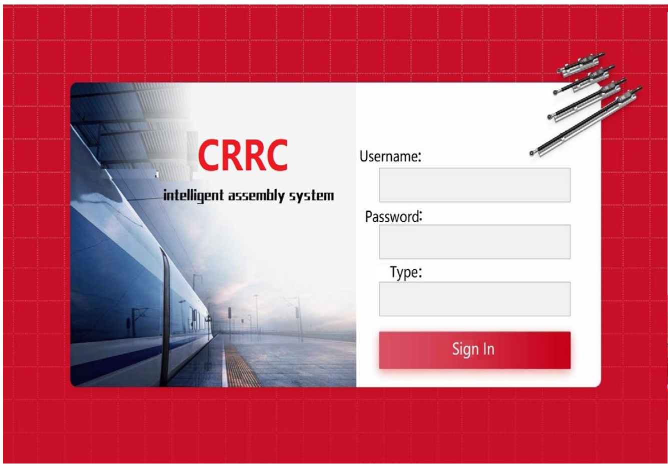
Figure 4: Design of Tool Cart

4. System Software Design

This chapter will describe two types of software clients for the system, one for Windows system and the other for Android system. This chapter will introduce both sort of clients under the main functionality section.

4.1. System Login Module

The system client software can log into the system either through account password or card-swiping method. Figure 5(1) displays the login page in Windows, while Figure 5(2) depicts the login page in Android.



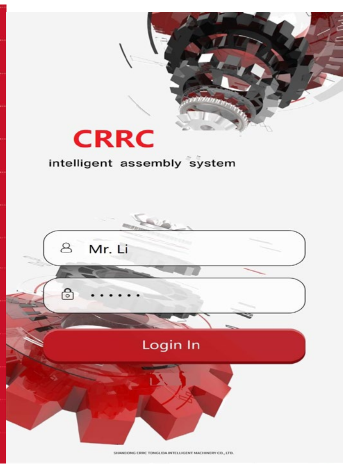
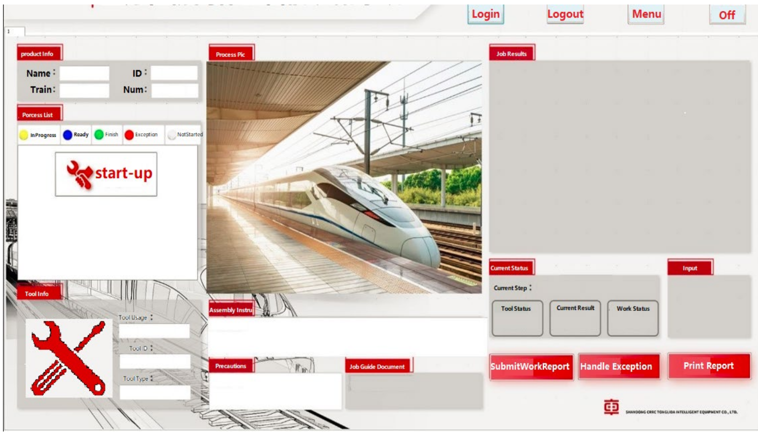


Figure 5(1): Windows version login interface *Figure 5(2): Android version login interface*

4.2. System Main Module

After clicking login button, the system will access to the main interface. The main interface of the Windows version client software will display modules such as product information, process list, tool information, process diagrams, assembly instructions, precautions, job results, job guides, current status, etc. Thanks to the advantage of the large screen of the device, this version of the client software will basically display all the modules that are used on the same page. Figure 6(1) displays main interface in Windows, while Figure 6(2) depicts the main interface in Android.



