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A measuring method for large antenna assembly using laser and vision guiding technology

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ABSTRACT

In this paper a new conception of a measuring method is proposed to assist precision automatic assembly of large radar antenna. Different from conventional 6-DOF tracking methods, the measuring system decomposes the measurement task into several independent steps. The measuring system consists of a camera, two laser distance meters, two position sensitive detectors (PSD) and an inclination angle sensor. The camera is adopted to guide antenna position and orientation adjustment over a large space. Laser meters and PSD sensor is used to precisely measure the position and orientation of radar antenna. To improve the practicability of measuring system, a robust vision measurement method is proposed. The mathematical models and practical calibration methods for measurement are elaborated. The preliminary experimental results agree with the methods currently being used for orientation and position measurement. The measuring method provides an alternative choice for the metrology in precision assembly. By using the method proposed in this paper, the measuring system can achieve a measurement accuracy of approximately 1 mm, which meets the accuracy requirement of large radar antenna automatic assembly application. Besides, the measuring method provides an alternative solution for large scale metrology which take the environmental impact into account.

1. Introduction

Currently, large-scale mobile radars are still erected manually by using lifting equipment, which often fails to meet the requirements on precision, quality and efficiency in the erecting process. Therefore, to keep pace with the increasing demand on mobile radar's mobility, precision and combat effectiveness, an automatic assembly technology of large antenna is needed to replace the traditional manual erecting method. The automatic assembly technology of large components has already found its way into the field of aeronautics and astronautics [1]. The size of airplanes and rockets is usually enormous, so it takes a very large space to manufacture and assemble their components. Instead of being manufactured as a whole, the main body of these aircrafts are usually manufactured separately, and then assembled with each other to form the whole part [2]. Automated assembly of airplanes' large components could work without human interference with the help of computer information processing, computer numerical control (CNC) automatic positioning, high-precision digital measurement and information feedback technology [3,4], which expands the working distance, improves precision, and saves time.

However, to complete the process of automated assembly of large components, the primary task is the accurate measurement technique in large scale. For instance, to assemble the large components of aircrafts, the accuracy of pose-and-position adjusting device, and measurement device should be guaranteed. Only with an accurate measurement can we locate the position of large components precisely, and then proceed with the position adjustment of pose-and-position adjusting device [5].

As a result, considerable attention in the area of large-scale metrology [6] (LSM) has been focused on the position as well as orientation measurement, such as satellite assembly and integration of spacecraft components [7]. With the development of digitization technology, LSM technology has witnessed a rapid development in recent years. Since the 1980 s, measurement facilities like computer aided theodolite (CAT), laser tracker [8], indoor GPS, Optical base method [9] etc. have been widely used as large scale digital measuring instrument [10] both home and abroad.

Some commercial instruments have been developed and put into use on the basis of optics [11–13], mechanics, electromagnetics and acoustics. Compared with other techniques, optical measurement systems have many advantages, such as large working volume, high

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resolution and immunity to electromagnetic interferences. For position and orientation measurement, the laser tracker can be applied to monitor six degrees of large-scale components with high accuracy over large range. But, it is hard to realize automated measurement because of some time-consuming manual operations, such as transporting the retroreflector to points of interest [14,15].

Vision based method has presented in field of industry robots, assembly line inspection etc. Machine vision measurement is a precise means to measure and locate three-dimensional objects with the help of machine vision technology. Vision based method is non-contacting, low cost and suitable for the measurement of large and moving objects [16–19]. But its measuring accuracy and efficiency could not meet the industry demand for precision assembly.

However, there are limitations inherent to the commonly used techniques for large radar antenna assembly with precision orientation and position measurement. Firstly, most large-scale metrology (LSM) approaches and instruments are actually employed in indoor environment [20,21], while mobile radar antenna assembly activities are operated in outdoor. So the operation conditions and environmental influences is a challenge for precision measurement of radar antenna. Secondly, commercial techniques such as GPS and laser tracker based measurement system commonly require time-consuming installation and precisely calibration [22,23]. It cannot meet the requirement of mobile radar antenna assembly, because the operation position and condition is changeable in different radar assembly task. Finally, the cost of commercial instruments such as laser tracker is too expensive for mobile radar application.

