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Process Simulation and Optimization of Ammunition Filling Robot based on DELMIA

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***Abstract*—The development of ammunition production technology directly affects the level of national defense construction, the application of industrial robot improves the automation degree of ammunition production line, but its work path is complex and the craft is numerous, so simulation verification is needed before the actual installation and debugging, domestic simulation research is still in its infancy. This paper uses Robotics module of DELMIA software to model its working process, on this basis, the work path setting, robot trajectory optimization and collision and interference detection are carried out, the production process was optimized by PERT diagram and Gantt diagram. The results show that the optimized process improves the production efficiency and saves the working time. This method has reference significance for the application of other robots in specific industries.**

Keywords-robotics; process optimization; PERT diagram

I. INTRODUCTION

Ammunition is an unique national defense equipment, its production technology directly reflects the national defense manufacturing capabilities, since the middle of last century, the ammunition production technology in our country has experienced the development process of manual operation, semi-automatic, automation and digitalization. With the introduction of robot, the automation degree of ammunition production line becomes higher and higher. Ammunition manufaction line has the characteristics of large amount of production and reserve, various production links, complex production process and so on. Therefore, it is necessary to carry out the simulation and optimization of the work process before putting into production, so as to reduce unnecessary production investment and waste of resources.

DELMIA software comes into being based on 3D digital simulation, it can build models in virtual space before the factory is put into real production. On this basis, it can carry on the virtual simulation and path planning to the real production process, the optimized results can reduce production costs and improve production quality. Each action of the robot is accurately simulated before production, which can greatly enhance the accuracy of the robot work and shorten the preparation time. At present, the research on industrial robot simulation in our country is basically in the initial stage, most of which are developed on the basis of existing software.

The simulation of industrial robots is widely used in aerospace, automotive, shipbuilding and other fields, but in the military industry, the application is relatively rare. In this paper, DELMIA/Robotics is used to simulate the working process of the robot on the ammunition production line, and DELMIA/DPM is used to optimize the working path of the robot. The results show that using DELMIA to simulate the optimized work path can effectively improve the efficiency of production line.

II. DELMIA/DPM AND DELMIA/ROBOTICS

DELMIA is a digital PLM platform provided to customers by French Dassault Company, the software focuses on the simulation of complex manufacturing/maintenance process and related data management and collaboration, it can provide complete 3D digital design, manufacturing and digital production line solutions. The main functions are divided into three parts, namely DELMIA E5(DPE), DELMIA V5(DPM), DELMIA D5(QUEST), these three relatively independent parts can be connected by PPR(Process, Product, Resource) hub, as shown in figure 1.

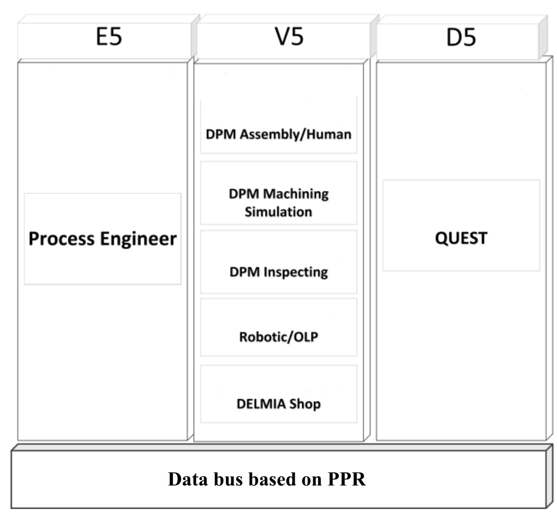

Figure 1. The module dipartition of DELMIA.

As digital solutions, DELMIA/DPM not only can create a three-dimensional technology and resource planning application environment, but also can carry out the planning

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and verification of the details in the process, which achieves synchronization of 3D product data and 3D process data. As a sub module, DELMIA/Robotics is mainly used to simulate, optimize and program robot. The software covers the world famous manufacturers of robots, whether it is a single robot unit or multiple robot joint operations, Robotics can provide a realistic virtual environment to work on the path planning and simulation of robot. The simulation work of this paper mainly involves resource layout, device building and device task definition. Resource layout is used to simulate the layout of factory environment, help users quickly import the required resources, build three-dimensional simulation environment. Device building is used to set device and motion parameters. Device task definition is used for the simulation of each station and action when the robot is working.

