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Visualization Technology Framework of Industrial Cloud Computing

Zhe Lu[1], Zhicheng Chen[2] , Rong Zheng[2], Chaoru Liu[2], Xiaolin Wu[2], Songbin Chen[2], Wang Zhang[2] and Song Zheng[1,*]

[1]College of Electrical Engineering and Automation, Fuzhou University, Fuzhu, China
[2]IAP(Fujian) Technology Co., Ltd. Fuzhou, China

*Corresponding author email: s.zheng@fzu.edu.cn

Abstract. Industrial cloud computing is considered to be an essential technology for future industrial enterprises. Under the influence of Industry 4.0 and Industrial Internet concepts, industrial cloud computing related technologies are becoming a hot topic in recent research. How to observe and analyze the intermediate and final results of industrial cloud computing is the first problem to be solved in this research field. This paper proposes a new industrial PaaS (Platform-as-a-Service) architecture, which has a very important relationship with the visualization of industrial cloud computing, and it deploys a large number of structurally symmetric Data Engine computing units. Configuration and reusable methods are used in this paper to form a visualization technical framework and establish a data mapping relationship with the Data Engine, which significantly improves the efficiency of visualization application development. Finally, we validated the technology using an industrial internet test bed. The experimental results show that this visualization framework technology can provide industrial users with an advanced industrial application development environment, and effective real-time monitoring of industrial cloud computing through the internet.
Keywords: Industrial cloud computing; Industrial PaaS; Visualization technology framework; Data engine.

1. Introduction

With the rapid development of industrial production and management technology, computing tasks of enterprises are also increasing simultaneously. The computing environment, computing resources, and storage capabilities of traditional industrial information systems have been difficult to meet the requirements of this trend. The industry is combining industrial production and management technologies with cloud computing technologies to form an industrial cloud computing system, which is expected to enhance the level and ability of enterprise information management with the help of powerful computing power, storage space and a large number of shared and reused computing resources of cloud computing. Driven by the cloud computing technology, it is expected that in the near future, the application of industrial cloud computing systems will become a new pattern of industrial production, and even evolve into a new industrial ecosystem. This will be a highly complex system, which contains not only a wide variety of data but also a lot of data calculation methods. And any change in one element will make a very big impact on the entire industrial cloud computing system. In recent years, the concepts of Industrial Internet and Industry 4.0 have been heatedly discussed and got preliminary practice in industrial society, among which industrial cloud computing related technologies are also hot issues [1-2].

Considering the complexity of industrial cloud computing, how to make the process data and result data of industrial cloud computing present in front of users visually has become an important requirement of industrial cloud computing. Visualization technology is an effective way to solve this problem. It displays the calculation data on the terminal device through various forms of charts, providing users with sufficient information for analysis and decision-making [3-4]. However, to realize the visualization of industrial cloud computing, we still face many difficulties and challenges. In addition to the high demands placed on the processing of massive data and complex data structures, the industrial cloud computing architecture (mainly refers to industrial PaaS) has a significant impact on the establishment of visualization technology. If computer software code programming method is continued to be used to adapt to the diversity of visualization applications, the costs of software development will remain high, which will also limit the construction and application of industrial cloud computing systems to a certain extent. Therefore, it is necessary to propose a new industrial PaaS architecture and visualization technology framework to unify the computational problems in the visualization application into the industrial PaaS. Only based on this, the graphical configuration framework technology can achieve the high efficiency and low-cost of the visualization application development.

2. Visualization Technology Problems in Industrial Cloud Computing

The industrial cloud computing system is mainly composed of two parts, including data and algorithm. The purpose of the visualization application is to judge the rationality of the calculation method while knowing the calculation results through the display of relevant data. The latter will occupy a very important position in the practical application of industrial cloud computing systems. To understand the rationality of the calculation method, the best way is to know the intermediate results of the calculation instead of the final calculation results. Industrial users and application developers can make judgments about the operational performance of industrial systems based on changes in these data or the relationship between them, and further optimize decision of calculation method (or management, control methods). However, this observation is very difficult in terms of technical implementation. Because we not only need to know where the data needs to be displayed, how to transmit them through communication technology and perform necessary calculations on the obtained data, but also face the changing pressure of visualization requirements.

