Research on selection of commercial industrial simulation software oriented to virtual commissioning

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Abstract. Virtual commissioning can find problems in the PLC program earlier and improve the efficiency of on-site commissioning. When constructing the FMS digital twin system with Beckhoff TwinCAT as the master control system for virtual commissioning of the production line, in order to select the most suitable modeling environment, this paper conducts research of predecessors based on commercial industrial simulation software. The four common commercial industrial simulation software with virtual commissioning function (Visual Components, Tecnomatix Process Simulate, Emulate3D, Flexsim) are introduced, analysed and compared from the two perspectives of software functions and features. Finally, it explains which commercial simulation software should be used for simulation and virtual commissioning in different scenarios.

1. Introduction

With the development of a new generation of information technology (such as artificial intelligence, big data, cloud computing, Internet of Things, etc.), countries have successively proposed advanced manufacturing development strategies such as "Industrial Internet", "Industry 4.0", and "Made in China 2025". It is hoped that with the development of new technologies, intelligent manufacturing can be realized, which has also promoted the development of Cyber-Physical Systems (CPS) [1] and Digital Twin (DT) [2] technologies.

Tao Fei's team summarized 14 application scenarios of digital twins, among which virtual commissioning is one of the typical application scenarios of digital twins in manufacturing [3]. Virtual commissioning is oriented to line bodies, equipment manufacturers and system integrators in the discrete manufacturing industry, and is oriented to different production levels. It helps companies use the models built in the virtual environment to simulate process and mechanical motion before on-site commissioning, and the commissioning of PLC program logic. The value of virtual commissioning to the enterprise is reflected in: Verify the feasibility of the relevant logic of the process and control program in the early stage, reducing the cost of actual equipment; reduce the time and error rate of personnel going to the site for commissioning, and save the cost of business trips for commissioning personnel; after the fusion of virtual and real, it can provide a 3D visual interface for on-site commissioning, and improve the efficiency of large-scale production line-level equipment commissioning; after the workshop is completed, it can be integrated with the digital twin system to create a real-time data-driven 3D visual monitoring system, laying a solid foundation for the digital twin of the entire factory.

To achieve the purpose of virtual commissioning, a fully functional modeling software support is needed. This paper starts from the construction of the FMS digital twin system with the Beckhoff...
automation control software platform TwinCAT as the master control, and aims at the rapid virtual commissioning of the functional modules, and summarizes the previous research based on commercial industrial simulation software. This article introduces and analyzes the four common commercial industrial simulation software (Visual Components, Tecnomatix Plant Simulation, Emulate3D, Flexsim) that can communicate with PLC for virtual commissioning from the two perspectives of software functions and features, which can provide reference for related research.

2. Research and application done by predecessors
There are many types of current industrial simulation software, but for the rapid development of simulation, commercial industrial simulation software is the best choice. It has a complete human-computer interaction interface and a more powerful functional model library. In recent years, the research and application of simulation software based on commercial industry has attracted widespread attention from many scholars and engineers. Jiang Li and others took the valve body parts production line as an example, using AnyLogic and Visual Components software to carry out layout simulation and capacity planning [4]. Russkikh P A and others describe the process of developing a simulation model of the assembly shop of electronic production using Tecnomatix Plant Simulation software, used to find the best optimal capacity utilization of the workshop [5]. Daniela Marasova and others presents the simulation model and simulation experiments aimed at the rationalization of bottle necks in operations in terms of the capacity utilization of the material handling equipment in the Tecnomatix simulation environment [6]. Md. Sadekul Islam and others identifies the opportunities for improvement of current sewing line by performing RPWM (Ranked Positional Weight Method) line balancing technique and testing feasibility using Tecnomatix simulation software. [7]. Leiding Wang and others used Emulate3D software to simulate the logistics dynamics for the sorting and scheduling of the warehouse area of a certain automobile assembly shop, and used the Jscript language to write the control program [8]. Chao Yin and others built a visualized monitoring system for workshop production status based on Flexsim [9]. Based on Flexsim, Xiaoqian Nie and others build a 3D simulation platform to simulate different operation scheduling modes of rail mounted gantry crane in railway container central station [10]. In summary, the use of commercial industrial simulation software has been studied and applied in equipment digital modeling, production line planning and layout, production line process verification and optimization, and PLC program virtual commissioning.

3. Introduction of commercial industrial simulation software
Based on predecessors' research and application of commercial industrial simulation software, four common commercial industrial simulation software (Visual Components, Tecnomatix Process Simulate, Emulate3D, Flexsim) are introduced and analysed from the software functions and software characteristics.

3.1. Visual Components software
Visual Components (VC) software is an intelligent manufacturing 3D digital factory simulation software developed by Visual Components. It was originally produced in Finland and was acquired by KUKA under Midea Group in 2017. VC can provide a fast, simple and efficient way of design and development for manufacturing companies, system integrators, and automation equipment manufacturers, and provide users with a convenient and true digital factory simulation solution. Its software interface is shown in figure 1.
3.1. Function of VC software. VC software has three main functions: PLC virtual commissioning; Simulation of discrete logistics; Offline programming of robots.

3.1.2. Features of VC software. VC software has the following features:

- Network component library: In terms of digital twin modeling, VC comes with a network component library with more than 2,000 mature components, including robots and other automated production line elements from major brands such as KUKA, ABB, FANUC, YASKAWA, Kawasaki, and is still being updated continuously. Most of these components are parameterized components, after lightweight processing, can greatly reduce the burden of the simulation computer.

- Freedom of development: In terms of real-time mapping, VC uses Python as a script development language. Compared with other scripting languages, this language is easy to understand. It can perform effective logic processing on signals and data during simulation and virtual commissioning, and can also be imported into open-source Python function module to quickly realize the required functions.