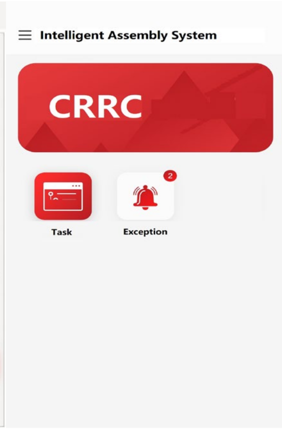
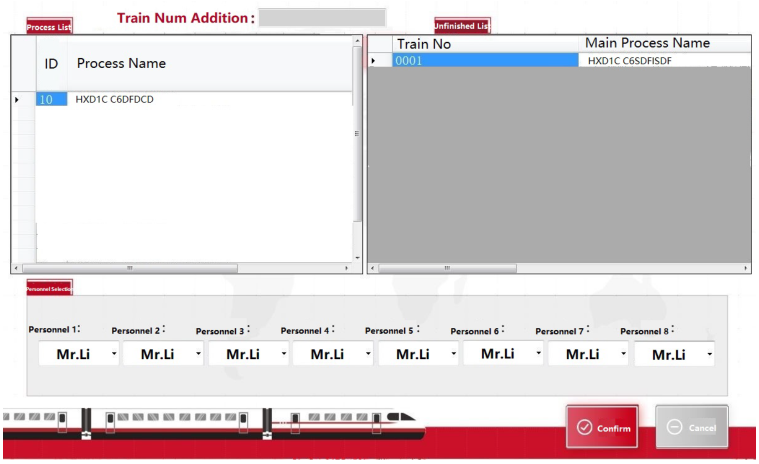


Figure 6(1): Main Interface for Windows *Figure 6(2): Main Interface for Android*

Due to the small screen of the PDA, the Android version of the software will only display the main module content on each page. Different modules will be displayed on separate pages. The main page will only display task selection, and the relevant modules will be displayed in sequence according to the order of worker operations.

4.3. Task Selection Module

The workstation supervisor selects tasks assigned for the day and chooses the on-site operators for execution. In the task selection module, any previously unfinished work orders will be displayed for selection. Task selection for Windows and Android is presented separately in Figure 7(1) and Figure 7(2).



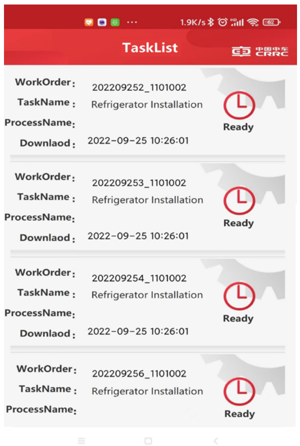


Figure 7(1): Task Selection for Windows *Figure 7(2): Task Selection for Android*

4.4. Task Assignment

After selecting a task, on-site operators will execute the relevant tasks according to the process requirements. The process types are categorized into tightening, measuring, taking photos, and confirming. Once the task is initiated, the system automatically displays the relevant tasks, and on-site operators only need to perform the corresponding operations according to the process requirements. After selecting the task work order, on-site workers only need to view the process list and work according to the requirements of the process list. Craft list for Windows and Android is presented separately in figure 8(1) and figure 8(2).

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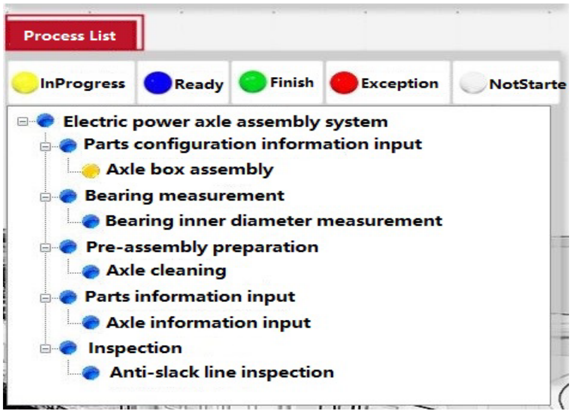


