Assembly Method for Satellite Device Installation based on HoloLens

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Abstract. As the satellite design changes from the traditional 2D mode to the 3D digital mode, the satellite assembly also enters the 3D assembly mode. An effective and accurate device installation process information transmission method from designers to operators is not formed, and accidents with incorrect polarity in device installation often occur. In order to improve efficiency and quality of satellite device installation, modelling method of R point of device is regulated and a system based on HoloLens is designed. With the help of the system, the code and R point are clear at a glance, so an ordinary operator can verify the polarity correctness of the device installation and the efficiency can be doubled.

1. Introduction

Device installation is a frequent operation in AIT process of satellite, installation errors of important device can lead to accidents of final assembly, such as equipment bumping and cable squeezing, telemetry signal errors, etc., and even more directly affects the functionality of the satellite. The devices which are numerous are divided into several subsystems, and the devices have a complicated layout on the satellite. Before the installation of devices, the operator must confirm the installation location, the installation direction, and the installation process information through the 2D drawings and process files. After the installation of devices, the inspector must check the polarity of the devices, and other installation processes such as the thermal control implementation of the device.

Model based definition (MBD) technology is a method of 3D digital product definition, the core issue of the design is ensure that the MBD technology is perfectly integrated into the model to make it work better[1-2]. As the satellite design changes from the traditional 2D mode to the 3D digital mode, research on how to create effective MBD process information model is one of the major problems. Most satellites belong to one-piece customized production, the device layouts of different satellites have large differences, the final assembly space is small, the operation conditions are complex, the various layouts of small devices are scattered and coded, and therefore, the final assembly of the satellite device is heavily dependent on manual work. In order to complete the installation, the worker needs to obtain the required information from the drawing or 3D model before installation and confirm installation polarity and fastener mounting specifications after installation in the satellite cabin. The disadvantage of this type of method is that the relevant design information is manually matched to the real physical environment, and it is inefficient and error-prone. Work efficiency is reduced...
significantly because workers have to bear a lot of additional cognitive burden to confirm the correctness of assembly.

The device installation is error-prone, in recent years, virtual assembly technology is widely used [3-9]. In order to improve efficiency and quality of satellite device assembly, a device assembly system based on AR technology is designed. This method automatically matches the device installation information with the real physical environment, and guides the workers to complete the assembly. In the field of complex mechanical assembly, enterprises have researched the assembly guidance method based on augmented reality, but cannot meet the needs of satellite single-piece production and unable to systematically solve the problem of automatic conversion of device assembly 3D models to visual process information.

2. Device Installation in Traditional AIT Process of Satellite

2.1. Process of Satellite Device Installation

Device installation is a frequent operation in AIT process of satellite, and the process of device installation in AIT process of satellite is showed in Figure 1. Before the installation of devices, the operator must confirm the installation location through the code of the device using 2D drawings, confirm the installation direction through the R hole using 2D drawings, and confirm the installation process information using process files. The basis of the process documentation includes 2D drawings and technical requirements of mechanical designer, technical requirements of thermal control designer, etc. After the installation of devices, the inspector must check whether the position and polarity of the devices installation are correct, and whether other implementation processes such as the thermal control implementation of the device are correct. In short, it takes a lot of time to find the response drawings and process documentation before the operation.

![Figure 1. Process of Satellite Device Installation](image1)

2.2. The traditional 2D drawings of Satellite Device Installation

In addition to the process documentation, the operator needs to look at the drawings before installing the device. The 2D drawings of satellite device Installation is showed in Figure 2, for example, the code of the temperature controller is R01, the number of fasteners is four, the specification is M4*14, the position of the device is on the +Y side of the deck 21-03, the R Point Feature which is labelled on the device is on the +X-Z direction of the deck. The polarity of the devices and the mechanical installation process information are clear, but the thermal control installation process information which can only be seen in process documentation is not included. The operator needs a lot of prior knowledge to confirm the position of the devices.

