

## Design and Realization of Integrated Control Platform for Production Process of Mechanical Products

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**Abstract.** Aiming at the informatization requirement of production process management in traditional machinery manufacturing enterprises, an integrated control platform for production process is developed. The platform includes production process modeling, real-time monitoring of production process and production guidance, data mining and other functions. This paper expatiates the architecture, function and principle, and design method of the control platform, which has been applied in practice.

### 1. Introduction

Traditional production process of machinery manufacturing enterprise bases on manual management of the table, whose shortcomings can be summarized as several points: Firstly, the information of product materials, tooling, process and others is huge, and the description about the information is not detailed. Secondly, the production process and order is not intuitive, and it is difficult to provide effective production guidance for the process manager and front-line workers. Thirdly, the data management of production is scattered, and there are some problems such as data gap and data source inconsistencies between different information, and the utilization of production data is not high. Lastly, it is difficult to look back the production process expediently and effectively, and not easy to achieve the quality control of the production process <sup>[1]</sup>.

Therefore, we need to establish a reasonable way of information management and production processes to address the first and second issues; need to establish an integrated control platform containing information management, process modeling, production process control and other functions, which not only help to control the whole production process, but also be a good solution to the data gap and the data source inconsistencies; need to build specific data mining module for the mechanical production data, and looking for quality information implied in production data, thus guiding the quality control of production process.

In this paper, we propose an integrated control platform for the production process of mechanical products, which contains functional modules such as production process modeling of mechanical product, real-time monitoring of production process and production guidance, and data mining for the production data. It means that the platform not only supports the production information collection, data management and data statistics, but also supports data mining and quality tracking and so on.

### 2. Software Architecture

This paper designs a kind of architecture for integrated control platform for the production process of mechanical products, as shown in Fig. 1.