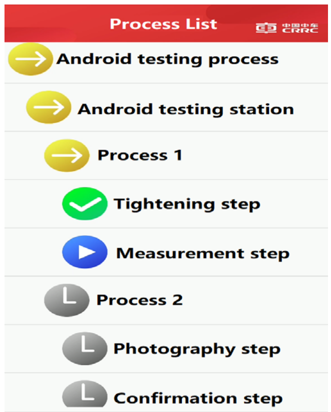
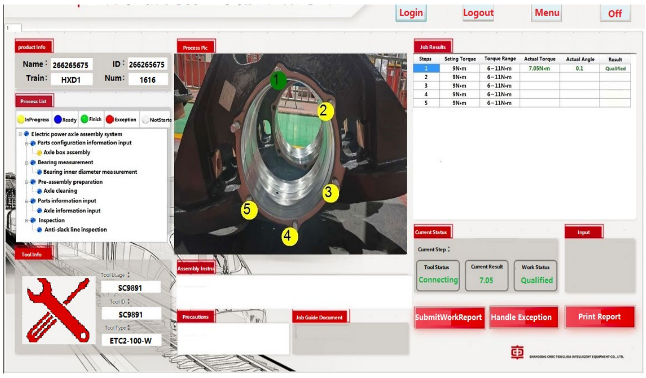


Figure 8(1): Craft list for Windows *Figure 8(2): Craft list for Android*

In the processes of tightening, measuring, entering data, confirming, and taking photos, on-site operators can use assembly vehicles and PDAs respectively to control the relevant equipment. After the equipment completes its work, it will automatically lock, and operators return the equipment. The equipment data will be transmitted and saved in the assembly vehicle or PDAs. If the network is connected, the data will be uniformly sent to the server. The system will later analyze the relevant data and display it on the system dashboard. Tightening step interface for Windows and Android is presented separately in figure 9(1) and figure 9(2).



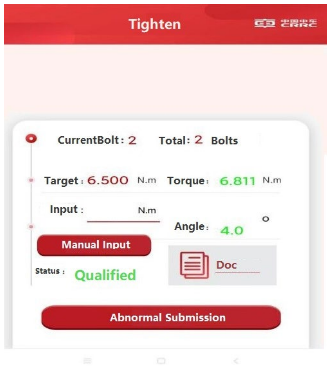
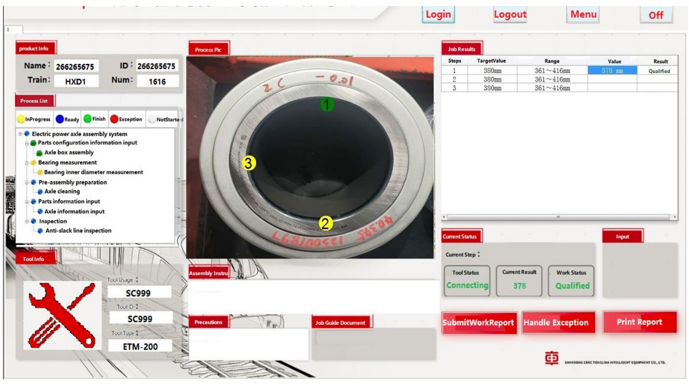


Figure 9(1): Tightening step for Windows *Figure 9(2): Tightening step for Android*

Measurement step interface for Windows and Android is presented separately in figure 10(1) and figure 10(2).



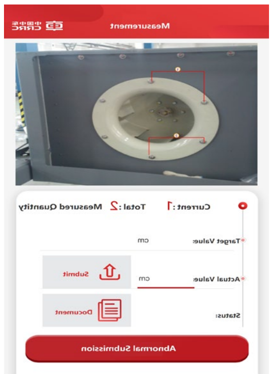


Figure 10(1): Measurement step for Windows *Figure 10(2): Measurement step for Android*

Photo-taking step interface for Windows and Android is presented separately in figure 11(1) and figure 11(2).

