Application of Augmented Reality in Satellite Cable Network Assembly

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Abstract. This paper reviews the traditional cable installation in assembly and integration process of satellite. An effective and accurate cable network assembly information transmission method from designers to operators is not formed, in the process of laying complex cables, operators need to frequently confirm cable laying status back and forth between satellite and computer stations, this can easily lead to cable routing error or cable fixing point selection error. In order to improve efficiency and quality of satellite cable installation, a cable assembly system based on AR technology is designed. The successful application of this system provides a new solution for satellite cable laying and marks a new step in the digital assembly capacity.

1. Introduction

Cable network is widely used in final assembly of all platforms of satellite. Its main function is to transmit power and signal between various electronic devices. Satellite cable network consists of many single cables; a single cable includes several branches, with cable electrical connectors at the end of the cable branches or directly connected to the instruments. Each cable and connector has a unique number to ensure that the cable is laid without errors. Cable brackets are used to fix the cable and are installed on the satellite panel before the cable is laid, cable network assembly not only needs to ensure that the cable is tied to the correct cable brackets and routed through correct holes in the deck according to the design requirements, but also needs to ensure that the free length of the cable end meets the requirements of subsequent cable plugging. Due to the huge difference in cable direction between different satellites, the narrow operating space and complicated operating conditions, the cable network assembly is heavily dependent on manual operations. In order to complete the laying, the operator needs to obtain the required information from the drawing or 3D model, lay the cable in the satellite cabin, then adjust and tie the cable.

At the satellite assembly plant, a fixed Kanban system is currently used to display the information required for cable assembly, and the worker operates according to the drawings or the 3D model. The workers perform the operation in the cabin with the memory of the information required for assembly, and needs to constantly switch the viewing angle between the display screen and the satellite due to the poor openness of 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 cable brackets and deck holes 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 cable assembly.
Cable Installation which is flexible assembly is complicated and error-prone, in recent years, virtual assembly technology is widely used[2-6]. In order to improve efficiency and quality of satellite cable installation, a cable assembly system based on AR technology is designed. This method automatically matches the cable laying information with the real physical environment, and guides the workers to complete the cable 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 cable laying models to visual augmented reality interactive information.

2. Cable Installation in Assembly and Integration Process of Satellite

Satellite comprises several modules which will be mated in subsequent stages in AIT process of satellite, and the cables are installed before equipment in a single module. The cable installation step in AIT process of satellite is showed in Figure 1, cable brackets which contain many nylon bases and several connecter brackets are installed on satellite with bolts before cable laying, cable fixing is performed according to relevant standards after cable laying; the cables are divided into high frequency cables and low frequency cables, and the low frequency cables are divided into signal cables and power cables, power cables are usually laid outside the low frequency cables. Currently, nylon base bundled with nylon tie is the main harness support to fix cable for domestic satellite, as is showed in Figure 2.

As the satellite cable design changes from the traditional 2D mode to the 3D digital mode[7-8], the satellite cable assembly also enters the 3D assembly mode. Cable Installation is flexible assembly, the design input is inconvenient to use, and an effective and accurate cable network assembly information transmission method from designers to operators is not formed, so it leads to cable routing error and cable fixing point selection error, etc. The current 3D model based on desktop computer has poor human-computer interaction, In the process of laying complex cables, operators need to frequently confirm cable laying status back and forth between satellite and computer stations, and therefore, new technology is needed to improve cable assembly efficiency.

3. Augmented Reality

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[9] was released as a development edition in 2016 and is now available as a consumer version. The Google Glass was marketed as an AR device, however it is merely a transparent display lacking many necessary features, such as spatial mapping and a usable display, to interact with the real world and provide true AR capabilities. Another AR HMD, the Daqri Smart Helmet, is designed for industrial use but is currently still in development. Since the Google Glass is not capable of running AR assembly applications and the Daqri Smart Helmet is not yet released, the Microsoft HoloLens is the ideal choice for investigating an AR assembly application on a commercially available device.
The decision to use the HoloLens to investigate an AR assembly application on a HMD is strengthened by its’ state of the art capabilities. Unlike AR HMDs in the past, the Microsoft HoloLens is a completely self-contained HMD, i.e, it does not require the HMD to be tethered to a separate computing 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. Other features include 4 microphones, gaze tracking, gesture input, spatial sound and voice support[10]. The HoloLens is shown in Figure 3 below.