III. The Creation of Simulation Environment

Building virtual environment in DELMIA usually needs to import assembly model and information from other 3D design software. Currently commonly used three-dimensional modeling tools include: UG, Solidworks, Pro/Engineer, CATIA, etc.. The software includes the wireframe model, surface model, three-dimensional entity, feature model design and virtual environment, which can provide virtual model consistent with the actual production. In data transfer, the input of model can be converted by model format. This paper uses Solidworks modeling, the model is imported into DELMIA through data interface to ensure the consistency between virtual environment and real working environment. The import of model brings great convenience to software application

The relevant data in the DELMIA ammunition production line can be divided into three types include products, resources and process, namely hierarchical data product - process - resource model based on PPR (Product, Process, Resources) data model, hierarchical relationships are shown in Figure 2, various components in the production line are managed uniformly.

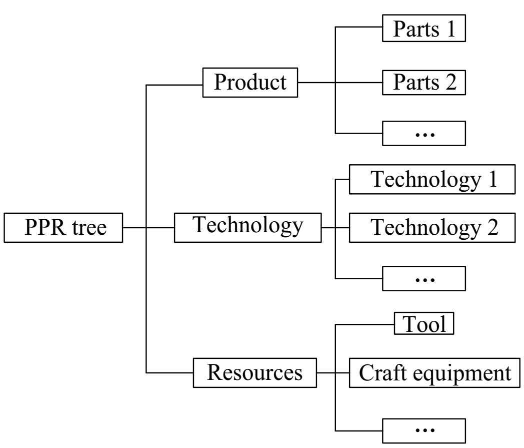


Figure 2. PPR data model structure

This article takes the guide rail, the tool head placing frame, the AGV trolley and the medicine preparation stand as the resource, drug blocks (including cylindrical, fan-shaped, tapered) are introduced into the DELMIA working environment as a product, KUKA's six joint 160X robot is loaded from the resource directory, the virtual simulation physical model of the ammunition production line is shown in figure 3.

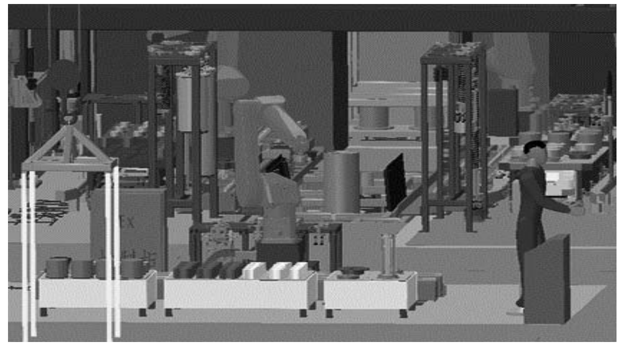


Figure 3. The overall layout of the ammunition production line.

IV. Simulation of Working Process of Ammunition Grabbing Robot

The grab of the medicine block and the placement station are the most common positions in the ammunition production line. The preparation range of the medicine block is usually provided with hundreds of different shapes of medicine blocks and fixtures which is suitable for different drug blocks. In order to ensure the movement of each station can be carried out smoothly before the actual production, virtual simulation software for the robot's work path planning and analysis is usually needed. This paper uses DELMIA module of Robotics to simulate the working path of drug grabbing robot.

A. The Setting of Robot Working Path

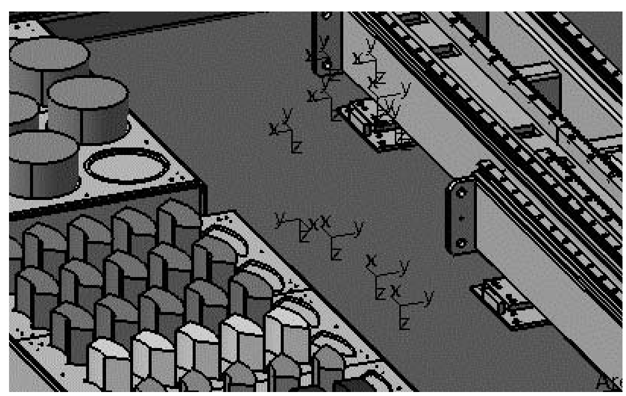


Figure 4. The distribution point group of robots.

To realize the movement of each station of the robot, we must first set its trajectory. Create a robot track point group has three kinds of methods: 1) in the " device task definition " table, " new task " was created to form the " task group ", then each point of the robot are orderly connected to form the point group of motion track; 2) under the "arc welding" module, the "tag on surface Intersecting" command is used to form a point group in two intersecting planes; 3) under the "workcell sequencing" module, the information of point group can be imported directly, which saves a lot of time. Figure 4 shows the point group distribution of robot trajectory, the robot can complete the corresponding task according to the trajectory.