Due to the influence of consumer internet applications, the visualization technology of industrial cloud computing seems to be able to be realized by the so-called "industrial app". The advantage of this method is that it effectively utilizes the resources of IT technology, while also appears to reduce the coupling strength between visualization applications and industrial cloud computing. Currently, industrial app visualization functions are usually developed based on Application Programming Interface (API) [5-6]. Typical tools include HT for web, DirectX, OSG, and VTK. For example, Vtk [5] is an object-oriented visualization tool based on Unix and Windows environment and it has the advantages of open source, code portability and cross-platform; OSG is a C++ platform-based API developed by OpenGL technology and it can be used to create high-performance, cross-platform interactive graphical program. However, this development mode is only suitable for visualization applications with relatively fixed data. In addition, the cost of development is high and software testing takes a longer time. As the effects of visualization applications are relatively limited, they are of little help to the optimization of industrial cloud computing systems.

Regarding the above requirements and the problems existing in the current development methods, a development method based on the new industrial PaaS architecture and visualization technology framework is proposed, hoping to separate the data processing content and data display form in the visualization application. The visualization framework is an application architecture based on graphical configuration. In this architecture, the display of each data depends on the specific configuration component, and the presence of the configuration component in the visualization window can be achieved simply by performing configuration editing. At the same time, if we determine the data communication and correspondence between the industrial PaaS and the visualization technology framework according to specific standards, the visualization application development process of industrial cloud computing can be greatly simplified.

3. A New Industrial Paas Architecture

According to the above design thought of visualization requirements and visualization technology architecture, we need to propose an industrial PaaS architecture which is corresponding to it. All computing tasks in industrial cloud computing systems, including those specific to the needs of visualization applications, are fully limited to the industrial PaaS level, so the benefit of the design is to make full use of the computing resources at that level, making the development of visualization application more flexible. By changing the calculations in PaaS, richer display content can be provided for visualization applications. This change is completely independent of the visual application software, so the development efficiency of this model is relatively higher. This method of appending specific computational content in the industrial PaaS to accommodate to the needs of the visualization application is particularly important because of the need to observe intermediate calculations or to observe the dynamic relationship between multiple data. Correspondingly, the SaaS layer in industrial cloud computing systems degenerates into a pure visualization technology framework which is regardless of the source and processing of the data, and only requires the configuration of specific graphics.

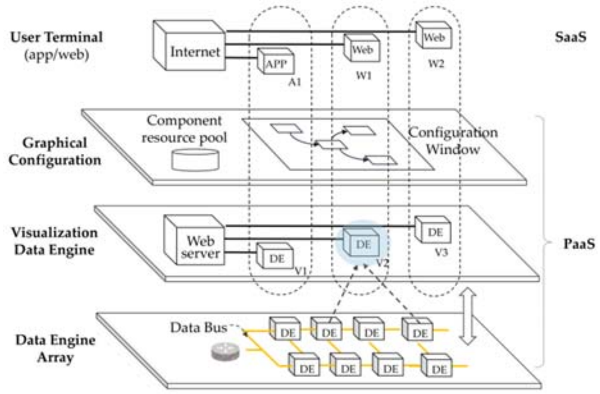
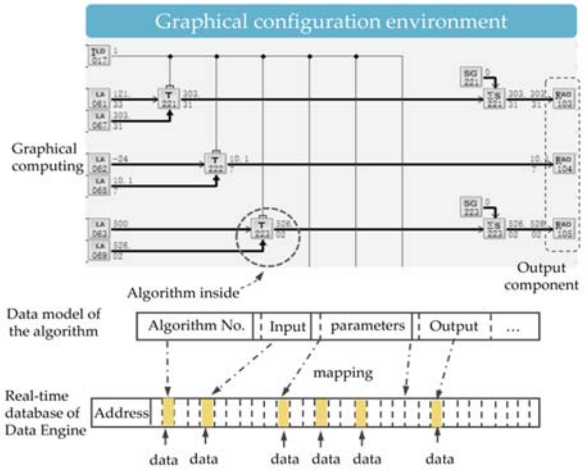


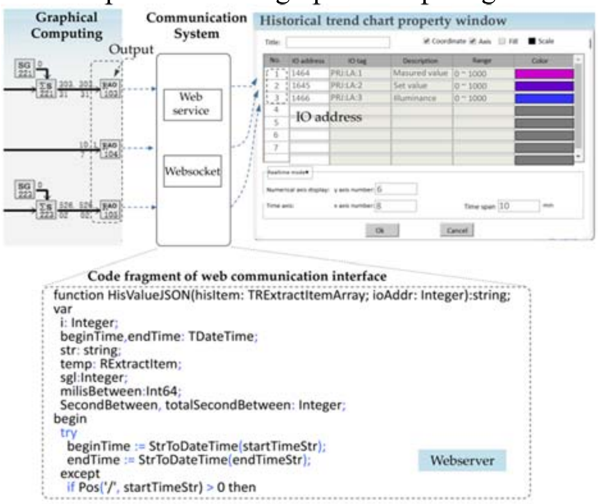
Figure 1. The schematic diagram of the visualization technology framework.