- Three communication interfaces: In terms of PLC virtual commissioning, VC comes with three industrial communication interfaces of Beckhoff ADS, OPC UA, and Siemens S7, which can be directly connected to Beckhoff and Siemens S7 series PLC, and Python scripts also support a variety of development of communication interface.

- Easy to learn and use: The software interface adopts the mainstream UI scheme on the market, which is very user-friendly. The plug-and-play function of VC software makes the connection of components in the virtual space more convenient. Provides three sets of layout solutions, Machine Tending, Works Library and Process Modeling, which can quickly implement complex layouts.

3.2. Tecnomatix Plant Simulation software

Plant Simulation is a product of Siemens Tecnomatix, also known as SIMPLE++, It is an object-oriented, graphical, integrated modeling and simulation tool, and the system structure and implementation meet the requirements of object-oriented. Classified academically, Plant simulation is a typical software tool of discrete event simulation. The software interface is shown in figure 2.
3.2.1. Function of Plant Simulation software. Plant Simulation software has four main functions: Man-machine simulation; Robot path editing and simulation; Offline programming of robots; Communicate with PLC for virtual commissioning.

3.2.2. Features of Plant Simulation software. Plant Simulation software has the following features:

- Software supports Chinese, English, German, Japanese and other languages;
- Modular, multi-level modeling;
- It is the core tool of Siemens’ complete digital manufacturing solution Tecnomatix suite, which can more effectively match and link in the solution based on Siemens products;
- Support ODBC, Oracle11g, SQLite, ActiveX, COM, DDE, HTML, Socket, OPCUA, OPCClassic, PLCSIM, SIMIT and other interfaces;
- There are no technical obstacles when it communicates with Siemens brand PLC for virtual commissioning, and it has strong adaptability.

3.3. Emulate3D software

Emulate3D is an engineering software developed by the British company Emulate3D for digital simulation of industrial automation systems. In 2019, Rockwell Automation Co., Ltd., the world's largest industrial automation and information technology company, acquired Emulate3D. The software interface is shown in figure 3.
3.3.1. Function of Emulate3D software. The main function of Emulate3D software is to perform virtual measurement and control of the fully automated system. It supports the use of external PLC signals to control virtual equipment models to achieve the goal of significantly reducing equipment commissioning time.

3.3.2. Features of Emulate3D software. Emulate3D software has the following features:
- Based on the Demo3D model, the logic verification of automation equipment is carried out based on the real physical characteristics (acceleration and deceleration, impulse, resistance, friction, inertia, gravity, etc.);
- Supports soft PLC and various PLC hardware devices that support OPC and Fetch/Write protocols, such as: Mitsubishi, Siemens, Rockwell, Beckhoff PLC;
- Digital twin modeling and production line layout need to be carried out in the supporting Demo3D modeling software. Demo3D is based on the .NET architecture, allowing users to design their own modules from scratch. The built-in modules are all open source. The internal development languages are C# and Jscript, which are easy to learn and use.

3.4. Flexsim software
Flexsim is a Windows-based, object-oriented discrete event process simulation software developed by Flexsim in the United States. Its software interface is shown in figure 4.

![Figure 4. Interface of Flexsim software.](image)

3.4.1. Function of Flexsim software. Flexsim software mainly has four major functions: 3D simulation and production line layout; 3D modeling and model analysis; Optimization of the program; Virtual commissioning of PLC.

3.4.2. Features of Flexsim software. Flexsim software has the following features:
- Use the C++ language to define the logic of the model, create and modify components, and each component uses the inheritance method when modeling, which allows users to make full use of the hierarchical characteristics of C++ and save development time;
- PLC emulation is fully integrated with Process Flow, including the PLC connections;
- One-click associations between OPC DA/UA tags or Modbus registers and the 3D objects in the model;
- Provides a powerful database connection function, making it easy to import and export data in the digital twin system;
- The HTTP protocol can be used to communicate with devices connected to the Internet to obtain real-time data from the real-time system.

4. Comparison of main features of software
Based on the purpose of virtual commissioning, the above-mentioned four kinds of commercial industrial simulation software are listed in terms of communication interfaces and supported PLCs, supported development languages, as shown in table 1.

Table 1. Comparison of main features of software.

| Name of software         | Communication interface and supported PLC                                      | Supported development language   |
|--------------------------|--------------------------------------------------------------------------------|----------------------------------|
| Visual Components        | Beckhoff ADS, OPC UA, Siemens S7 communication protocol                       | Python, .NET                     |
| Tecnomatix Plant Simulation | Siemens PLC, OPCUA, OPCClassic, PLCSIM, SIMIT                                   | C++, Python                      |
| Emulate3D                | OPC, PLC with Fetch/Write protocol, Beckhoff Soft PLC                         | C#, Jscript                      |
| Flexsim                  | OPC DA/UA, Modbus                                                              | C++                              |

5. Conclusion
In summary, to build an FMS digital twin system with Beckhoff TwinCAT as the master control system for virtual debugging of the production line, VC software should be selected as the development platform, because it has the direct connection with Beckhoff PLC. The connection function can be connected only by simple configuration. Although Emulate3D software can also communicate with Beckhoff PLC, digital modeling still needs Demo3D software, which is more cumbersome than VC. If the main control system of the production line is based on Siemens’ products, Tecnomatix Plant Simulation software should be used for virtual commissioning, because it is more targeted, easier to match with its own products, and the technology is more mature. Other virtual commissioning schemes can be analyzed in detail based on the functions and characteristics of the simulation software introduced above.

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