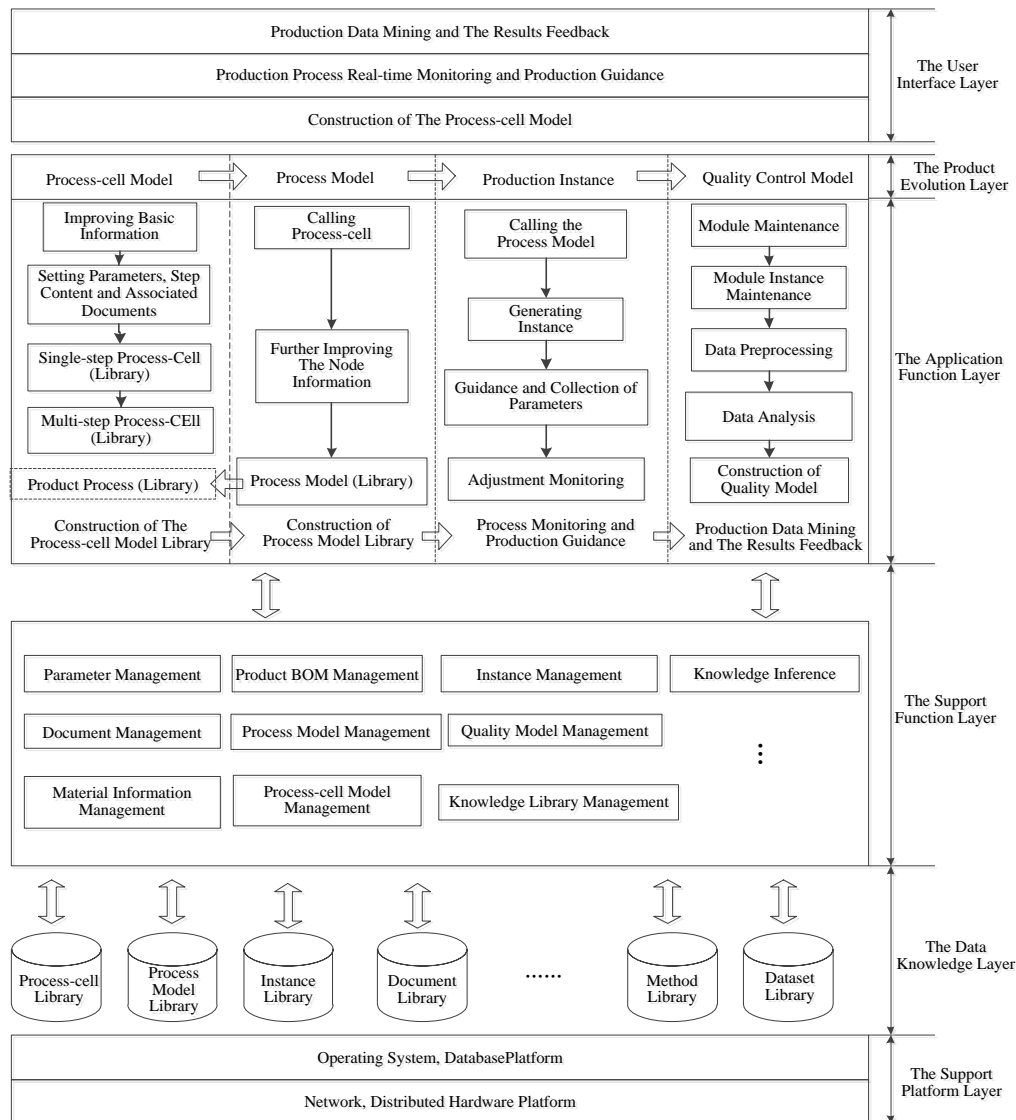


Fig. 1 Software Architecture

The architecture mainly including the following levels:

(1) The support platform layer. This layer which is the basis of system design and operation provides the underlying platform for system operation, including network, distributed hardware platform, operating system, database platform and so on.

(2) The data knowledge layer. This layer provides the data support for the system operation, including the process-cell library, the process model library, the production instance library, the document library, the method library, the data set library and so on.

(3) The support function layer. This layer provides the function support of the system operation, including following functions: process parameter management, process document management, material information management, product BOM management, process-cell model management, process model management, production instance management, quality model management and so on.

(4) The application function layer. This layer describes the functions of the system and the processes of the various functions, including the construction of the process-cell model library, the construction of process model library, the production process monitoring and production guidance, the production data mining and the results feedback.

(5) The product evolution layer. It is the results of realizing application function, reflecting the gradual transition from customer requirement to product which meets customer requirement, including the process-cell model, process model, production instance, quality control model and so on.

(6) The user interface layer. According to the user's authority and role, the function interface can be

custom-made to meet user-specific functional requirements, and to achieve the applications of the integrated control platform for the production process of mechanical products.

### 3. Functional Tree and Main Function Model Design

According to the integrated control process for the production process of the mechanical products, we determine five major function modules as follows: information management, process modeling, production process real-time monitoring and production guidance, production data mining and quality model establishment, and system management. We design these five function modules and establish functional structure of the platform as shown in Fig. 2.