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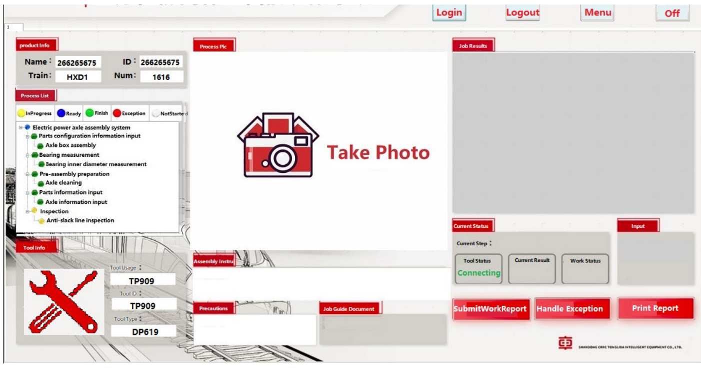


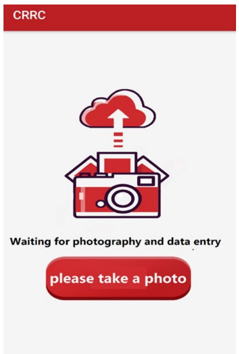
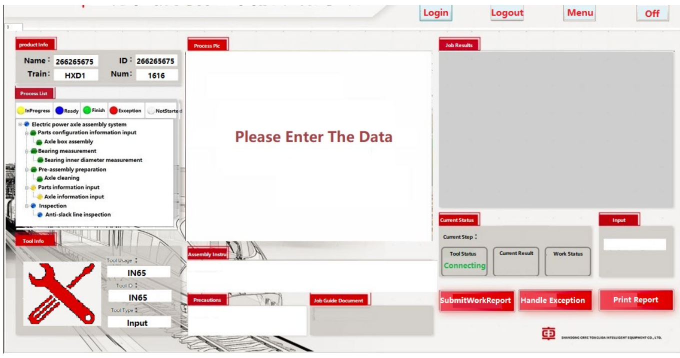


Figure 11(1): Photo-taking step for Windows *Figure 11(2): Photo-taking step for Android*

Input type step interface for Windows and Android is presented separately in figure 12(1) and figure 12(2).



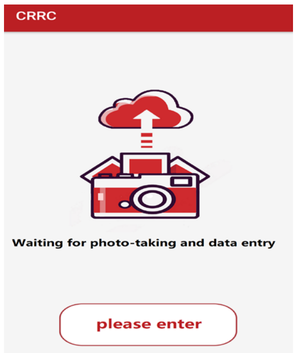


Figure 12(1): Input type step for Windows *Figure 12(2): Photo-taking step for Android*

Confirmation step interface for Windows and Android is presented separately in figure 13(1) and figure 13(2).

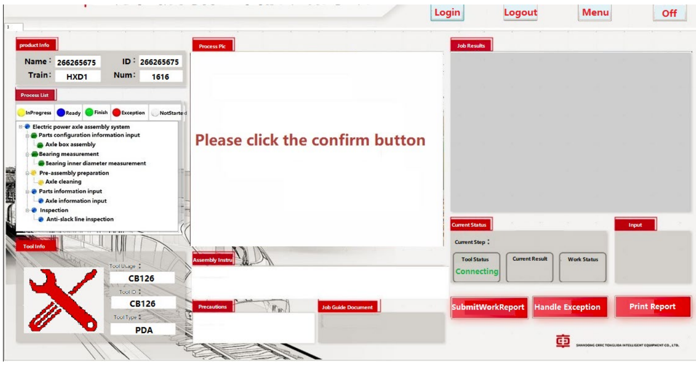


Figure 13(1): Confirmation step for Windows *Figure 13(2): Confirmation step for Android*

4.5. Exception Handling Module

In the exception handling module, work orders that cannot proceed due to reasons such as material shortage will be saved to the exception list. If all conditions are met, on-site operators can select the relevant tasks from the exception list for operation. Exception handling list for Windows and Android is presented separately in figure 14(1) and figure 14(2).

