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Using RPA+BIM for High Efficient Operation of Smart Building's Equipment Room

Jiang Haigang, Ling Rui

Shanghai Installation Engineering Group Co., LTD., Shanghai 200080

Abstract: Base on building information modeling(BIM) plus with Robotic process automation (RPA) technology is rapid development in smart building operations and maintenance (O&M). RPA is a workflow-based automated execution tool that is particularly well suited for replacing manual execution of simple and repetitive tasks using computer systems. The use of RPA technology can saves man-hours and increases productivity, which is important for the automation of building operations and maintenance operations.. The BIM technology, as an advanced technology in the construction industry, it can provide new ideas and methods for building operation and maintenance based on its visualization characteristics. That's integrating RPA with BIM technology which will enhance the digitalization and virtualization of smart building operation and management. In this article will first introduce the features of RPA and BIM technology and then discuss the technical roadmap for remote automated operation and maintenance of smart building equipment room to implemention a low-cost and high efficient building equipment room operation and maintenance solution.

Keywords: robotic process automation; RPA; building information model; BIM; Smart Building; Remote Operations and Maintenance; On-line monitoring

1. Introduction

In smart building systems, there are many anomalous data. At first initially requires manual investigate for extremely individual of abnormal data. The manual processing of the same thing for a long time often will overlook the individual abnormal data due to judgment fatigue. The smart building's critical equipment room often suffer serious failures or even major disasters due to these oversights. In addition, these data are often increasing, the manual approach will not only consume a lot of human. The manual approach is not only labor-intensive, but the results are also unsatisfactory. Recently the automation and digitalization is a great technology to replace manual data processing at building O&M area. That's relies on Robotic Process Automation (RPA) plus Building Information Model (BIM) to solve above problems of huge manual workload, meanwhile it will saves a lot of building O&M resources cost for business profit. It true that will reduce the amount of time employees spend on repetitive and repetitive and boring tasks after apply automation and digitalization technology on smart building O&M which will giving employees more time to devote to creative work. Thus enhancing employees' work efficiency. That is, while reducing the working time and working load of employees, it can also the system's accuracy can be improved by solving the problem of human error operation.

Robotic Process Automation (RPA) is the practice of using software bots or pieces of code to automate, and therefore make more efficient, repetitive tasks that otherwise take up valuable human time. For technical services in the building facilities management, rapid processes that

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deliver efficiency are a non-negotiable attribute. This ability to deliver efficiency at scale can help them deliver better experiences to building end-users. An example of the need for efficiency in complex processes is one precipitated by the building room routine patrol. A large number of fixed device inspection and device running status recording tasks need to be performed by facilities management staff every day. In fact, these inspection tasks are simply repeated. Therefore in the construction industry in recent years tried to use Robotic process automation (RPA) to process automation tools, to help improve the traditional inspection efficiency, through the construction machine room equipment layer data acquisition equipment running status and judgment of the threshold, the abnormal data to trigger alarm process, if the relation to facilities management work order module can realize the automation of building inspection process, This will greatly optimize the workload of traditional building inspection workers and improve the quality of equipment inspection in the building room.

Building Information Model (BIM) is a concept that brings a new look at the life cycle of buildings. BIM method can be applied in two ways. The first is the implementation of BIM method already in the construction project, through implementation and then in operation and maintenance (O&M). This can only be applied to new constructions. For buildings that are already built, it need to implement BIM afterwards. BIM implementation process for existing buildings may vary, depending on the available documentation, information, software used, data formats, the level of detail requirement or the expected usage.

2. Theoretical Background

2.1 The Robotic Process Automation (RPA) Technology

The role of digital technologies in the construction sector has increased dramatically over the past few years. Their widespread use often leads to profound changes in the functioning of not only individual entities, but also the entire construction industry.. Yu-Cheng Lin and Yu-Chih Su indicated that Facility maintenance management (FMM) has become an important topic for research on the operation phase of the construction life cycle[1]. Zhun Wang, Le Zhang, and Fan Zhang emphasized that Digitization is an important trend of current social development. In order to better adapt to the needs of enterprise marketing business intelligence and digital development, and reduce the cost of manpower use[2]. RPA is called "digital labor" , which can effectively eliminate the repetitive, rule-based basic tasks that required a lot of manpower and time in the past. By replacing manual operations, RPA robots effectively release manpower, enabling existing employees to provide more value in areas where robots cannot yet function. Its consequence is a radical improvement in the organization's productivity and achievements[3]. According to the conclusions of the above-mentioned study, the application of this RPA technology will benfit of building O&M as below points:

- RPA refers to Robotic Process Automation, through specific technology that can simulate human operations on a computer interface and automatically execute corresponding process tasks according to rules, replacing or assisting humans in completing related routine building services work;
- RPA robots belong to operating software, which is essentially a software system that can complete work according to specific instructions.This software is installed on a computer, the

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automation of routine operations can be realized by simulating manual operations such as daily building inspection;

- RPA it can automate building service processes without the need to modify the original building system logic , this non-intrusive technology is fine for building O&M field.