To achieve the above industrial PaaS, we use Data Engine technology which is a basic calculation unit which can accept graphical configuration algorithms [7]. The Data Engine itself has the potential of visualization computing because its core is a real-time database based on memory and all intermediate are the content of this database, so it is theoretically observable, thus satisfying the application demand of visualization technology framework in the industrial cloud computing. Industrial PaaS consists of a large number of structurally symmetric Data Engine arrays, forming a large parallel computing environment to meet the needs of industrial cloud computing [8]. In this environment, the visualization technology framework is associated with specific Data Engines, and the visualized data content can be changed synchronously by changing the data in the Data Engine. We call this Data Engine as a "visualization Data Engine" to distinguish it from other functions of Data Engine in industrial PaaS. Data can be exchanged between different Data Engines via the data bus in the industrial PaaS. Therefore, the data of the visualization Data Engine can be obtained from other Data Engines by graphical configuration method. Figure 1 shows a schematic diagram of the industrial cloud computing visualization technology framework. As can be seen from the figure, behind each visualization application, there is a corresponding "visualization Data Engine", which provides a data source for the visualization application. The visualization technology framework only needs to focus on the form of data display. The content of the data display depends on the algorithm of the visualization Data Engine and its communication relationship with other Data Engines of the industrial PaaS. Figure 1 clearly illustrates the separation principle of visualization content and its form.

An important purpose of visualization application is to optimize the algorithms of industrial cloud computing, which naturally links the technologies of visualization technology framework and industrial PaaS. The industrial PaaS based on the Data Engine adopts graphical configuration form as an algorithm, as shown in Figure 2(a). This is a typical form of graph computing, and the optimization process is relatively easy. The algorithm consisting of this kind of configuration is attached to a graphical space and can be mapped to another data space by a specific transformation, which is the real-time database contained in the Data Engine. The execution process of each Data Engine in industrial PaaS is equivalent to the data update process of the real-time database.



a) The relationship between the graphic computing and Data Engine.



(b)Software interface in the visualization technology framework.

Figure 2. The graphical configuration and Data Engine techniques.

The visualization Data Engine has two functions: one is to integrate the data required by the visualization technology framework into the visualization Data Engine from different Data Engines, and the other is to perform necessary computing processing of the relevant data. These integrations and data processing are performed in a graphical configuration environment with intuitive and transparent processes. The right component in Figure 2(a) is the output component of the Data Engine and has the ability to communicate with the visualization technology framework. Take an example of data that needs to display a trend graph on a visualization window. In the visualization technology framework, the configuration process of the trend component consists of setting a set of data, that is pairing with the corresponding data points of the visualization Data Engine. It can be seen that changing the configuration in Figure 2(a) without changing the configuration of the visualization technology framework can also change the content of the visualization. Figure 2(b) is the software interface for the trend graph in the visualization technology framework. In addition, it should be noted that the visualization technology framework is built in the app environment of the PC browser or mobile terminal, so we also need to deploy the webserver service on the industrial PaaS to realize the data transmission.

4. Design of Visualization Technology Framework

The visualization technology framework is designed to make the industrial cloud computing data display on the web or industrial app windows, and display in various forms under the premise of rapid configuration, such as data list, trend chart, bar graph, pie chart, radar maps, etc. The applications of industrial cloud computing in the future concerns a very large population and the needs of each application are not exactly the same. Therefore, another purpose of setting such a goal is to meet the needs of diversified and continuous dynamic changes of applications. The visualization technology framework also includes two important back-end support, including user and project management module, and the webserver service module. The former is designed to provide the authorized access for users to ensure that the information security of industrial cloud computing will not be damaged by illegal users, and also provides the engineering management function of related applications, such as storing and dynamic invoking the configuration results of visualization applications. The latter is used to handle the web access transaction, connect the visualization technology framework with the corresponding visualization Data Engine, and provide data communication services for the visualization window.