B. Simulation of Robot Working Process

The ammunition warhead is composed of different shapes of medicine, such as circular, fan-shaped and conical, the bottom of the clamp is made into a suction cup, so picking up and releasing of the drug blocks become the focus of simulation.

When the robot carries on the medicine block grasping operation, its working path is actually formed by TPC Frame through each Tag point, In order to achieve accurate positioning of the tool head and the drug block, TPC Frame is set at the center of the tool tip. The role of Base Frame is to accurately install the tool head at the end of the robot actuator, the robot TCP Frame is default to its end effector, by set tool instruction, the coincidence of tool head Base Frame with robot flange coordinates can be realized, which can accurately install the tool head on the robot, Figure 5 is TPC Frame and Base Frame of the tool head.

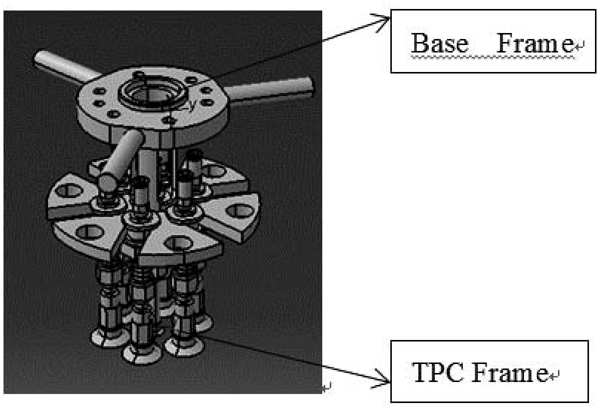
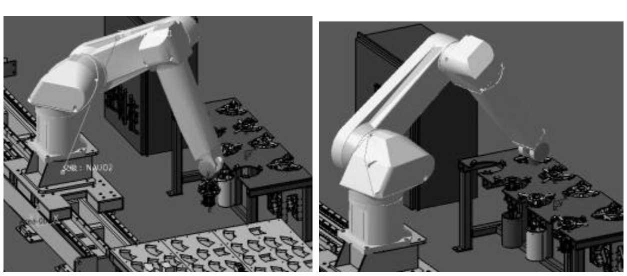
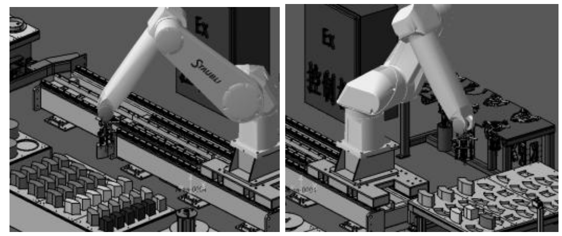


Figure 5. The TPC Frame and Base Frame of tool head.

Due to the wide range of robot motion and complex working path, it is necessary to test the trajectory repeatedly. The "configure an operation" function of robotics module can achieve custom for action, according to the needs, the user can set the action of picking up and releasing. Figure 6 is the process of picking up and releasing for tool head and medicine block, which completes the exact movement of the corresponding block or tool head.



a）Tool picking b）Tool releasing



c）Drug picking d）Drug releasing

Figure 6. The process of robot picking and placing.

C. Teaching and Trajectory Optimization for Robot

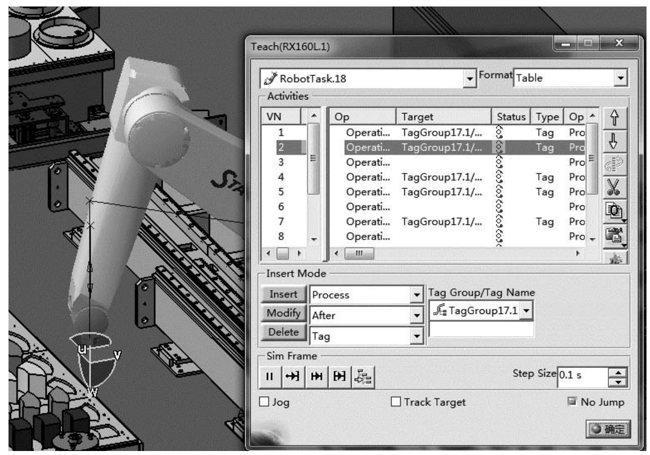


Figure 7. The teaching for robot.