Usually RPA technology is used to develop software robots. This is one of the fastest growing categories of software for automated processes. However, so far no applicable definition has been developed for this type of tool applied to building operations and maintenance (O&M). Based on the literature, the authors tried to identify the differentiating factors of such building O&M data-enabled solutions.Based on an analysis result, the following points can be made:

- RPA can develop software robots that operate directly on the user interface of the information system, which means that it is possible to automate large-scale (high-volume) activities (performed multiple times in a hypothetical unit of time - for example, every hour or every day) in building O&M most often scenario-based reproduction of inspection activities previously performed by humans in building operations and maintenance (O&M)[4-6].
- The development of software robots using RPA tools does not require a traditional coding phase. Instead of writing out the code logic of a set of robots, the process is configured as a graphical object using a workflow engine through a low-code model, followed by inputting a specific automated execution plan or operator triggered process activity execution[7-8].
- It's true that RPA robots has apply for perform inspection tasks automatically in building operation and maintenance(O&M) field. Usually, robot automation process needs to be configured by requirements and rules-based to determine whether the device data uploaded by the RPA robot is normal or not. In recentlly, the artificial intelligence technology has been apply to RPA robots judge logic that is enhancing the automatic fault diagnosis capability of RPA robots.

2.2 The BIM-based Building Operation and Maintenance Management

The application of BIM-based technology in the field of building facilities O&M has become more popular at last decade.BIM's application has started early in building design phase and its development level, system and application are relatively perfect at all of the building life cycles. The results of cutting-edge research based on building facilities management (FM) concluded that the application of BIM technology to the operation and maintenance phases of buildings would realize the following advantages:

- Realize the integration and sharing of building information. The whole life cycle of a building can be roughly divided into four stages: planning stage, design stage, construction stage and O&M stage, as shown in Figure 1. Each stage covers a variety of architectural information, and some seemingly unimportant information in the early stage may be become a very important at the O&M of buildings. Such as the service life of the air conditioning end –side equipments, in the early stage of the equipment procurement phase, maybe it won't care about the service life of a specific device, but the information is able to provide accurate and useful information for building O&M services, if we mark this information in BIM models, then when the service life of the equipment will due soon, we can get one message it should be replaced. Therefore, BIM is not only take of building information, actually is an "Digital base" on building O&M phase that can collect and visualization building information and

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equipment operation and maintance records on one platform.

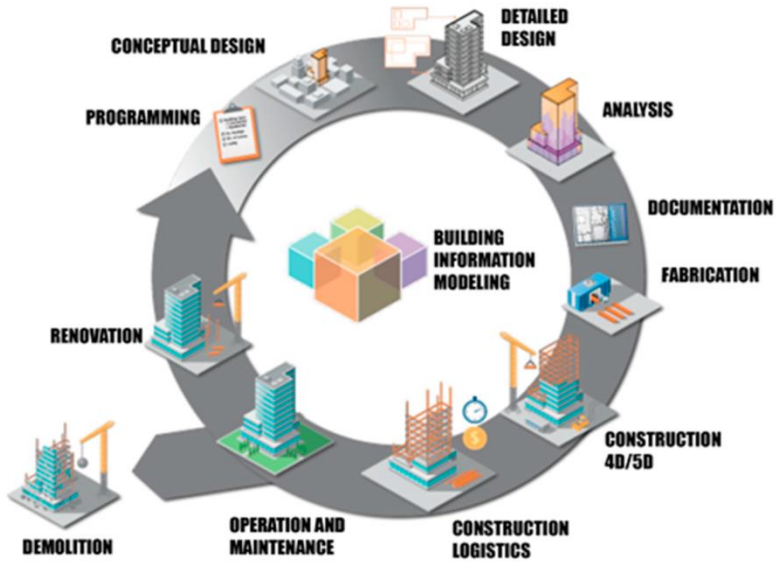

Figure 1. Building information modelling (BIM) uses across building lifecycle (copyright Lloyd's Register)

- As known the BIM model is Three-dimensional modeling of architectural it can be build based-digital twins modeling's buildging running online-monitoring application.The 3D feature based on BIM can build a digital building in a virtual environment, which is a realistic mapping of the real physical environment which is more convenient and intuitive than traditional equipment management. It can clearly understand logic and releation of construction's system by BIM model. Taking refrigeration plant room as an example, it can intuitively see the flow rate of the water supply pipe and understand the change of water supply pressure at the end points in BIM . In case of equipment failure, the 3D model of BIM can be used to quickly locate and view the refrigeration plant room's equipments information, so as to facilitate the O&M people to take maintenance works on times. Based on the three-dimensional features of BIM, the digital twin capability of building facility O&M can be obtained and the integration that means it will possible for remote O&M of building facilities using BIM-based O&M platform.