The configuration components are important assets of the visualization technology framework, and each component has a specific data display function in the visualization application. The reason why developers can quickly configure and build visualization applications is that the configuration components are embedded in the framework, they use graphical configuration method to develop, thus eliminating the need for developers to program and develop related software functions. Take the data trend display requirements commonly used in visualization applications as an example. Figure 3 shows the schematic diagram of the configuration process of the trend chart configuration component. When the developer enters the configuration editing environment of the visualization technology framework, he can select the target component from the configuration component menu window. The displayed state of the configuration component on the web page is determined by the location parameter of the component, the component size parameter, and the data information that needs to be displayed. These parameters are written into the webpage code corresponding to the component, and stored in the cloud server, which can be accessed by users and obtain corresponding visualization result of these data. The "container" module technology is required in the configuration process. All configured components are placed on their respective container. The principle is that when a component is dragged to a specific location on the web page, the framework will automatically load the corresponding web page code fragment from the container's library. The developer can modify the contents of the container placed in the webpage editing area through the property bar of the client, including position, size, background color, transparency, visibility, border curvature, border color, and so on. To improve the efficiency and quality of the configuration, the visualization technology framework provides a configuration preview function to help developers implement a plug-and-play development model. The framework also supports multi-server application architecture, which not only provides the data service of the visualization Data Engine but also supports video services and other web services.

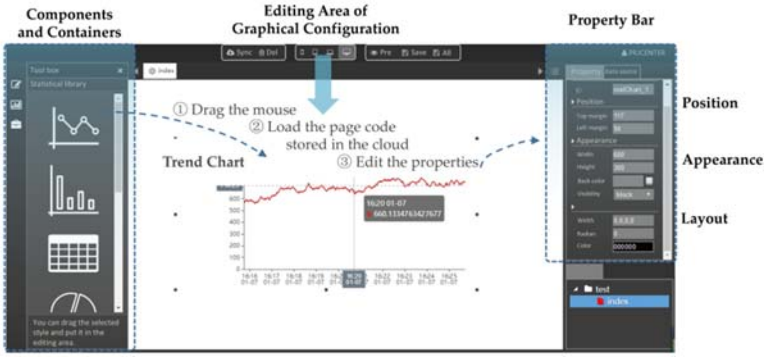


Figure 3. Configuration process principle of the trend chart component.

How to make the visualization framework be compatible with all applications in the industrial field is a very important topic. Therefore, it is necessary to analyze different industrial application models, package more common technologies in components and reuse them infinitely, and obtain computable and observable capabilities. The next work in the visualization framework is to realize the efficient design and development of these components. This means that users can participate in the design and development of components to a certain extent to improve the scope of visualization applications and the development capabilities. The component designer can be considered as the design, development, and resource management tool for the configuration components mentioned above. In the future, when the developer enters the component designer editing environment, they can select new components and complete the task of editing, compiling, debugging and encapsulating of component display algorithm in the component script code development module. Drawing tools, property editing, and component categorization management will also be the basic functions of the component designer, by which developers can use it to edit the component icons, names, types, inputs, outputs, parameters, and numbers. The design and development principle of a new component is that it must have the possibility of reuse at a certain scale. Therefore, with the extension of the application of industrial cloud computing technology, the design component standards and specifications for the visualization framework technology must be established to create the necessary conditions for the wide application of industrial cloud computing systems. In general, the component designer will be provided by the industrial cloud computing service provider, and they should be responsible for managing and maintaining the newly generated components while ensuring that developers can find new component menus and their corresponding instructions in the visualization application configuration environment.

5. The Experiment of Visualization Technology

We will use an industrial cloud computing test bed to verify the industrial PaaS and corresponding visualization technology framework proposed in this paper. The test bed hardware system is composed of a set of cloud servers, gateway devices, controllers, web terminal devices, servo motors, OMRON photoelectric encoders, color lights, and illuminance sensors, etc. As shown in Figure 4, the OMRON PLC(Programmable Logic Controller) controller, servo motor and photoelectric encoder in the test bed constitute the motor control and speed measurement system; the color light and illuminance sensor are connected to the motor control system through the gateway device, which constitutes the color light show system changing with speed of motor. All devices are connected to the local gateway device through the local area network, and all data of the test bed is uploaded to the industrial PaaS of the cloud server. The structure of this test bed is very close to the industrial production site working environment, which can well meet the research and testing needs of industrial cloud computing visualization technology framework.