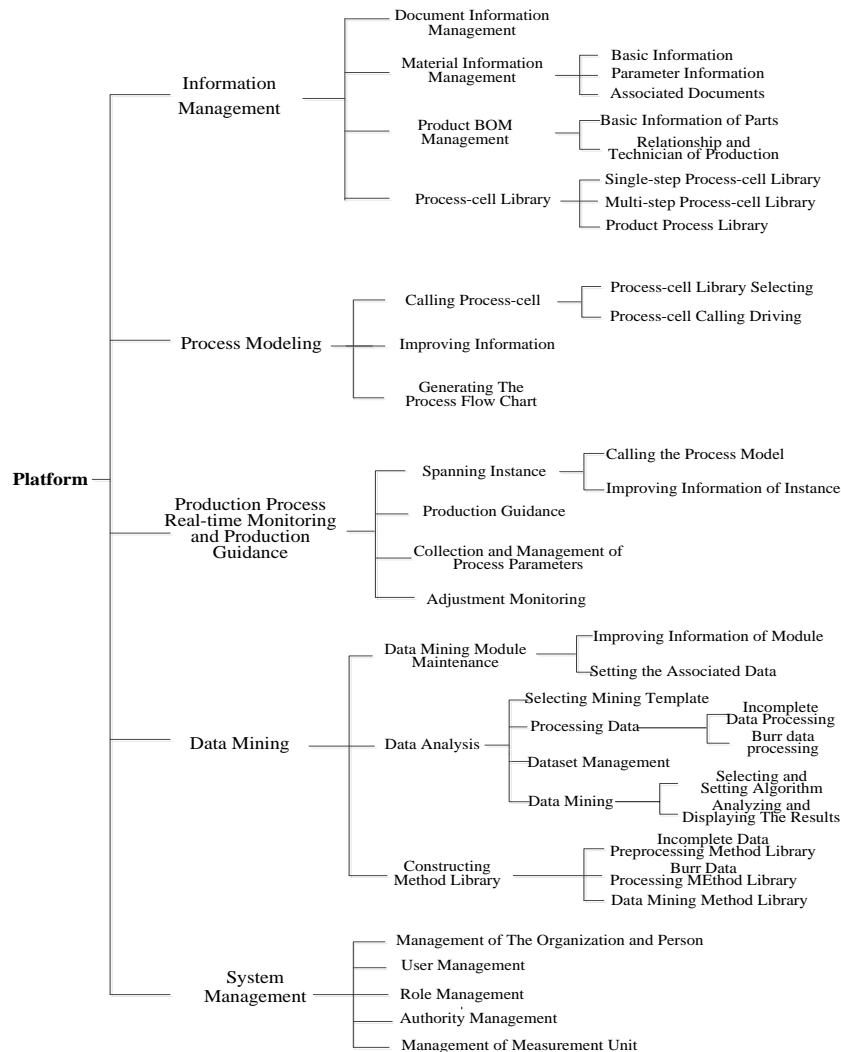


Fig.2 Functional Structure of Platform

#### 3.1 Information Management

The information management module achieves the function of standardized management of the numerous information orderly and uniformly, which involved in production process. The module includes document information management, material information management, product BOM management, process-cell library management and so on.

The part of document information management uniformly manages the documents related to product materials and process-cell. The document information mainly includes document name, document type, version, document description, document usage and sub-document, etc., In this part we improve the corresponding information for each document, and establish a standardized document library.

The part of material information management achieves the orderly management of product material information. The material information which need to be improved includes material code,

material name, specification and model, measurement units and material description. The establishment of material information library helps us to achieve the unified management of material information, and to call or view the material expediently.

Product BOM management refers to the unified management of materials bill of product .In this part we can builds product BOM by three sub-functions as follows: adding nodes, adding sub-nodes and deleting nodes. The material related to additional node or sub-node can be called from the material information library.