3. Related Work

3.1 Design RPA's Building Operation and Maintenance Framework

RPA is an approach to automating processes within a broad pool of different technologies for process automation, each of which suits different processes and objectives[10-11]. In building operation and maintenance situations in which human labor or the construction and integration of business process management are too expensiv[12], RPA software robot technologies as a transition element between human work and extensive building operation and maintenance business process automation [13]. Thus, RPA is called software robots that is access systems and perform tasks for the most part similar to humans or by imitating them[14]. The process automation capabilities enabled by RPA are well suited for the automation of building operations and maintenance tasks. For example, a software robot can perform simple, repetitive, but labor- and time-intensive tasks in building O&M such as collecting data on equipment operation in

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building rooms similar to meter reading, automatically identifying whether thresholds are normal, and determining whether alarm messages are triggered[15].

According to the study the framework of RPA robotics application includes three parts: input, processing, and output. Combined with the needs of building operation and maintenance, the RPA robot is introduced to the building operation and maintenance scenario its input data sources are equipment monitoring spots, equipment master data, and BIM lightweight engine. Usually the RPA processing unit part consists of IoT collection device, RPA workflow engine, data gateway, real-time data processing unit. The alarm unit, work order processing module, and operation log analysis form the output part of the RPA robot, which is visible and operable to the operator. In this study, we designed the working framework of the RPA robot system as shown in Figure 2.

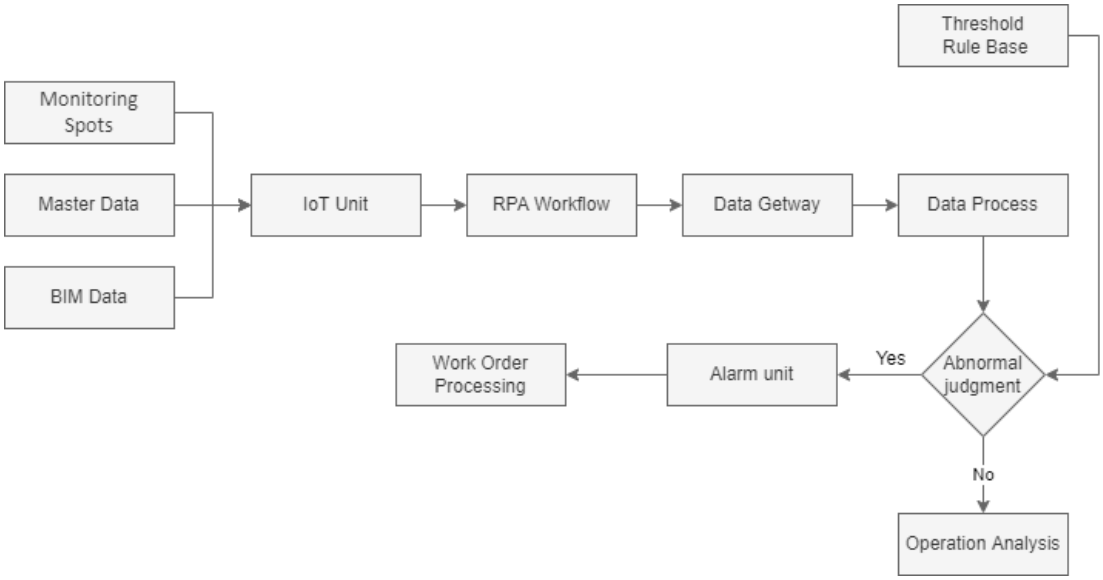

Figure 2 The RPA robot system working framework

3.2 The Established BIM-based of Facility Management System

BIM has been used as research ground for more than its original purpose as a project planning tool thanks to its versatility. For instance, research has been carried out on indoor escape routes planning using BIM model[16]. In the author research, the inverse modeling technique is applied to digitally model an equipment room, and the method of associating the BIM model with the equipment points of the building room to form virtual to real mapping and reflecting the data collected[10] by the RPA software robot to the BIM model to enhance the visualization of building operation and maintenance is investigated.

Reverse modeling is a method to obtain 3D spatial model by combining the point cloud data scanned in the project with professional modeling software[17-20]. According to the different ways of 3D model representation, there are two methods to reconstruct 3D models from point cloud data: one is 3D surface model reconstruction, which mainly involves constructing meshes (triangular meshes, etc.) to approximate the surface of objects; the other is geometric model reconstruction, which is commonly used for contour models in CAD[21-22]. The former method is simple and suitable for terrain modeling, while the latter is suitable for more regular entities such

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as buildings, but the amount of point cloud data is too large for PC client to process the those point cloud data.