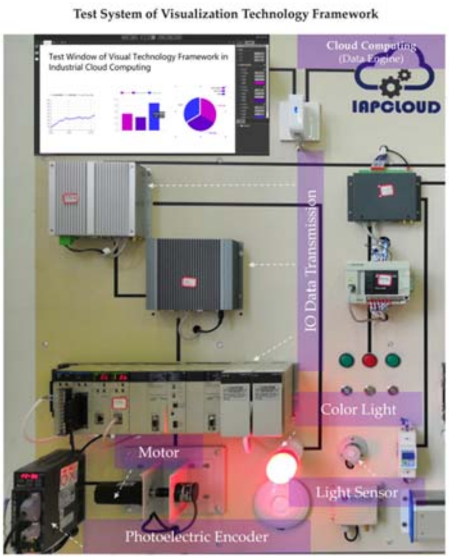


Figure 4. Photo of visualization technology framework test system.

In order to verify the effectiveness of the industrial cloud computing visualization technology framework method, this study designed two sets of experiments. One is to test whether the industrial cloud computing process data can be visualized in various forms through the internet terminal display window, and the second is to verify whether the new application effects can be generated quickly by utilizing technical framework configuration reconstruction method. In this study, the speed setting value of the motor speed control system can be set to a fixed value, or be set to a continuously changing periodic signal; the actual feedback value of the motor speed will be continuously adjusted according to the calculation result of the OMRON PLC and approach the set speed; and the color light display system will respond differently as the motor speed changes.

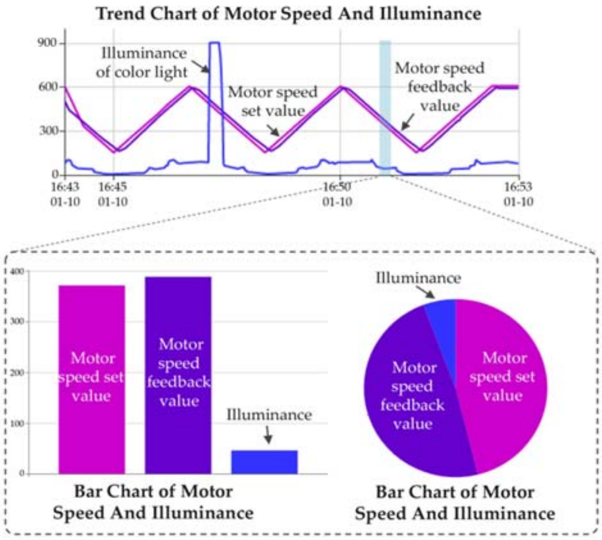
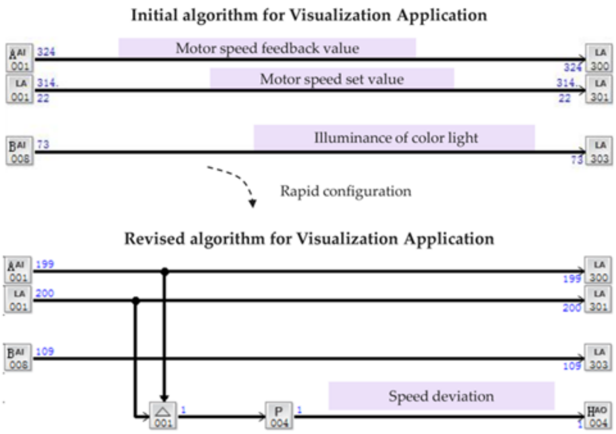


Figure 5. Different data display forms in visualization framework.

