Assembly Method for Satellite Propulsion System based on HoloLens

Wei Zhang¹, Jie Zhang¹, Huajun Chen¹, Bin Zhang¹, Feng Liu¹ and Jun Zhao¹

¹ Beijing Institute of Spacecraft Environment Engineering, Beijing Engineering Research Center of the Intelligent Assembly Technology and Equipment for Aerospace Product, Beijing, China

E-mail: zhangwei308308@163.com

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 propulsion system assembly information transmission method from designers to operators is not formed, in the process of complex propulsion assembly, operators need to frequently confirm status back and forth between satellite and computer stations, and accidents with incorrect polarity in component installation often occur. In order to improve efficiency and quality of satellite propulsion system installation, a system based on HoloLens is designed. The successful application of this system provides a new solution for satellite propulsion system installation and marks a new step in the digital assembly capacity.

1. Introduction

The satellite propulsion system is a complete set of devices that use the principle of reaction to provide thrust to the satellite and is an important part of the satellite. The propulsion system has a complicated layout on the satellite, and the components involved are numerous. The large devices are mainly propellant tanks and pressure tanks; the small devices include engine, thrusters, pressure transducers, latch valves, filters, fill drain valves and etc. the exclusive parts for integration include pipe brackets, pipe clamps and thermal insulation pads; each type of components are subdivided into several specifications. The propulsion system assembly mainly includes the installation of devices and exclusive parts for integration on the satellite, the fixing of the propulsion system piping and the thermal control implementation of the propulsion system.

Most satellites belong to one-piece customized production, the propulsion system layouts of different satellite have large differences, the final assembly space is small, the operation conditions are complex, the various layouts of small devices and exclusive parts for integration are scattered and coded, and therefore, the assembly of the satellite propulsion system 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 the identification of the exclusive parts for integration which are densely distributed 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 propulsion system assembly is complicated and error-prone, in recent years, virtual assembly technology is widely used[1-5]. In order to improve efficiency and quality of satellite propulsion system assembly, a propulsion system assembly system based on AR technology is designed. This method automatically matches the propulsion system 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 propulsion system assembly 3D models to visual process information.

2. Propulsion System Assembly in AIT Process of Satellite
Propulsion system assembly is the first stage in AIT process of satellite, and the process of propulsion system installation in AIT process of satellite is showed in Figure 1, devices with polarity installation requirements needs to be thermally implemented before installation. In addition to installing devices, there are a large number of exclusive parts for integration that need to be installed, the exclusive parts for integration include pipe brackets, pipe clamps and thermal insulation pads; each type of components are subdivided into several specifications. After the installation of devices and exclusive parts for integration is pipe welding and screwing, then start the pipe thermal control implementation.

![Figure 1. Process of Propulsion System Assembly](image)

As the satellite propulsion system design changes from the traditional 2D mode to the 3D digital mode, the satellite propulsion system assembly also enters the 3D assembly mode. Because the 3D design input is inconvenient to use, and an effective and accurate propulsion system assembly information transmission method from designers to operators is not formed, accidents with incorrect polarity in component installation often occur. The current 3D model based on desktop computer has poor human-computer interaction. In the process of complex propulsion system assembly, operators need to frequently confirm status back and forth between satellite and computer stations, and therefore, new technology is needed to improve propulsion system assembly efficiency.

3. Microsoft HoloLens
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[6~7] 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. The HoloLens features four Intel Atom x5-Z8100 1.04 GHz Intel Airmont Logical Processors, a HPU/GPU Holographic Processing Unit, 64 GB Flash, 2 GB RAM and 2-3 hours of active battery life that allows standalone operation of this device. All of this processing power is used to run 2 HD 16:9 light engines that project light through holographic lenses leading to a total resolution of 2.3 million light points. High resolution spatially located 3D content is generated by this system. The HoloLens also consists of an Inertial Measurement Unit (IMU), 4 environment-processing cameras, an RGB camera, and 1 depth camera to map its surroundings and allow interaction between the real and virtual world while tracking the device’s position.