We are point cloud model is obtained by the 3D laser scanner, and the point cloud model is stitched, dried and aligned to form a complete building point cloud model[23-25]. Although the point cloud model is established, but this point cloud model can not add relevant data attributes, not really combining 3D laser technology with building information Therefore, we need to reverse the process of building information modeling and roadmap see Figure 3.

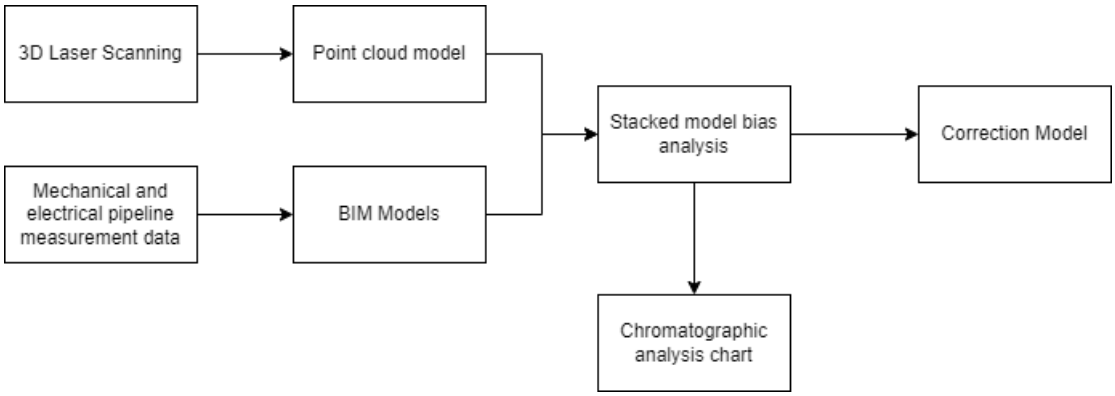

Figure 3 BIM model reverse modeling roadmap

After completing the data measurement of the mechanical and electrical pipelines in the site, the actual site conditions were reviewed by 3D laser scanning to obtain a high-precision point cloud model of the mechanical and electrical and building structures[26]. The scanned point cloud model is loaded into AutoDesk NavisWorks to compare and analyze the actual site conditions with the BIM model to locate the deviations. In this study, post-processing was performed using SCENE, a software package for the instrument, after the scanning of the on-site machine room was completed, including combining the point cloud model, removing noise and adjusting the coordinates of the point cloud model. The software automatically matches the same marker in different sites by manually marking the target spheres placed in the SCENE view, thus combining the data from each scan site to form the completed point cloud model.

When processed point cloud model then imported into AutoDesk Revit 2020, and the point cloud model and the flip model are imported into Geomagic software for fitting and comparison to generate one report for show the offset of electromechanical chromatography[27-28]. The geomagic software can export the offset distribution map and the model displays different colors according to the size of offset, visually scanning the deviation of the whole area and local detailed analysis is performed to obtain specific deviation data with millimeter accuracy. We are choiced 10pipes for check between BIM mode design with actual gaps the result is show at Table1.In case BIM LOD(Level of detail) is reach to 500 (Figure 4) that is fine for operation and maintenance use.

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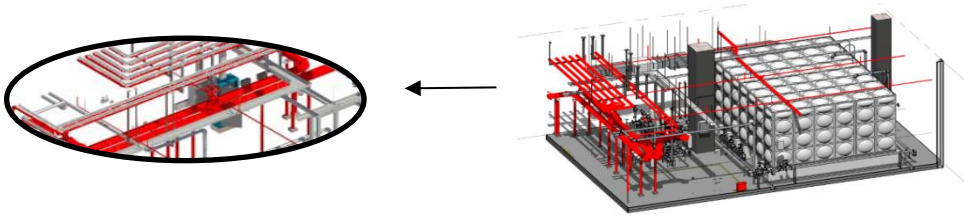

Figure 4 Model and point cloud model overlay validation results

Table1 Analysis and comparsion pipes length offset between BIM design annd 3D Laser scanning (mm)

ID	Design Length	Actually Length	Offset	Offset Rate	ID	Design Length	Actually Length	Offset	Offset Rate
1	600	615	-15	-2%	6	450	465	-15	-3%
2	600	614	-14	-2%	7	450	462	-12	-3%
3	600	605	-5	-1%	8	450	443	7	2%
4	600	595	5	1%	9	450	462	-12	-3%
5	600	610	-10	-2%	10	450	445	5	1%

The lightly of BIM model we study is based on the architecture of IFC standard (Figure 5), which meets the requirements of information interaction and sharing in the construction industry and is the de facto standard for data exchange and sharing in the construction industry.IFC standard is a similar object-oriented building data model[29-30].IFC model includes all aspects of information throughout the life cycle of a building.The purpose of IFC standard is to support the collaboration of various specific software used for The IFC standard aims to support the collaboration of various specific software for the design, construction and operation and maintenance of buildings, and is the most comprehensive and detailed specification for the description of building information.

