Long span ranging system based on aircraft vision

Boyang Sun¹ and Jianmei Sun²*

¹ School of Economics and Management, Shanghai University of Electric Power, Shanghai, China, Shanghai, 200082, China

² School of Economics and Management, Shanghai University of Electric Power, Shanghai, China, Shanghai, 200082, China

*Corresponding author’s e-mail: sby@sh.sgcc.com.cn

Abstract. At present, the transmission line in the field has a large potential safety hazard, and professionals often encounter difficulties in patrol inspection and distance measurement. In view of the current situation of safe distance between equipment in power grid construction, this paper proposes a long-span distance measurement method based on aircraft vision, which can automatically achieve high-precision distance measurement between equipment, and ensure personal safety, avoid equipment failure and other problems. Then the long-span ranging technology based on aircraft vision is analyzed, and the research and application of the given technology are discussed.

1. Introduction

Overhead transmission lines have a bad operating environment with many points, long lines and wide areas, and long-term exposure in the field, making line safety monitoring difficult [1]. At present, the most common way for power transmission and maintenance management departments to measure the distance between the traverse and the object beneath the traverse is to use a laser range finder or an electronic theodolite, which is widely used and easy to operate. However, it is not possible to measure special areas in the field, especially between two points in space that cannot be carried out due to terrain limitations [2]. High voltage in high voltage transmission lines makes it easy for operators to enter the operation area, which can lead to electric field distortion. If they are too close to non-equipotential devices, it can easily lead to transient or steady-state electric shock or even breakdown. Therefore, it is necessary to keep a safe distance from high voltage live devices, which brings difficulties to the distance measurement of live devices[3].

Document [4] uses a new form to resolve flight conflicts by referencing two decomposition algorithms. Reference [5] presents a monocular visual positioning method. In this paper, a long-span ranging method based on aircraft vision is proposed to solve the problem of difficult ranging under long-span conditions. The method obtains image data from the scene of the object to be measured by the visual sensor carried by the aircraft itself, then sends the acquired data to the server side, uses the visual photogrammetry technology based on the SFM algorithm, and passes through the server side. Processing can quickly achieve long-span target length or distance measurement between devices [6]. The field test and application prove that the accuracy and robustness of the visual distance measurement method based on three-dimensional reconstruction for image data and location data acquisition meet the actual requirements of the field current power engineering, and the operation is convenient, can greatly improve the efficiency of engineers, and ensure the safety of work.
2. Structure from motion algorithm

SFM (structure from motion) is to recover the structure from motion and obtain the 3D coordinates of the scene in the image through a series of 2D images, so as to reconstruct the 3D scene. SFM and monocular multi view 3D reconstruction images are out of order. It requires skills to select the first two images and add the best next image. Its main purpose is to realize 3D reconstruction. Offline processing method does not require strict processing time, but has high accuracy [7,8].

2.1. feature detection

Sift descriptor with scale and rotation invariance is used in feature detection, which is suitable for extracting various image feature points with scale transformation and rotation angle. In practice, the position information (x, y) of feature points is calculated by Gaussian filters of different sizes, and a description sub information is provided. In the 4*4 square histogram around a feature point, each histogram contains the gradient direction of 8 bin, that is, a feature vector of 4*4*8=128 dimensions is obtained, without using the size and direction information [9,10].

2.2. feature matching

After the feature points of each image are extracted, the feature points between two images are matched, and the feature points around image I are represented by F (I). For each image pair I and J, consider each feature to find the nearest neighbor feature vector \( f_{nn} \in F(J) \), as shown in equation (1)

\[
\begin{align*}
\text{arg min}_{f_{nn} \in F(J)} \| f_{nn} - f \|_2
\end{align*}
\]

In fact, a high-dimensional index tree data structure is used to calculate the nearest neighbor matching [11], iteratively looking for the nearest neighbor distance before and after two times, and when the ratio of the two is less than a specific threshold, it is actually set to 0.6, which is determined as an acceptable matching pair [12]. Finally, the algorithm of eliminating duplicate feature points matching solves the problem of many to one feature points, and uses geometric constraints to enhance the reliability of feature matching.

When all pairwise matching image pairs are determined, the common feature matching points in multiple images are connected to form trajectories [13,14]. Until all the trajectories that meet the conditions are found, the image connection graph is formed, which contains the nodes of each image and the image edges with common trajectories.

2.3. Structure From Motion

If the parameters of the camera are represented by 3*3 rotation matrix R and 1*3 translation vector (or camera center coordinate vector), the internal parameters of the camera are represented by focal length f and two radial distortion parameters k1 and k2. Then, through the projection equation, a 3D point X is projected onto the 2D image plane of the camera, that is, the projection error is the distance between the projection point and the real point on the image.

