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Trajectory and attitude measuring scheme for launching projectiles of inflight aircraft

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ABSTRACT

In this paper, a novel non-contact scheme, based on stereo vision technology and close range photogrammetry, is presented to measure the trajectory and attitude of launching projectiles of inflight aircraft with high accuracy. A conjugated camera group, which is rigidly connected and calibrated to an ensemble, is designed to archive the whole measurement. First, a camera position self-correction method is proposed to eliminate the measurement error caused by aircraft vibration. Then, two trajectory and attitude measurement methods are proposed and used in different stages of the projection process. The single-camera method based on the theory of space resection is applied in the beginning of projection with short measurement distance and small intersection area. The multiple-camera method based on the means of point cloud registration is applied in the following stage with small effective measuring area. Furthermore, a point tracking method is developed to improve the robustness and speed of the algorithm by predicting the position of non-coded target. A novel system is developed and the accuracy test in laboratory confirms that the trajectory and attitude measurement errors of the system are 0.02 mm/m and 0.02°/m respective. A simulation experiment is carried out and the well measured result by the system proves the feasibility and the efficiency of this scheme.

1. Introduction

At present, the trajectory and attitude measurement of a moving body is involved in many fields, such as aerial, spacecraft, marine, vehicles and robots [1–5]. Especially for the military application, it is important to accurately measure the trajectory and attitude of missile or projectile launching separated from inflight aircraft.

It is state of the art to use accelerometers or special tensor placed inside the moving body for dynamic attitude measurements [6–8]. However, these measurement systems are sensitive to electro-magnetic fields. Besides, some extra installations inside the projectile such as placement of cables for power supply and data transfer are required for these applications. Moreover, these electronic sensors cannot provide trajectory data for moving projectile centroid.

The videogrammetric model deformation (VMD) measurement technique is an optical method based on the principles of close-range photogrammetry and stereo vision technology for measuring aero elastic deformation and attitude of a model during aero dynamic testing [9]. The model deformation measurement capability at NASA includes both single-camera and multiple-camera videogrammetric measurement systems, with emphasis on the measurement of the change of wing twist due to aero dynamic loading [10–16]. However, most of the tests and application are exclusive work in wind tunnel. And studies on dynamic trajectory and attitude measurement are not investigated further and technically. The accompanying flight, placing measuring cameras to another airplane to capture the projectile falling images, was used to measure the projectile trajectory in aircraft flight test. However, for the long distance, poor quality images and limited measuring position, this method cannot obtain the accurate result and the beginning trajectory and attitude data in the module.

In this paper, a systematic scheme to measure the trajectory and attitude is developed with high accuracy for the testing of aircraft projectile launching process in flight. In order to obtain the most complete data of the projectile launching process, there is no alternative but to install measuring cameras on the ceil of the

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module. Thus, the key point of this measurement scheme is to solve two problems. One of the problem is the measuring basis instability caused by aircraft vibration. A camera position self-correction method using the conjugated camera group is designed to solve this problem. The other problem is the measurement robustness and accuracy in the view field along the direction of optical axis. The single-camera, multiple-camera measurement method and the point tracking method are combined to solve this problem. A novel system based on this scheme is developed and achieves accurate measurement result.

2. Measurement scheme

2.1. Camera layout and target placement

Fig. 1 shows the measurement setup and the layout of the camera. The projectile is dropped down along the direction of camera's axis. The coded and non-coded targets fixed on rigid reference area are used to provide the measuring basis for the system. The conjugated camera group consisting four high-speed CCD is used to monitor the dynamic behavior of the projectile in operation. The camera **C1** is used to correct the position of all the cameras continuously. The camera **C3** is used to measure the trajectory and attitude of the moving projectile in the range **S1**, and the camera **C2** and **C4** are used to measure the trajectory and attitude of the projectile in the range **S2**.