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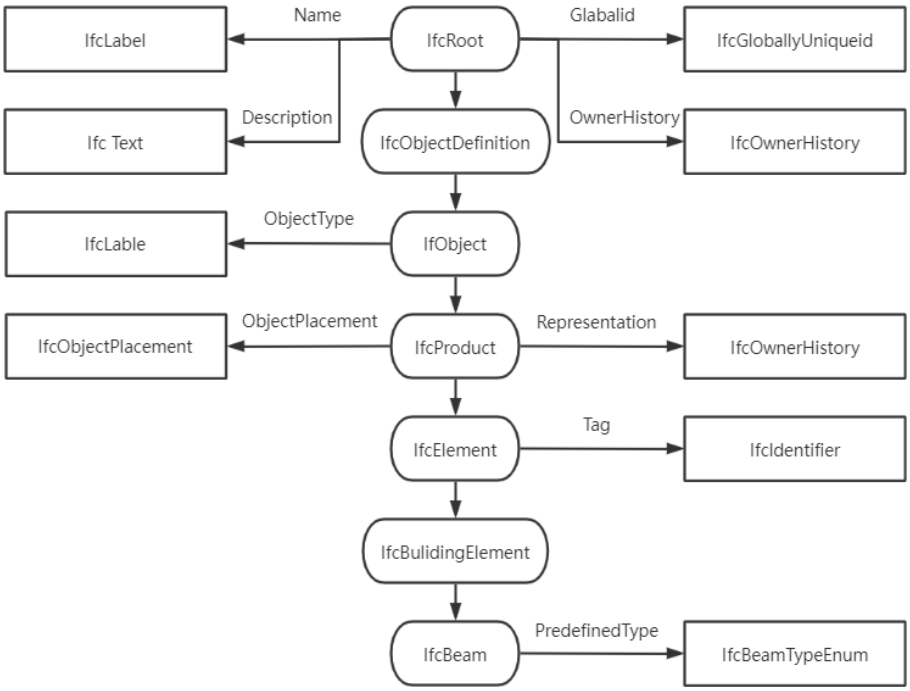

Figure 5 IFC standard structure illustration

Basically, based on the IFC standard parsing conversion model, the geometric information and attribute data in the BIM model are extracted and compressed and segmented[30-31], and the segmentation and compression can significantly reduce the model size and improve the network transmission speed of loading the model on the web side to achieve several times of compression rate. The model size of the BIM model of this project is 10% of the design model after being compressed by the lightweight engine, which meets the hardware configuration constraint required on the WEB side call.

The RPA robot management platform applies BIM technology to show the 3D visualization of the server room. Based on the BIM 3D visualization feature, RPA robot management platform realizes the digital twin of BIM technology-based server room operation and maintenance[32]. In this case, in order to optimize the performance of front-end BIM model rendering, through the following three technical ways to meet the real-time WEB front-end and mobile model detail rendering requirements[32-35].

- The Client-side caching acceleration: 3D geometry data is downloaded from the server side to the memory of the client computer or mobile device for caching.
- The Client-side arithmetic optimization solution: Use the computer or mobile GPU (graphics card) arithmetic to achieve efficient real-time rendering of 3D geometry data and restore the real 3D BIM model scene.
- The Based on the lightweight engine API interface calling mechanism scheme: to achieve real-time operational feedback for the operation and management of 3D BIM models and their components.

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4. Case Study

4.1 Case Background

In case of Virtual inspection robot platform is based on the RPA technology that is support operation and maintenance for the National Convention and Exhibition Center (Shanghai) 's A0 office's pump room that is the core of the A0 office building water supply system, the safe and reliable operation of this machine room is so crucial, the equipment running of efficient, stable and safe g is the majorly business requirements and difficult with building operation and maintenance team.

In the process of technical implement of automatic inspection of A0 water pump room. The RPA system is combine with the IoT data collection devices such as flow meters, vibration sensors and energy consumption monitoring points installed on site in the plant room, the manual inspection of pump units, fans, UV disinfectors and inverters in A0 water pump room was carried out by means of RPA's soft robot, which ensured the main The safe and stable operation of the main equipment of A0 domestic water pump room is ensured.