![Figure 2. 2D Drawings of Satellite Device Installation](image2)
3. R Point Modelling of Device in 3D design model

R Point Feature is an important process parameter in AIT process of satellite, and it guarantees the correct polarity of the installed instrument. In designing 3D models, different designers use different expressions, mainly in three forms. As is show in Figure 3 and Figure 4, the stretch feature and the sketch feature are suitable for operators to use when viewing model entities on a computer, not suitable for machine identification. The point Feature which is show in Figure 5 is suitable for machine identification, but not suitable for operators to use when viewing model entities on a computer, the large amount of annotation information may lead to the hedgehog phenomenon, which will impact on the quick and correct expression.

![Figure 3. Stretch Feature](image1)
![Figure 4. Sketch Feature](image2)
![Figure 5. Point Feature](image3)

Suggested modelling method of R point of device which is show in Figure 6 can be easily accepted by the operator through subsequent technical means, R point which is labelled on the device is also created by point feature. For example, the device has 6 mounting holes, and the A06 is the R point.

![Figure 6. Suggested Modelling Method of R Point Feature of Device](image4)

4. Augmented Reality and the Microsoft HoloLens

As the satellite design changes from the traditional 2D mode to the 3D digital mode, the satellite device installation also enters the 3D assembly mode. Because the 3D design input is inconvenient to use, and an effective and accurate device information transmission method from designers to operators is not formed, accidents with incorrect polarity in device installation often occur. The current 3D model based on desktop computer has poor human-computer interaction, In the process of device installation, operators need to frequently confirm status back and forth between satellite and computer stations, and therefore, new technology is needed to improve assembly efficiency. Compared with Virtual Reality technology, Augmented Reality technology can not only see virtual scenes, but also superimposes virtual scenes in real scenes by calculating operator position and perspective in real time. The Microsoft HoloLens was released as a development edition in 2016 and is now available as a consumer version. It is the ideal choice for investigating an AR assembly application on a commercially available device.
5. The Process of Assembly Method for Satellite Device Installation based on HoloLens

A system based on AR technology is designed to improve efficiency and quality of satellite device installation, the flow chart of the method is showed in Figure 7. Compared with the traditional method, this method automatically matches the device installation information with the real physical environment, and guides the workers to complete the assembly.

5.1. Footprint Solid Model Creation

The 3D device model which is designed using CAD modelling tools such as PROE is large, and the required hardware performance is relatively high, so the 3D design model is not suitable for application in mobile terminals. The 3D design device model contains much modelling data, such as cables and electrical connectors. In order to improve the subsequent display rendering effect, the unnecessary model information should be deleted first. The most important indicator that affects Unity rendering efficiency or whether the picture is stuck is the Tris and Verts in the states panel, Tris are the total number of triangular faces rendered within the camera’s field of view, and Verts are the total number of vertices rendered within the camera’s field of view. In order to reduce the Tris of the model, footprint surface model is created, but footprint solid model is used because the footprint surface is coincident with the deck and the flickering occurs when displayed. The footprint solid model is created by stretching 1 mm of footprint surface. The footprint solid model has the advantages of small file size, easy operation and smooth display.

5.2. Extraction and Creation of the Device Xml File

While installing device, the operator needs to know the code, the position, the fastener and the related process information, so it is necessary to extract some information in design 3D model through secondary development of software. The installation process information of the device is showed in Table 1, and they will be added to the corresponding position of the lightweight and Footprint Solid Model. The code of the device, the centre position, R point Position and the Normal Vector are extracted through 3D model; the thermal control, the Fastener and the name are created from technical requirement document of mechanical designer and thermal control designer. All the installation process information of the device is written in an xml file named by the device code as the xml file provides a way to describe a cross-platform language.

| Type                    | Device                                      |
|-------------------------|---------------------------------------------|
| Code                    | K405f                                       |
| Name                    | Line Box F                                  |
| Model Name of Footprint | K405f_Fp.prt                                |
| Fastener                | 6*M5×16                                     |
| Thermal Control         | Coated thermal Grease                       |
| Ground Wire             | Installation                                |
| Centre Position(X,Y,Z)  | 450,-862,451                                |
| Normal Vector(X,Y,Z)    | -1,0,0                                      |
| R Position(X,Y,Z)       | 450,-965,373                                |

5.3. 3D Registration
The 3D registration technology mainly realizes the correct fusion of virtual components and real assembly scenes through the conversion between coordinate systems. Accurate 3D registration of virtual and real scenes is a key technical problem to be solved in the real-time fusion, to accurately register the virtual assembly object in the corresponding position in the real environment, the conversion relationship between the virtual space and the real space coordinate system must be established in the virtual fusion assembly system. Registration error reaches a certain value will result in erroneous results. In this system based on AR technology, 2D codes which can be recognized very quickly are used in 3D registration, and it is pasted on satellite deck structure.