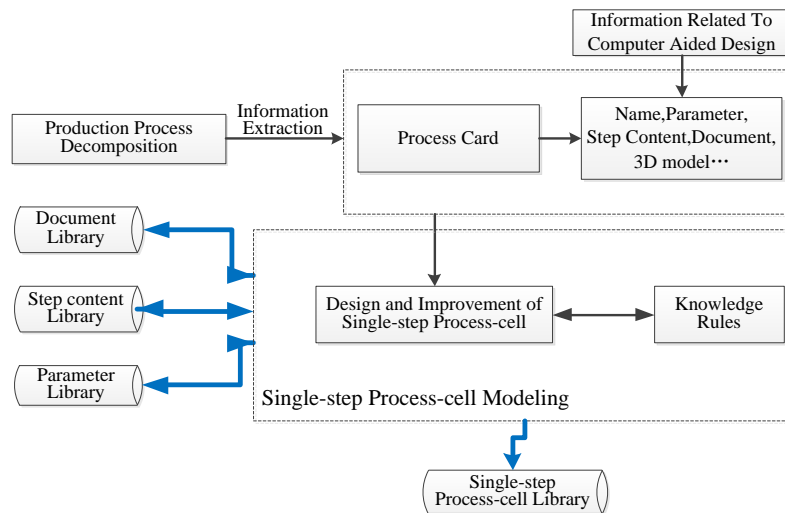


Fig. 3 Single-step Process-cell Modeling Process

A number of production activities form a production of products, these production activities called process-cell. Process-cell library management includes single-step process-cell library management, multi-step process-cell library management and product process library management. Process-cell modeling is the use of a unified way to describe the process-cell normatively and formally. Among them, the single-step process-cell library stores the information of single-step process-cell, including the basic information of the process-cell, process parameters, step content and associated documents [2].The modeling process is shown in Fig. 3. The multi-step process-cell library stores the information of multi-step process-cell which is orderly established by a number of single-step process-cells based on the single-step process-cell library, as shown in Fig. 4. The product process library is established based on the single-step process-cell library and multi-step process-cell library. Actually, the product process is the same as the production process model which the next will introduce to. The product process library plays an important role in establishing the model of whole production process of product, which involves a number of parts.

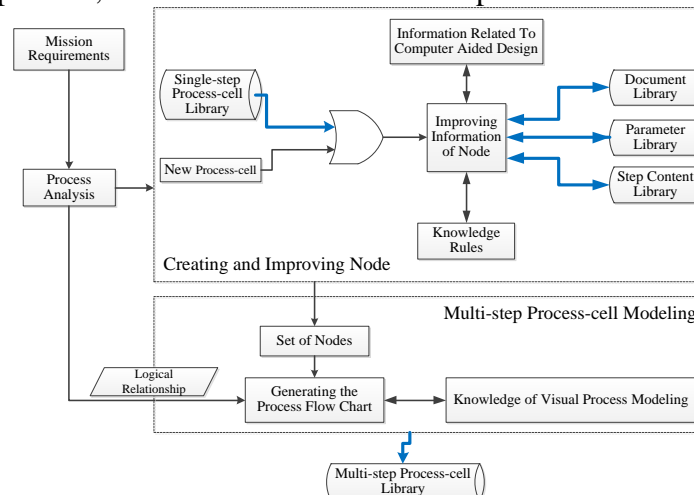


Fig. 4 Multi-step Process-cell Modeling Process

### 3.2 Process Modeling

Process modeling refers to building a standardized process model quickly for different products using the visual modeling method (graphical description method) based on process-cell library. We establish the process model library for the unified management of process models to achieve the standardization, formalization and informatization of process. The process modeling process is shown in Fig. 5.