4.2 Establishing a Virtual Inspection Robot Management Platform

According to the A0 water pump room inspection workflow. The RPA soft robot automation inspection process is formed, as shown in Figure 5; the RPA soft robot can automation execute inspection process, through the virtual inspection robot management platform actived operation and maintenance commands at remote user client, as shown in Figure 6.

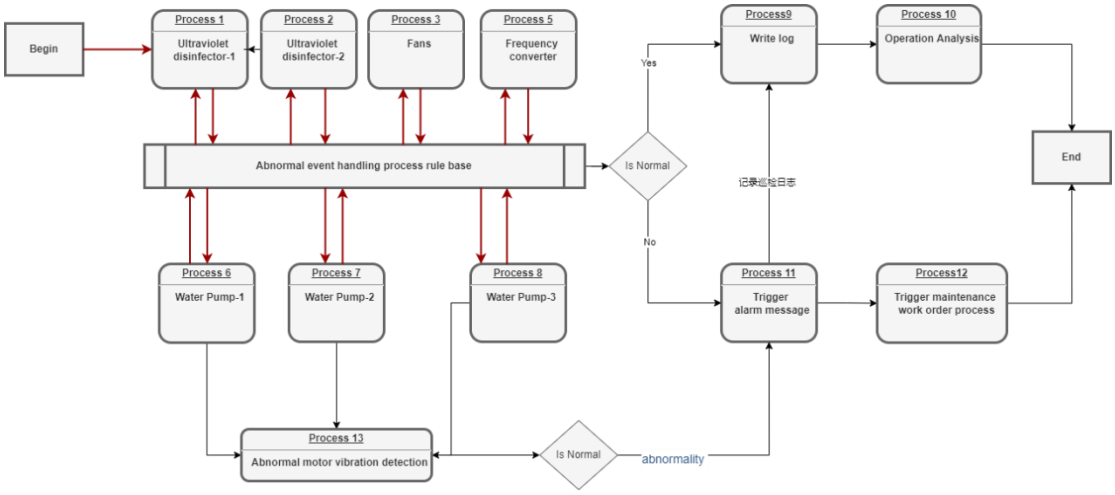

Figure 5 RPA soft robot automation inspection process

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Figure 6 Virtual inspection robot management platform calls RPA automatic inspection

The RPA automated inspection robot performs 8 times a day remote inspection tasks of pump room in A0 living water pump room, and performs 480 rounds of inspection operation plan and 7200 hours of work during the pilot period (15 minutes of single inspection), which can save 150 man-days/day (1 person 150man-days for inspection tasks, 8 hours of work, 30 times a month).The total labor saving is about 4500 man-days/months that means it will cost benefit for building operation and maintenance routine tasks .

4.3 Case review

Currently, RPA technology allows for automated inspections by configuring and defining the behavior of the robot inspection process[36]. The virtual inspection robot platform automates and remotes the inspection of the server room using a manned RPA interaction mechanism, as shown in Figure 4-7.

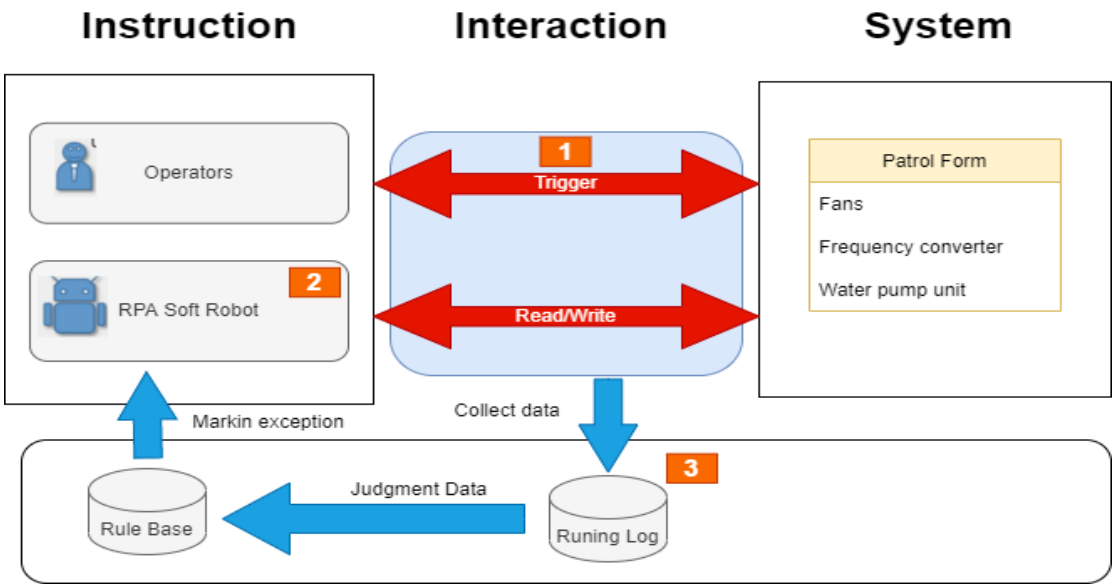

Figure 7 Manned RPA human-computer interaction

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The conceptual description of the inspection data identification method using a ruled-base in the virtual inspection robot platform is as follows, and the framework design of its identification logic, as shown in Figure 4-8. Define the inspection form and collect the information of the equipment level data collection points on this form.