5.4. Fusion and Display of 3D Drawings
The system based on AR technology was developed using Unity3D, Vuforia and the Microsoft HoloLens. Unity3D is an excellent development tool for the Microsoft HoloLens. To achieve higher precision, the embedded Vuforia system was used to perform marker based tracking. After 3D registration, the HoloLens can properly track position as the user moves around in the assembly area using its IMU and environment processing cameras. An assembly application with a user friendly UI has been built to improve the user experience.

6. The Typical Case of Application in Satellite Device Installation
The assembly method for satellite device based on HoloLens is tested during the AIT process of a remote sensing satellite in the paper. The 3D model of device installation is showed in Figure 8. The footprint surface model of device is showed in Figure 9, and the footprint solid model of device is showed in Figure 10, the footprint solid model is better than footprint surface model in terms of display. As is shown in Figure 11, a 2D QR code is printed on paper and pasted on the satellite deck structure where is easy to determine the location. The operator must first wear Microsoft HoloLens before device installation and use the gesture to enter the corresponding module of the remote sensing satellite, secondly, scan 2D QR code in the satellite deck structure to complete 3D registration, and then select device to be installed from the UI interface. The process of this system is very simple, and the assembly information is clear at a glance, thereby greatly improving the visibility of the 3D model and guiding principle. Figure 12 shows a typical case of application in a satellite device installation, the code and the R point of the device is clear, if needed, other installation process information is also can be shown in this system. With the help of the assembly system based on AR technology, an ordinary operator can verify the polarity correctness of the device and the efficiency can be doubled.

![Figure 8. The 3D Design Model of Device Installation.](image-url)
Figure 9. Footprint Surface Model.  
Figure 10. Footprint Solid Model.

Figure 11. The 2D QR Code Pasted on the Satellite Deck.  
Figure 12. Fusion and Display of Device Installation.

7. Conclusion
This paper reviews the traditional device installation in AIT process of satellite. As the satellite design changes from the traditional 2D mode to the 3D digital mode, the satellite assembly also enters the 3D assembly mode. In order to improve efficiency and quality of satellite device installation, modelling method of R point of device is regulated and a system based on HoloLens is designed. The process of this system is very simple, and the assembly information is clear at a glance, the successful application of this system provides a new solution for satellite device installation and marks a new step in the digital assembly capacity.

References
[1] ZHANG Yu 2018 Research and Application of Design Method of MBD Technique with Simplified Dimension Annotation Aeroengine 44(1):22-26
[2] Ye Sheng 2015 MBD-based three-dimensional assembly process modeling and application Journal of Drainage and Irrigation Machinery Engineering 33(2):179-184
[3] ZHANG Qiuyue 2017 Application of Virtual Reality and Augment Reality in Aircraft Assembly Aeronautical Manufacturing Technology 530(11):40-45
[4] LI Shiqi 2009 Mixed Reality-based Interactive Technology for Aircraft Cabin Assembly CHINESE JOURNAL OF MECHANICAL ENGINEERING 22(3):403-409
[5] YIN Xuyue 2018 Augmented Reality Training System for Aerospace Product Assembly Process Guidance and Its Application Aeronautical Manufacturing Technology 61(1):48-53
[6] Gao Xiang 2018 A Survey on Mobile Augmented Reality Visualization Journal of Computer-Aided Design & Computer Graphics 30(1):1-8
[7] YANG Qing 2017 Development of the intelligent assembly assistant system for complex product based on augmented reality MACHINE DESIGN AND MANUFACTURING ENGINEERING 46(11):33-37
[8] Hou Ying 2017 A Survey of Augmented Reality Technology Computer Measurement & Control 25(2):1-7
[9] G Evans 2017 Evaluating the Microsoft HoloLens through an augmented reality assembly application Proc.of SPIE Vol.10197