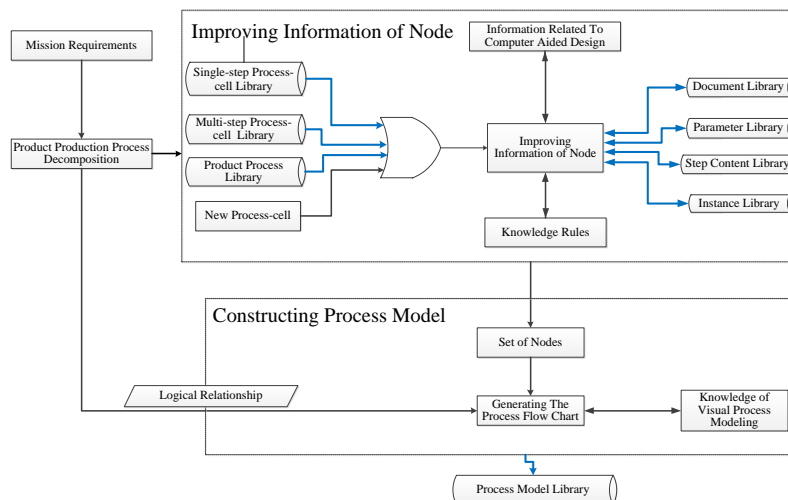


Fig. 5 Process Modeling Process

The process modeling mainly includes the following three steps: First, calling or adding process-cell. That is, selecting the corresponding process-cell from process-cell library or adding a new process-cell in sequence according to the actual production processes of the product. Second, further improving the node information. That is, according to the actual production requirements of product, improving the process content, process parameters, process files and 3D model, and other information associated with current process-cell. Third, generating the process flow chart. The process mainly consists of sequential processes, which use graphical elements and annotations in graphics to describe processes and logical rules. The linking line represent the relationship between process-cells and the flow direction of production. On the basis of the above work, the process model library is established to realize the unified management of the models.

### 3.3 Production Process Real-time Monitoring and Production Guidance

The production process real-time monitoring and production guidance means that tracking the whole production process of mechanical products, and providing efficient production Guidance for the front-line workers making use of the flow chart, production content, related documents and other information based on the established process model (Fig. 6). This module on the one hand can regulate the operation of workers to improve product quality, and on the other hand it contribute to the monitoring and retrospect of full production process.

The function module is mainly composed of production instance spanning, production process guidance, real-time collection and management of process parameters, and adjustment monitoring. First, generating the available production instance, that is, calling the model from the process model library according to the actual production requirements, and then improving the basic information such as batch, tracking number, bar code, etc., second, the front-line workers execute operation in strict in the light of requirements ,making use of the information contained in each node (including step contents, 3D model, process documentation, etc.); Third, executing the operation of collection and management of process parameters. In the step of process modeling, we have set parameters well which need to be collected, and the workers must measure and input these set parameters in the actual production operation, or it will not be able to jump to the next node of production process. Finally, the adjustment monitoring module records the information (including adjustment time, adjustment content, the responsible person, etc.) and the adjusted parameters of the second adjustment or even multiple adjustments.

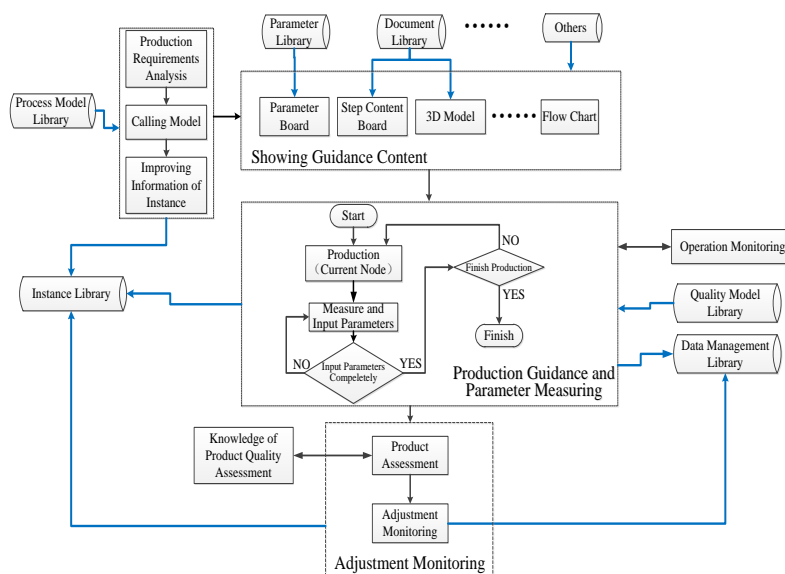


Fig. 6 Real-time Monitoring and Production Guidance Process

The operation of the whole process achieve the tracking and monitoring of production process. The related records and parameters can assist in looking back the product production process latterly.