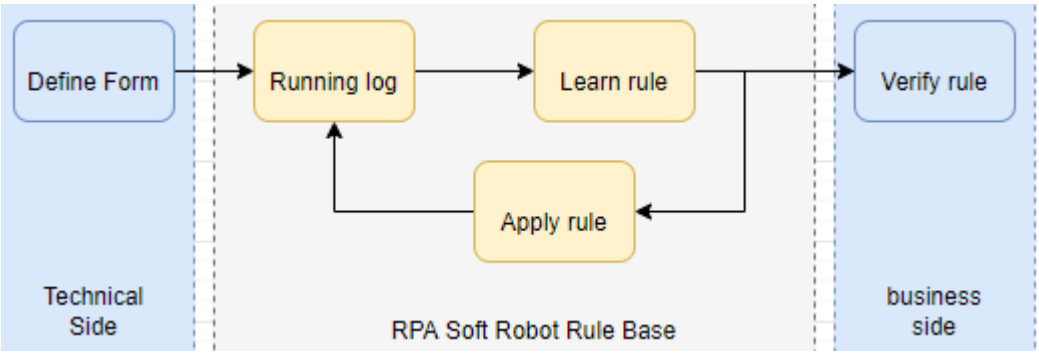

Figure 8 The RPA framework design of identification exception logic

Self-study the judgment rules from the rule base. These rules represent "if the result field of False then updated to "abnormal", When the content of False is put to trigger the abnormality handling process.A patrol threshold validates the rule validation condition. If the rule is validated to be active, it is adopted into the RPA automated patrol process. As Figure 4-9 is RPA platform alarm modules snapshoot.

Figure 9 The RPA+BIM platform's alarm modules

5. Discussion

Robotic process automation(RPA) is belong to software robot that is runs on an information system. It is intended to simulate human-computer interaction and to replace the manual handling of complex, tedious, and extensive building operations and maintenance services, thereby significantly reducing the human cost of building operations and maintenance, improving the overall efficiency of building operations and maintenance, and optimizing the building operations and maintenance process. Therefore, RPA robots are software devices[37-40].

The physical robot has various types of internal sensors and external sensors, such as vision and haptics. In addition to having receptors, the physical robot has effectors that act as a means to sense the surrounding environment. A physical robot can either accept human command, run a pre-programmed program, or act according to a strategy prepared with artificial intelligence

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technology. Thus, physical robots are hardware devices.

The RPA robot and physical robot return on investment periods were measured using the static Return on Investment period calculation without considering the time value of money (assuming a combined net return of CNY 100,000 per year for each finance period).As the results, as shown in Table 2.

Table 2 The comparisons with RPA robot and physical robot return on investment periods

Solutions	Project Period (million CNY)	Operation Period (million CNY) Forcast investment income						Return on Investment Period (Year)
		1	2	3	4	5	6	
RPA Robot	18	10	10					1.8
Physical Robot	60	10	10	10	10	10	10	6

The results in Tables 2 show that the static return on investment periods of the RPA robotics solution is 1.8 years under the same conditions, while the physical robotics solution takes 6 years to reach the balance point. Therefore, the measurement results conclude that the RPA robotics solution is better technical solutions. Under the condition of low cost, the building operation and maintenance project can realize the automated inspection business and achieve the expected technical investment income, which plays a positive role in achieving the business goal of "cost reduction and efficiency increase" for our mechanical and electrical property projects through new technology applications[41-42].

In case National Convention and Exhibition Center (Shanghai) project combined with RPA + BIM and other digital operation and maintenance technology for the National Convention and Exhibition Center (Shanghai) project of the maintenance of water pump room equipment maintenance operations to provide digital operation and maintenance capacity. According to the analysis of the group's operation data compared with the same period last year, it is believed that the use of the building virtual inspection robot program is about 5 times more efficient than the manual inspection mode, the quality of inspection data collection is about 17% higher, the failure-free rate of equipment in the plant room is about 11% higher, the unplanned downtime is reduced by 83%, and the amount of emergency maintenance work orders is reduced by 85%. From the above summary results, it can be concluded that the operation performance of pump room equipment after adopting the virtual robot solution has been improved or enhanced compared with the original manual method, and the relevant comparison details are shown in the table 3.