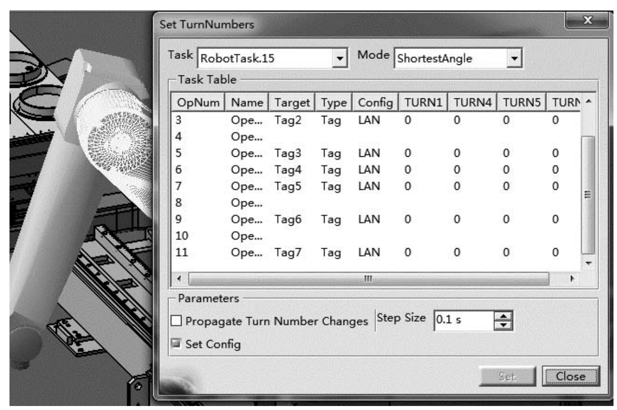


Figure 8. Robot trajectory optimization.

Usually after setting the working path of the robot, there is a certain discrepancy between the trajectory of the robot and the actual trajectory. Therefore, it is necessary to optimize the path of the robot after setting the trajectory of the robot, which can truly simulate the robot's attitude. The "Teach a device" command is used to select the robot to be taught and to plan the overall path of the robot, as shown in figure 7, this window can insert/delete tag points, adjust the robot's process, modify the robot pose. The set turn numbers command is then used to optimize the trajectory of the robot, as shown in figure 8. After the optimization of shortest angle mode, the robot can follow the optimized trajectory. The trajectory is input to the robot controller, which enables the robot to move in accordance with the optimized trajectory.

D. The checking of Collision and Interference

In the working process of the robot, the equipment on the station is densely distributed, the processing space of the station is relatively narrow, and the processing point of tag is widely distributed. Therefore, in the whole process of robot crawling the drug block, it is very likely that the collision happens between the robot and static equipment (workpiece, equipment, fixture), etc.. Robotics module provides a special analysis tool, which automatically detects collision detection function to effectively solve practical problems. The robot collision problem is effectively solved in the design process.

Through the clash command, in the dialog box, all components are selected, so you can detect the collision between robot and the device. If a collision intervention occurs, the action will automatically pause and generate a red warning area, as shown in figure 9. In the actual work process, the interference between the robot and the workpiece is not allowed, we can adjust the robot position, insert the tag point, optimize the trajectory of the way to avoid the occurrence of collision interference.

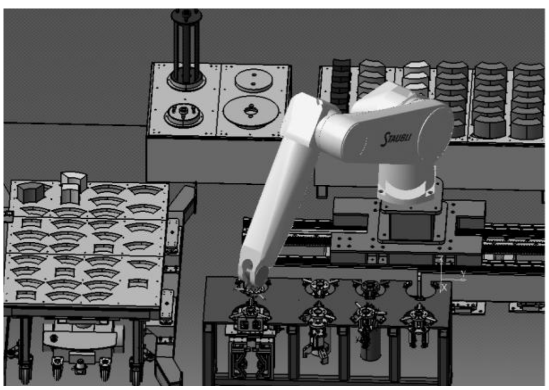


Figure 9. Collision and interference detection.

E. Process Optimization

The DPM module of DELMIA has obvious advantages in the verification and simulation of assembly process. It can provide the application environment of detailed planning, verification of the process and various analysis methods, which helps process personnel to simulate and optimize process details more accurately. In this paper, the Pert diagram and Gantt diagram of DPM module are used to adjust the process and optimize the process. The optimized process saves the working time.

F. The Prediction Model of Working Time

The prediction model of working time mainly includes three prediction models: serial relation, parallel relation and network relation.

1) The prediction model of serial relationship:

The relationship among the sub activities is carried out in accordance with a certain relationship, the operation time is the accumulation of each sub activity time, expected model:

$$T=T_1+T_2+\dots Tn=\Sigma T_i \quad (1)$$

2) The prediction model of parallel relation:

Each sub activity of a concurrent relationship is simultaneous, its operation is the maximum of each sub activity time, expected model:

$$T=max\{T_1,T_2,\dots, Tn\} \quad (2)$$

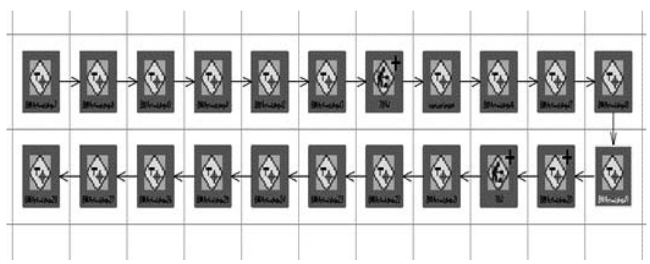
3) Network relation model:

For network relation model, there are both serial relationships and parallel relationships among their sub activities. So its operation time should be calculated according to the relevant theory of random network. Assume that one of the serial lines used for Ti, a total of M lines, its time model is:

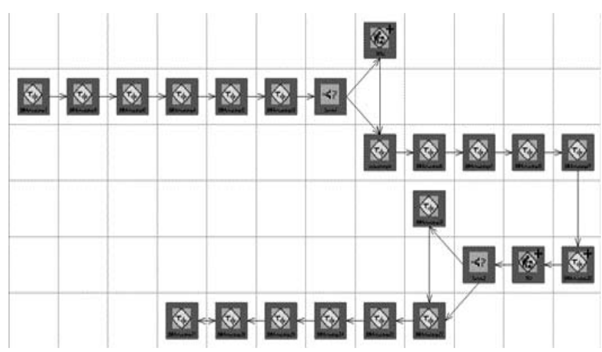
$$T=max\ \{T_1, T_2,\dots, Tm\} \quad (3)$$

G. Working Time Optimization

Based on the robot working process model built in DELMIA, the prediction of working time mainly includes two aspects. Firstly, the bottom of each station time is expected. Secondly, the entire operation time of bottom-up through the cumulative method is expected. PPR tree structure of DELMIA/DPM module is used, the process node is selected, by clicking on the Gantt charts, we can get the total cumulative time of robot from top to bottom. PERT diagram tool is used, process personnel can adjust the order of the stations to make the simulation of robot work more reasonable and personalized, as shown in figure 10.



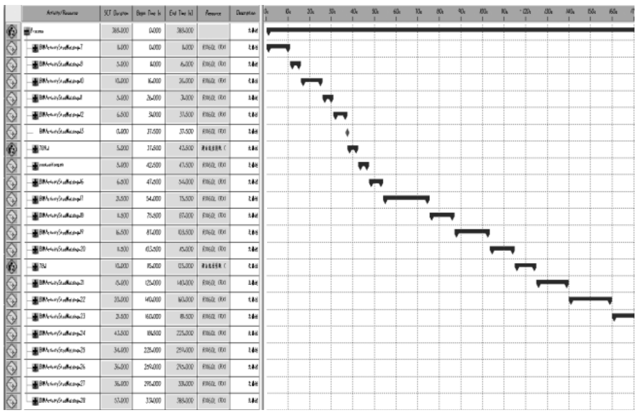
a) Before adjustment



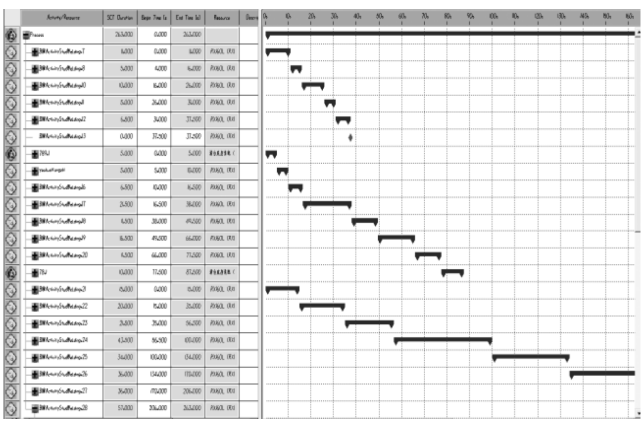
b) After adjustment

Figure 10. The adjustment of PERT chart before and after.

By adjusting the PERT diagram, we can see that the whole process of the robot is serial, adjusting the two stations can make it become a parallel relationship, the adjusted PERT diagram is shown in Figure b. By using the Gantt chart, we can see that the time before the adjustment is 368s, the time after the adjustment is 263s, which is shorter 105s than before.



a) Before adjustment



b) After adjustment

Figure 11. The adjustment of Gantt chart before and after.

V. CONCLUSION

Trajectory modeling and simulation of ammunition production line robot is an important part of virtual assembly of ammunition production line, which plays an important role in the automation of ammunition production line in our country. This paper uses the DELMIA Robotics module to complete the modeling and simulation of robot ammunition production line, which has successfully solved the problem that ammunition production line robot cannot observe the motion space directly. This is a useful attempt of the virtual assembly technology of ammunition. The DPM DELMIA module has been utilized for adjustment and optimization of robot working procedures and process, which reduces the operation time and shortens the period of production preparation. This method improves process planning guidance to the production site and provides a strong basis for the establishment of digital factory.

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