### 3.4 Data Mining

The data mining module mainly mines the production data, and uses the mining results to establish the product quality model. The quality model can realize the following functions: one is to realize the extraction, verification and storage of production knowledge; the second is to realize the statistics, tracking and retrospect of product quality. For example, we can get the overall quality distribution of one batch of the products, and find the processing steps causing a specific quality problems, etc.; the third is to achieve on-site production guidance and real-time adjustment of the process parameters, and to achieve the product quality forecast. That is, according to the current statistical data, we can use the model to predict the trend of product quality, and the model can optimize and hint the parameters of next process to achieve the purpose of optimizing product quality [3].

The data mining module mainly includes three parts: data mining module maintenance, method library construction and data analysis.

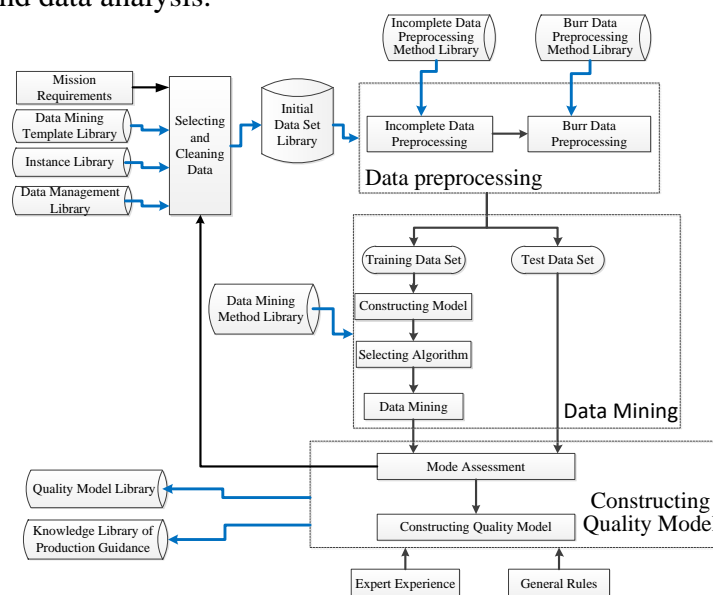


Fig.7 Data Mining Process

In the part of module maintenance, we improve the basic information and set the associated data to complete the data mining module. Setting the associated data refers to setting the process parameters and test parameters, in which the process parameter for the construction of test sets and training sets, and the test parameters equivalent to the result sets (the result of the analysis) which enterprise wants.

On the basis of the above work, we can generate the data mining template for different object (a template corresponding to a product production process, a product production process can correspond to multiple templates), and then establish a data mining template library.

The method library is divided into three parts according to the data mining process: one is incomplete data preprocessing method library, which integrates a variety of methods of incomplete data preprocessing; the second is the burr data preprocessing method library, which provides a variety of processing options for further preprocess (remove the burr) ; Third, the data mining method library, which provides four categories of data mining method: reduced dimension, regression, classification, and clustering. Each category of method has 2-5 specific algorithms to choose. The construction of the method library can cater to the different requirements of many mechanical product data analysis. In the actual operation, the appropriate method is selected for the specific analysis example, and the process parameters can be used furthest to obtain the ideal result.

Data analysis part realizes the function of data mining. Firstly, the corresponding data mining template is selected from the data mining template library according to the analysis object. Secondly, the production instances are selected, and the production data of the selected instances are sorted out, and the appropriate incomplete data preprocessing method and burr data preprocessing method is selected from the method library top reprocess the production data. Thirdly, on the basis of the above work, the data will be sorted into the data sets for being called. Finally, selecting one of the algorithms from the data mining method library (some algorithms need to set parameters), and then calling the data sets and executing the algorithm. After the analysis, the results are displayed in the interface, and the quality model is constructed by analyzing the results to guide the quality management of the production process [4, 5]. The whole process is shown in Fig. 7.