Table 3 Using RPA+BIM improve list for National Convention and Exhibition Center (Shanghai) project of the maintenance of water pump room

ID	Itme	RPA+BIM	Manpower	Upgrade %
1	Equipment inspection frequency	48 times/day	8 times/day	500%
2	Data Collection Correctness Rate	99.5%	85%	17%
3	Trouble-free rate of equipment	99.6%	90%	11%

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4	Unusual downtime	30 minutes	180 minutes	83%
5	Maintenance work order numbers	15 nums	98 nums	85%

The project research results output building virtual inspection robot platform, after pilot verification group that can visualize the timely tracking feedback pump room key equipment in the whole life state of the operating state, and based on the visualization results of the pump room equipment operation history data analysis, optimize the pump room equipment operation and control strategy, to achieve the effect of pump room unit equipment operating conditions optimization. According to the data comparison analysis of the same period last year, the electricity consumption of the pilot plant room decreased by about 4%-5% per month see Figure10 compared with the same period last year after the implementation of the virtual inspection robot platform. The relevant data is shown in the table below, and the month-by-month comparative analysis of energy consumption, as shown in the figure below. Therefore, based on the data comparison results, the group believes that the adoption of digital means by the building operation and maintenance professionals can enhance or enrich the technical means of the project team in the building server room energy consumption[41-43].

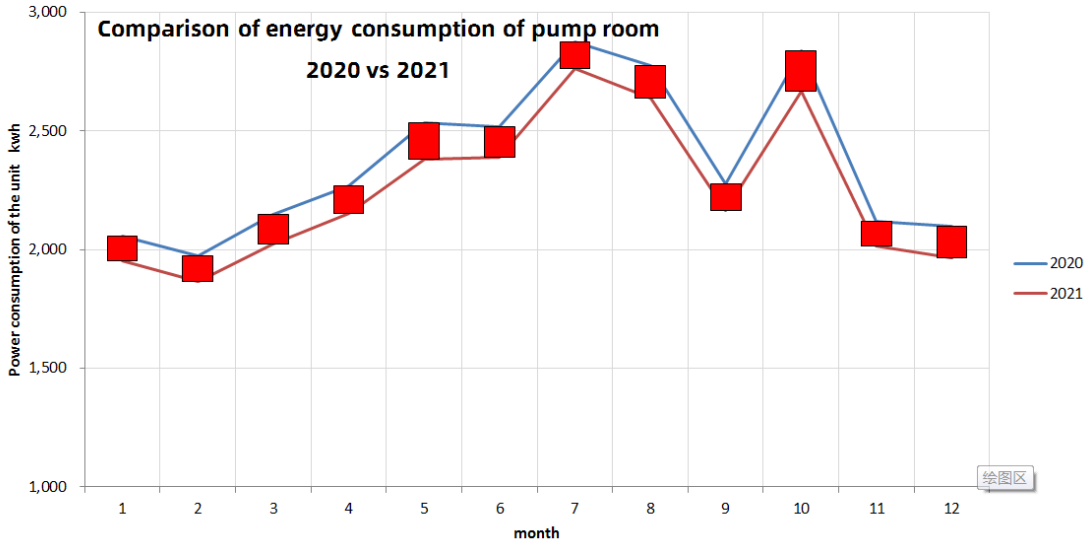

Figure 10 Comparison of energy consumption of pump room 2020 vs 2021 for National Convention and Exhibition Center (Shanghai) project of the maintenance of water pump room

6. Conclusions

With the maturity of IoT, big data, artificial intelligence and other technologies, the building operation and maintenance profession will gradually transform and upgrade from the traditional experience-driven operation mode to the data-driven operation mode[44]. In this case the comprehensive application of RPA, BIM, IoT for building RPA soft robot platform, the technically verifies the technical ways and methods to realize the automation and remote operation and maintenance of building equipment room based on "digital twins" mode through software robotics, BIM and IoT technology. At the same time, the research process also studies the visualization and analysis of equipment operation data and the use of equipment operation data

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for equipment fault diagnosis, and then enhances the feasible technical implementation mode of the active operation and maintenance mode of the building plant room.

The research takes the National Convention and Exhibition Center living water pump room as the background application project, based on the technical research results and pilot room operation performance analysis is indicate that the use of digital operation and maintenance technology roadmap similar to the building virtual inspection robot can significantly reduce the workload of simple and repetitive operations of the building operation and maintenance professional, optimize the quality of inspection and improve the quality of inspection data[45]. The use of BIM technology can form the digital base of the building operation and maintenance platform, enhance the visualization of the operation and maintenance of the server room, and realize the remote operation and maintenance capability of the building server room. the research results can support electrical property project management "reduce costs and increase efficiency" to achieve the operational goals and improve the profitability of mechanical and electrical property projects.

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