4. The Process of Application of Augmented Reality in Satellite Propulsion System Assembly

A system based on AR technology is designed to improve efficiency and quality of satellite propulsion system installation, the flow chart of the method is showed in Figure 3. Compared with the traditional method, this method automatically matches the propulsion system information with the real physical environment, and guides the workers to complete the propulsion assembly.

![Diagram](image)

**Figure 3. Process of Application of Augmented Reality in Propulsion System Assembly**

4.1. Dedicated 3D Model Generation

As the satellite design changes from the traditional 2D mode to the 3D digital mode, the 3D digital mode of a satellite contains much information, such as structural, cable and instruments. It is necessary to simplify the data by creating a dedicated 3D model which removed unused component parts. The propulsion system dedicated model tree which is shown in Figure 4 need to be reconstructed to facilitate subsequent display in HoloLens. The new model tree is divided into 4 nodes, the deck structure, device related, pipe support related and pipe. Pipe support related contains pipe bracket and pile clamp, so the operator can selects the object to display by type. The 3D propulsion system model is large, and the required computer performance is relatively high, so the 3D design model which is need to be lightweight is not suitable for application in mobile terminals. In order to improve the subsequent display rendering effect, the unnecessary model information should be deleted first, and then compress the 3D model by format conversion. The lightweight 3D model has the advantages of small file size, easy operation and smooth display.
4.2. Extraction of Propulsion Model Information

While installing device and pipe support component, the operator needs to know the code, the position, the fastener and the related exclusive parts for integration, so it is necessary to extract propulsion model information in design 3D model through secondary development of software. The propulsion model information is showed in Table 1, and they will be added to the corresponding position of the lightweight and dedicated 3D model.

Table 1. The propulsion model information.

| Type                | Device          | Pipe Support       |
|---------------------|-----------------|--------------------|
| Code                | T104a           | 23-02              |
| Name                | Pressure transducer A | Single pipe clamp   |
| ModelName           | T104a-3.asm     | danka.prt          |
| Fastener            | 4*M3×12         | 1*M4×12            |
| Thermal Control Part| 1*23-012        | /                  |
| Other exclusive parts| 1*23-013      | /                  |
| Position(X,Y,Z) (mm)| 732,189,208    | 341,445,883        |

4.3. 3D Registration

The 3D registration technology mainly realizes the correct fusion of virtual propulsion 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.

4.4. Fusion and Display of 3D Models and Objects
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.

5. The Typical Case of Application in Satellite Propulsion System Assembly
The assembly method for satellite propulsion system based on HoloLens is tested during the AIT process of a remote sensing satellite in the paper. Dedicated and lightweight 3D propulsion system model of the service module is showed in Figure 5. As is shown in Figure 6, 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 propulsion system assembly 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 or pipe support 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 7 and Figure 8 shows a typical case of application in a satellite propulsion system assembly, device assembly with polarity installation requirements is shown in Figure 9 and Figure 10, and assembly of exclusive parts for integration is shown in Figure 11 and Figure 12. With the help of the assembly system based on AR technology, the time of installing device and all component of a remote sensing satellite propulsion system can be reduced from 2 days to 1 day, and the satellite propulsion system assembly accuracy can reach up to 100%.

Figure 5. Dedicated and Lightweight 3D Propulsion System Assembly Model of a Satellite

Figure 6. The 2D QR Code Pasted on the Satellite Deck
Figure 7. The Typical Case of Application.

Figure 8. Fusion and Display of 3D Satellite Propulsion System.

Figure 9. Device Assembly with Polarity Installation Requirements.

Figure 10. Fusion and Display of Device with Polarity.

Figure 11. Assembly of Exclusive Parts for Integration.

Figure 12. Fusion and Display of 3D Models and Objects.

6. Conclusion
This paper reviews the traditional propulsion system 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 propulsion system installation, a system based on HoloLens is designed. The process of this system is very simple, and the assembly information is clear at a glance, especially for device with polarity installation requirements, thereby greatly improving the visibility of the 3D model and guiding principle.
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