### **3.5 System Management**

The system management achieves the management of the organization, the person, the role, the authority, and the measurement unit. It mainly includes five parts including the organization and staff management, user management, role management, authority management and measurement unit management. Among them, the organization and staff management realizes the function of overall management of organization and person that use the software. The user management realizes the function of unified management of the user information on the login system. The role management realizes the function of unified management of the type of user's authority. The authority management is to manage user's authority. The Measurement unit management is to achieve the unified management of units of measurement.

## **4. Platform Application**

In the previous article, we establish the architecture of the integrated control platform based on the production process modeling, and design the system functions and functional processes based on the theory and the results of the method. Accordingly, based on breaking the key technologies of system development, we select Oracle 11g for the database platform, and use Delphi2010 software development platform to build the integrated control platform for the production process of mechanical products.

### **4.1 Production Process Monitoring and Guidance**

The production process monitoring realizes the function of managing the process parameters used in actual production operation, including the adjusted information after completing production as shown in Fig.8.

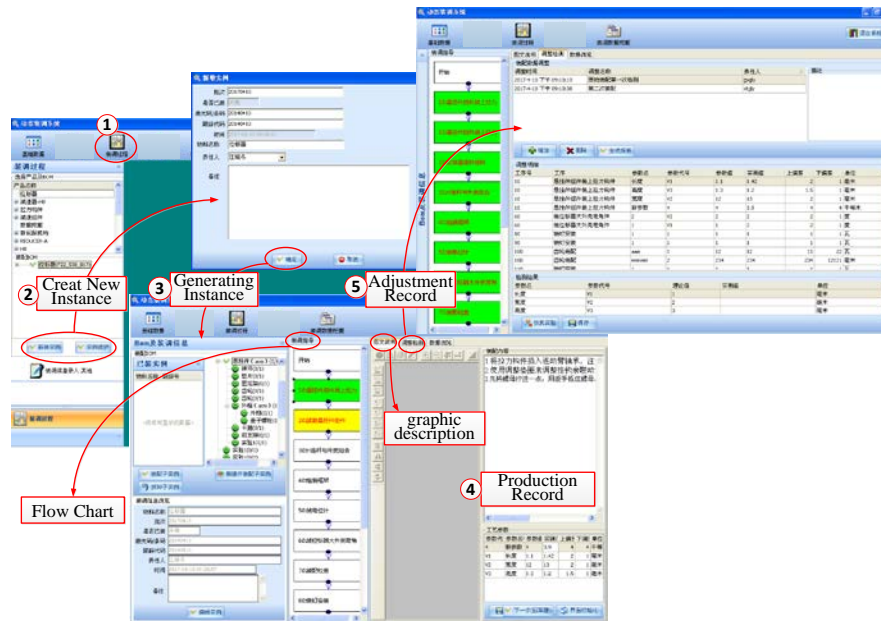


Fig. 8 Real-time Monitoring and Production Guidance Module

First, selecting the product, and then beginning to input the batch number, tracking code and other information to calibrate the instance. Second, entering the main interface, and the workers execute operation in strict in the light of the production flow chart and graphic description, documentation, step content and other guidance information contained in each process-cell, and then measure and upload the parameters of each process to complete the original production work. Finally, testing the product, if the performance parameters can't meet the standard, then this product should be reworked to adjust. The operation of adjustment includes increasing the adjustment records and modifying the adjusted parameters. It can achieve the function of records control of the production process, and it can assist in retrospect of the production process in the future.

#### 4.2 Data Mining

Production data mining module is as shown in Fig.9. First, the technical staff who master the knowledge of the production maintains the mining module. The module considers the product as the parent node, including the name of the data mining, description of the purpose, the relevant process parameters, product performance parameters etc., Second, after customization ,we can execute the operation of data mining. Data-preparing includes the selection of products, mining templates and data sources. After extracting the data, incomplete data preprocessing and burr preprocessing are performed to construct the data sets. Then select the appropriate algorithm according to the mining target, and it should be known that different algorithms need to be set in different settings. Lastly, executing the algorithm to get the results of data mining, and presenting the results to the technical staff to establish the product quality model.