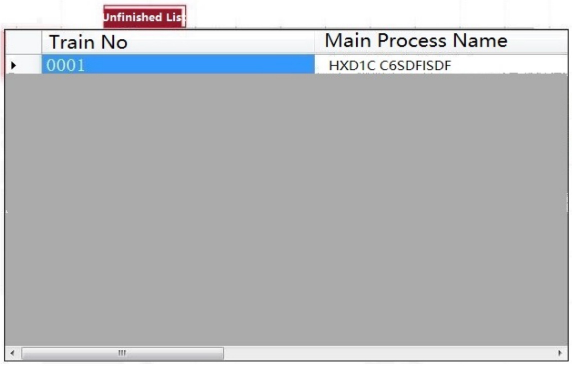


Figure 14(1): Windows Exception Handling List

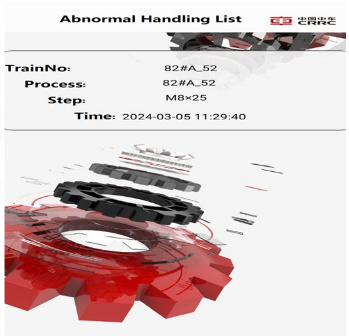


Figure 14(2): Android Exception Handling List

4.6. Data Statistics and Analysis Module

All job data will be centralized and aggregated to the server. The system server will display the data in real-time and provide trend analysis. Managers can obtain the latest on-site job results at any time.

5. System Application Scenarios

This system provides a cross-platform solution, allowing clients to achieve the same functionality across different operating systems. The system is designed to be flexible, capable of adapting to various environmental conditions such as inside vehicles, on vehicle rooftops, and for long-term outdoor maintenance, without being limited by location, operating conditions, or network signal interference. The system breaks through the limitations of traditional equipment tightening software, which could only be used in specific locations within production workshops. Maintenance personnel can perform maintenance and production operations anywhere within the workshop or even outside it, and maintenance and production data can be saved in real-time. Figure 15 shows field assembly operation.

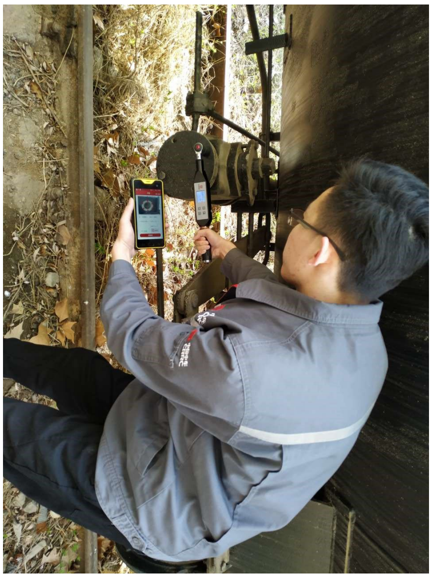


Figure 15: Field assembly operation

Not only that, this system can also add other assembly tools with wireless transmission modules. This ensures that one assembly management system can control multiple assembly tools, preventing compatibility issues with operating systems carried by production and maintenance personnel.

6. Conclusions

This system combines multiple operating systems with various types of hardware devices, enhancing the capability to collect data from multiple sources and ensuring compatibility and

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scalability with various tool assemblies. On this basis, the tool cart is equipped with a wireless router to bridge with workshop network devices, expanding the range of network communication and ensuring network stability. The system has been applied in actual production, demonstrating its practicality in various process operations, including tightening, measurement, photography, confirmation, etc. The accurate statistical analysis of the system data reflects the actual work situation, providing reliable decision-making basis for management personnel. In conclusion, the launch of this intelligent assembly system marks an important transition in China's rail vehicle production field towards automation and informatization, promising to further improve manufacturing efficiency, ensure product quality, and provide workers with a more intelligent and humane working environment.

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