In this paper, we present a holistic measuring solution to assist mobile radar antenna assembly, which considers the positioning task as well as the operation conditions and environmental impacts. Components of the measurement system consists of a camera, two laser displacement sensors, two position sensitive detectors (PSD) and an inclination angle sensor. It features stepwise measurement and low cost, as well as good environmental adaptability.

The paper is structured as follows. In Section 2, we outline the system configuration and positioning process of large radar antenna assembly. In Section 3, the measurement model of the proposed system is established, and both orientation and position geometrical relationships are analyzed. A robust vision algorithm is discussed in Section 4. Section 5 details preliminary experimental tests and results to verify the measuring accuracy. In the end, Section 6 demonstrates some concluding remarks and future work needs to be done.

2. Antenna automated assembly system design

2.1. Problem description

As is shown in Fig. 1, the large radar antenna mentioned before is divided into two parts which are the main antenna and the edge blocks antenna. The main antenna transported by the main vehicle is fixed during the assembly process and we call it the fixed antenna hereinafter. The edge blocks antenna transported by the antenna transporters will change its orientation and position during the assembly process and we call it the mobile antenna hereinafter.

At the beginning of assembly process, the fixed antenna is moved to the right position which is parallel to the horizontal plane. And then, the fixed antenna won't be moved during the whole assembly process. After this, the antenna transporter approaches the main vehicle, trying to be parallel with the main vehicle. The distance between them is approximately 0.5 m.

With the aid of automatic measuring system on the antenna transporter, the pose-and-position tuning apparatus starts to adjust the antenna array to achieve the alignment with the assembly position on the main vehicle. The following step is assembling and fastening the antenna to the main vehicle. After the radar has done its work, also with the aid of automatic measuring system, the process of disassembling the antenna array and putting it back to the antenna carrier is similar to the assembling process, only that it is in the inverse order.

The antenna array of radar usually has a truss structure. Each part of the antenna array is often more than 10 m in length and 3 m in width, and its weight can be more than 3 ton. Thus, the automatic assembling and disassembling of antenna array is a typical large components assembling problem. The antenna array on the main vehicle is fixed, while the antenna array on the antenna carrier can be adjusted so that they could achieve alignment with each other. Therefore, a pose-and-position tuning apparatus with six degree of freedom is installed on the antenna transporters in order to adjust the position and orientation of the mobile antenna.

The pose and position deviation between the fixed and mobile antenna are measured by the automatic measuring system, and this information is fed to the pose-and-position tuning apparatus in real time until the alignment is achieved and the assembling is done. It's worth noting that, to make the automatic assembly feasible, the assembly and fastening of the fixed and mobile antenna are done by a set of linked locking mechanism with taper pins. This makes it possible to lock and unlock the antenna automatically, and restricts the requirement on locating precision less than 1 mm, which makes this system much more practical to operate. This paper focuses on the measurement system design.

If we analyze the assembly process, we can notice that the main task is to achieve the alignment with the assembly position. So we can establish a model and regard the fixed antenna and the mobile antenna as rectangular blocks. As is shown in Fig. 2, we establish the body-fixed Cartesian coordinate system on the fixed antenna and the mobile antenna separately. We define that the *X*-axis direction is perpendicular to the assembly surface, the *Y*-axis direction is parallel to the assembly surface, and the *Z*-axis direction is perpendicular to the upper surface of the antenna.

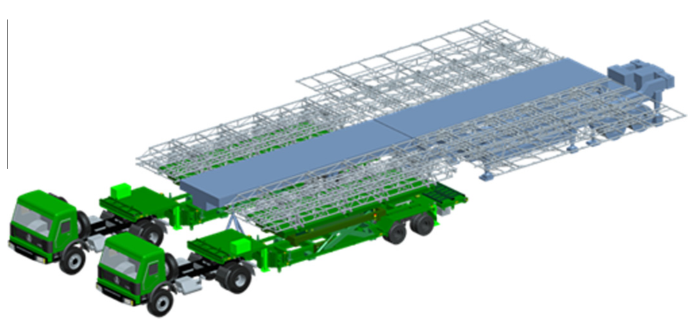

Fig. 1. Components of the assembly system.