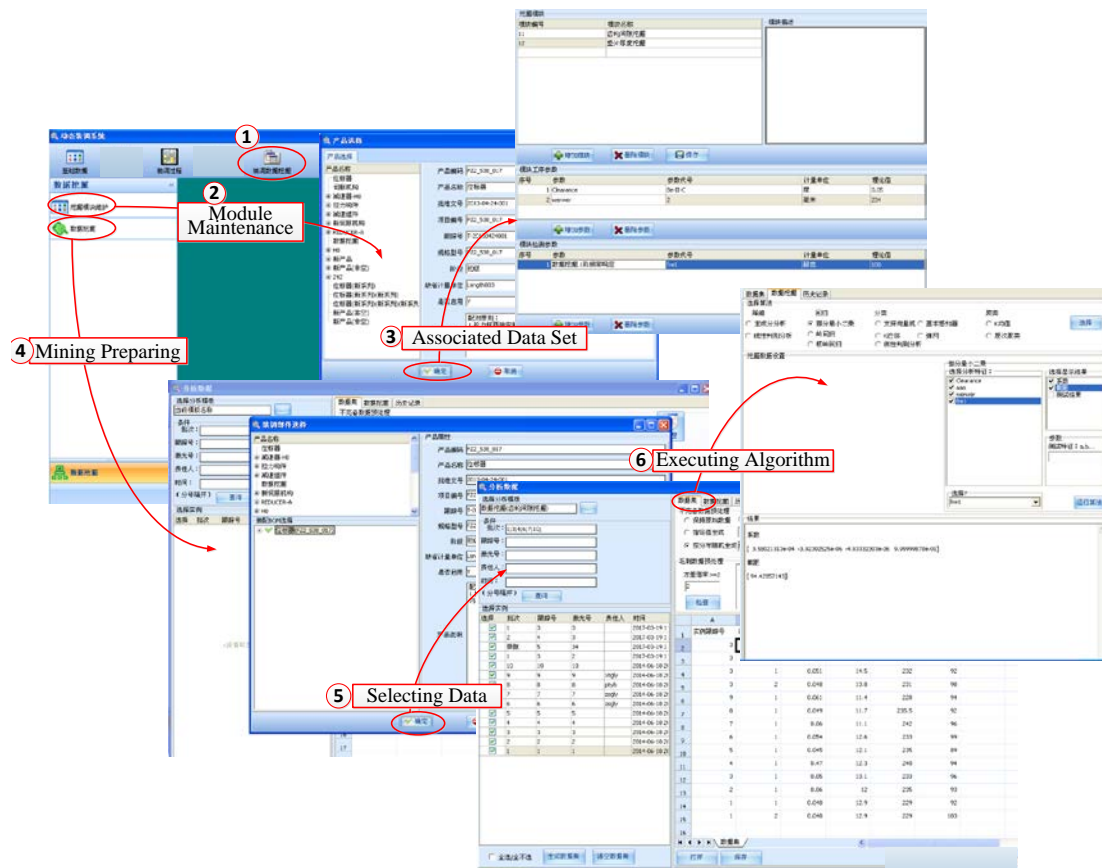


Fig. 9 Data Mining Module

## 5. Conclusion

This paper combines the concept design, process modeling, quality control and data mining functions to build an integrated control platform for the production process of mechanical products, which can be used to assist the designers to carry out the process modeling and guide the front-line workers to carry out the production operation, and assist manager to carry out the production management in production site. It also can be used to assist the mining of the production data and the establishment of quality models, which can guide the quality control of production process. It can also monitor and assist in looking back the production process.

The platform has been applied to the production of mechanical products in a military enterprise, which effectively improves the efficiency of process design, efficiency of production and product quality, and has achieved good results.

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