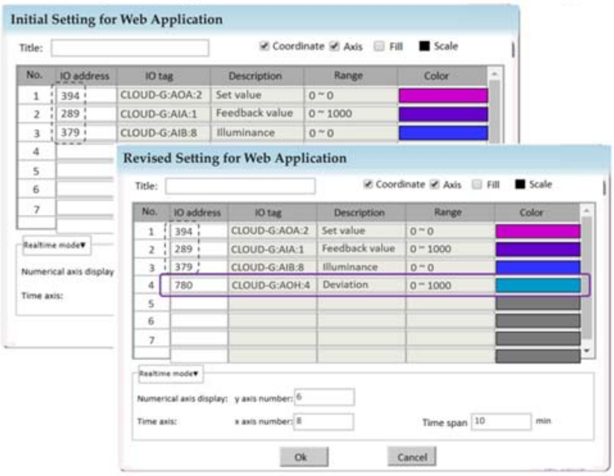
Experiment 1: Diversified display of industrial cloud computing data. In this experiment, the motor speed set value, the feedback value and the illuminance signal data of the color lamp are taken as the observation object, so as to test the multiple display effects of the same data signal under the visualization technology framework. In this experiment, the developer only needs to select three components including trend graph, pie chart and histogram on the web interface of the visualization technology framework, set the attribute information such as component display size and text content, and correlate the IO address to the corresponding data points (speed set value, feedback value and illuminance value) of the visualization Data Engine on the cloud computing platform, then the web program can run and the real-time value of each data point is obtained through the browser. As shown in Figure 5, the same data points can be displayed with different forms, by which users can intuitively and dynamically monitor the change trend and the proportional relationship of the real-time values of the three data points.

Experiment 2: Application of the visualization framework quick configuration function. The method of this experiment is to add a new variable based on Experiment 1 to observe the real-time variation of the motor speed deviation value. The variable is calculated by calculating the difference between the rotational speed feedback value and the measured value and then multiplied by a magnification factor. As shown in Figure 6(a), in order to monitor the new variable calculation process data, we only need to add two configuration components to the original algorithm configuration interface and associate the calculation results with the specified output component, then the new algorithm application can be quickly built. Figure 6(b) and Figure 6(c) respectively show the configuration method of the new application in the Web configuration environment and the change of the display effect of the trend graph before and after the experiment. It can be seen from the figure that the real-time curve of the motor speed deviation can be monitored by adding the data point address of the new variable output component in the original trend component attribute window. It can be seen that with the graphical configuration function of the visualization technology framework, users can reconstruct a new visualization application efficiently at low cost.

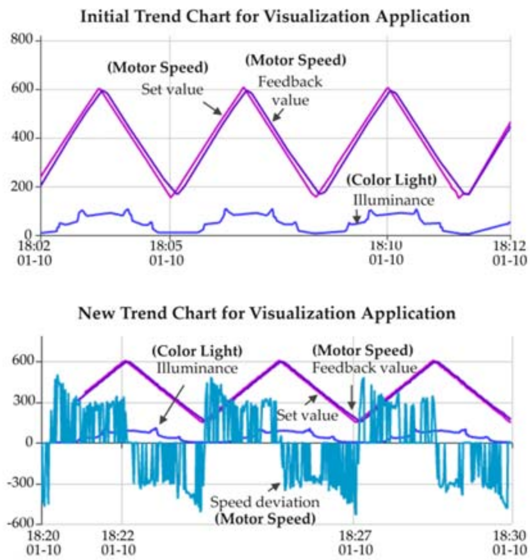
The experimental results show that the cloud computing visualization technology framework proposed in this paper can not only display the cloud computing process data in diverse forms, but also utilize the reusability of configuration resources to improve the development efficiency of new industrial applications, so as to adapt to the changing visualization needs of users.



(a) The change of algorithm before and after reconfiguration.



(b) Configuration method of new application in the web configuration environment.



(c) The visualization change effect of the trend chart.

Figure 6. Quick configuration example in visualization framework.

6. Conclusion

The visualization of industrial cloud computing is a hot topic in industrial information technology research. The lack of a good visualization framework to improve the monitoring ability of industrial algorithm computing process data and the ability to reduce the development cost of applications are key technical issues in the current industrial cloud computing visualization research, which are also reasons why industrial cloud computing is still hard to popularize and develop. The main contribution of this paper is to propose an industrial PaaS architecture based on Data Engine and graph computing and its visualization technology framework to solve the above problems. Lots of research results show that this technical framework is scientific and efficient. The visualization requirements of future industrial applications are complex, dynamic and changeable, which means the reusability of visualization resources on industrial cloud computing platforms will play an important role. Meanwhile, the visualization technology framework should also be developed in the direction of being able to develop secondary configuration components. With the emergence of new demands for industrial applications, the visual service pattern of the cloud platform will be further improved, including improving the designer of graphical component to meet the needs of users to design and develop visualization applications by themselves.

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