4. The Process of Application of Augmented Reality in Satellite Cable Assembly
A cable assembly system based on AR technology is designed to improve efficiency and quality of satellite cable installation, the flow chart of the method is showed in Figure 4. Compared with the traditional method, this method automatically matches the cable laying information with the real physical environment, and guides the workers to complete the cable assembly.

4.1. Lightweight 3D Cable model
The 3D cable model which is designed using CAD modeling tools such as CATIA and PROE 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. The 3D design cable model contains much modeling data, such as deck structure, devices, and electrical connectors. In order to improve the subsequent display rendering effect, the unnecessary model information should be deleted first, and then compress the 3D cable model by format conversion. 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. The lightweight 3D model has the advantages of small file size, easy operation and smooth display.

4.2. Extraction of Cable model information
While laying the satellite cable, the operator need to know the branch relationship of the cable, the length of the branch, the electrical connector code of each branch and the layout position of each branch in the cabin. Because much modelling data information, such as device and electrical connector information, is deleted in the process of 3D Cable model weight reduction, so it is necessary to extract cable model information in design 3D model through secondary development of software. The electrical connector code and location information of cable free end are very important cable model
information in laying the cable, and the electrical connector code is added to the corresponding position of the lightweight 3D model.

4.3. 3D Registration
The lightweight 3D model has the advantages of small file size, easy operation and smooth display. The three-dimensional registration technology mainly realizes the correct fusion of virtual cables 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 of cables, 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 cable virtual fusion assembly system. Registration error reaches a certain value will result in erroneous results. In this cable assembly system based on AR technology, two-dimensional codes which can be recognized very quickly are used in 3D registration, and 2D QR codes are pasted respectively on satellite several modules deck structure.

4.4. Fusion and Display of 3D models and objects
The cable assembly 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. 2D QR codes which are pasted respectively on satellite several modules deck structure are used to define the separate locations of the assembly workspace. After these locations are defined, the HoloLens can properly track those positions 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 during cable laying, it has 3 interaction modes, such as menu, 2D QR code and voice. The electrical connector code display orientation is set to always face to user, and the different types of cables are displayed in different colors.

5. The Typical Case of Application of Augmented Reality in Satellite Cable Installation
Cable assembly system based on AR technology is tested during the AIT process of a remote sensing satellite in the paper. Remote sensing satellite comprises service module and payload module, 2 lightweight 3D cable models were built and all cables were classified into 2 modules according to the actual laying process. Lightweight 3D cable model of the service module is showed in Figure 5, it contains 134 cables which were installed first in AIT process of satellite. The outer panel structure, all devices and electrical connectors are deleted, after format conversion, the 3D cable model of service module is compressed to 27.1 MB, and the Tris are 4.1 million, Verts are 2.1 million. Because only the cable to be laid is needed to display in actual use, The electrical connector code of a cable is extracted and added to the corresponding position of the lightweight 3D model which is showed in Figure 6.
As is showed in Figure 7, the 2D QR code which represents service module of the remote sensing satellite 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 installing the cable 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 cable to be laid from the UI interface. The process of this system is very simple, and the cable assembly information is clear at a glance, thereby greatly improving the visibility of the 3D model and guiding principle of the laying operation. Figure 8 and Figure 9 show a typical case of application in a satellite cable installation, with the help of the cable assembly system based on AR technology, the time of laying 134 cables in one module of a remote sensing satellite can be reduced from 7 days to 5 days, and the cable laying accuracy can reach up to 100%.
Figure 5 Lightweight 3D Cable Model of the Service Module.

Figure 6 Electrical Connector Code Extraction and Display.

Figure 7. The 2D QR Code Pasted on The Satellite Deck.

Figure 8. Laying Cables in One Module of a Remote Sensing Satellite

Figure 9. Fusion and Display of 3D models and objects.
6. Conclusion
As the satellite cable design changes from the traditional 2D mode to the 3D digital mode, the satellite cable assembly also enters the 3D assembly mode. Cable Installation is flexible assembly, in order to improve efficiency and quality of satellite cable installation, a cable assembly system based on AR technology is designed. The successful application of this system provides a new solution for satellite cable laying and marks a new step in the digital assembly capacity. Augmented Reality technology is particularly suitable for cable laying applications; subsequent exploration will be carried out in other AIT process of satellite such as pipe valve installation.

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