Furthermore, the objective optimization equation of n viewing angles, m trajectories and projection error is shown in equation (2)

\[
g(C,X) = \sum_{i=1}^{n} \sum_{j=1}^{m} w_j \| q_j - P(C_i,X_j) \|^2
\]

The cumulative sum of projection errors of trajectory j in camera i is expressed as \( \| q_j - P(C_i,X_j) \| \). In a word, the optimization process of the objective function is to find the appropriate camera and scene parameters, which is solved by the nonlinear least square optimization method.

The five point method is used to estimate the external parameters of initial matching. The initial 3D points are provided by trajectory triangulation. The first beam adjustment is carried out from the initial two images. In the iteration, all three-dimensional points are back projected to the pixel coordinates of each photo, and compared with the initial coordinates to optimize. Finally, the end condition of the iteration is that the number of points observed by the remaining cameras is no more than 20, and the
camera estimation parameters and scene geometry information, namely sparse 3D point cloud, are obtained.

3. Design of long span ranging system based on aircraft vision

This paper creatively puts forward the measurement method of "three-dimensional mapping", which uses the visual sensor of the aircraft to collect the image data of the target equipment. At the same time, the position data of each image is obtained through IMU (inertial measurement unit) or GPS. Through feature matching, the two-dimensional data of the target area is converted to the spatial information. Finally, the image matching is realized on the visual interface of the device. Any long span distance measurement. Through the implementation, this paper discusses and studies the application of vision based photogrammetry technology in engineering at home and abroad, so as to realize the successful application of large-span ranging system based on aircraft vision. The scheme framework is shown in Figure 1.

3.1. Hardware component

M100 is used for aircraft platform. Considering that enough original images are needed for single reconstruction effect, its endurance time must be about 40 min, and its load capacity is strong (3.6 kg), flight stability is good (low vibration), which makes the data recorded by camera have good effect, fully meeting the requirements of large-span measurement.

3.2. Software part

The software is divided into three parts: VINS fusion based on vision and IMU information, 3D scene reconstruction based on MVS and data communication between mobile phone and server based on SCP protocol. The basic workflow of the whole system is shown in Figure 2.

3.2.1. Data communication between mobile client and server based on SCP protocol. SCP command (secure copy) is the most convenient and useful command in SSH, which is used to copy remote files. Data transmission is based on SSH, and uses the same authentication method as SSH to provide the same security. The schematic diagram of SCP communication mechanism is shown in Figure 3.
3.2.2. 3D scene reconstruction of server based on MVS. MVS based 3D reconstruction technology belongs to the passive vision 3D reconstruction, that is, by analyzing all kinds of information in the image sequence, reverse engineering the object modeling, so as to get the 3D model of the scene or the object in the scene. The reliable alignment of video frame image and IMU pose data is realized by loop detection, that is, the image data obtained by the monocular camera is fused with the IMU data through VINs, and the pose data is associated based on the loop detection. Therefore, the reconstructed 3D scene has the actual scale information. The position and attitude data based on loop detection is lost [15].

4. Field test and analysis

In the process of survey and acceptance of power engineering construction, the visual measurement system can be easily used to assist in survey distance, real-time image returned by aircraft, reconstruction process and point selection and ranging based on 3D model, as shown in Figure 4.

4.1. Field test

In order to avoid accidental factors of single measurement experiment, taking a flower bed as an example, the length and distance of different objects are measured several times, and the measurement accuracy is compared with the actual engineering construction drawing, as shown in Figure 5, and the error range is shown in Table 1.
### 4.2. experimental analysis

It can be found that the non-contact visual measurement method proposed in this paper has significant advantages in measurement efficiency and cost investment through multiple experiments of multiple scenes and comparison of on-site drawing data. But on the other hand, compared with the traditional ranging method, because ranging depends on good imaging conditions, this scheme also inevitably has some limitations. Improving the accuracy and good visibility of the reconstructed three-dimensional model is the premise of the subsequent ranging accuracy. Therefore, in the future work, more energy will be put into the accurate description of the three-dimensional model and to achieve more convenient point selection and ranging.

In addition, as far as the relative accuracy is concerned, the average error of multiple measurements of the proposed ranging scheme is basically stable at about 1%, which meets the requirements of the actual measurement work of power engineering.

### 5. Conclusion

This paper studies the long-span scene ranging system based on aircraft vision. Firstly, the image data of the object scene to be measured is acquired by the airborne vision sensor. Then, the obtained data is sent to the server through the mobile client, and the long-span target length or distance between devices can be quickly measured by using the three-dimensional reconstruction of SFM algorithm and the visual measurement technology integrating IMU data. Finally, the mobile client obtains the 3D model of the server, and the construction personnel selects the length of any 3D virtual target to get the corresponding actual distance. After the project site and many tests, this scheme can optimize the design scheme, reduce rework, reduce accompanying and stopping equipment during equipment hoisting and pressure withstand, more importantly, ensure the safety of installation and pressure withstand, ensure the safety of project management, and improve the quality of project management.

### Acknowledgments

Thanks for the support of the project: National Social Science Fund Project(17BGL010), “The Belt and Road Initiative” formation mechanism and countermeasures of safety cost in power investment project.

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