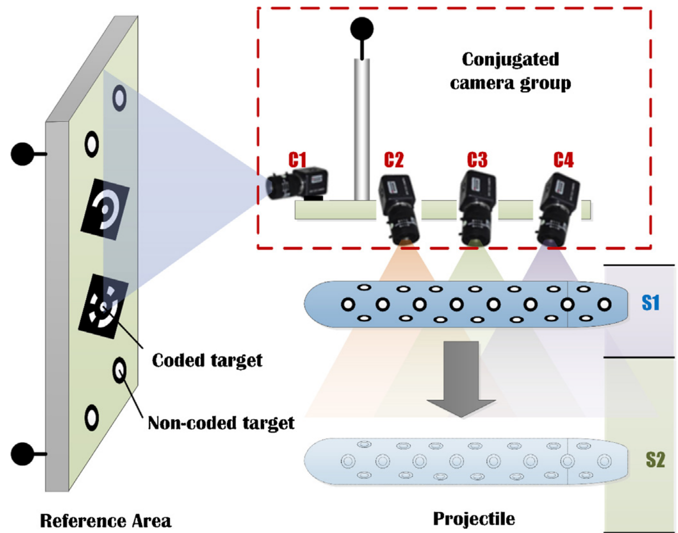

Fig. 1. The measurement setup and camera locations.

2.2. Working procedure

As shown in Fig. 2, the whole measuring process is divided into 8 steps:

(1) Internal parameters of all the cameras are obtained by the self-calibration method in ground [17].
(2) Relative exterior parameters of all cameras are orientated to the camera **C1** in laboratory before the camera group is installed.
(3) All the targets on reference area are exactly measured in world coordinate system by XJTUDP system which is a close range photogrammetry system developed by our group [18].
(4) All the targets (non-coded) on projectile are measured in its local coordinate system using the same method of *Step3*.
(5) Synchronous image collected by four CCD are detected, and the ellipse centers of all targets on each image are obtained. In order to improve the efficiency of target recognition and the veracity of common targets association, an improved ellipse detection method using point tracking, presented in Section 3.3, is used.
(6) Absolute exterior parameters of all cameras are orientated with the image of camera **C1** only. The camera position self-correction method which presented in Section 3.1 is used.

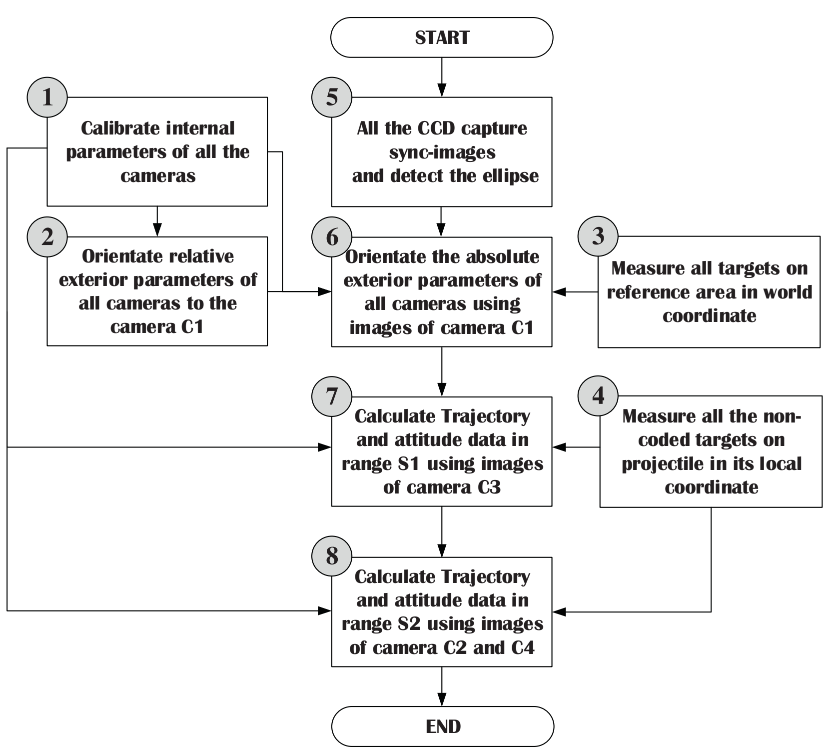

Fig. 2. Full process chart of the working procedure.