論　文　の　要　旨

題　目　　A Study on 3D Reconstruction for Moving Objects Using High-Speed Active Camera-Projector System

（高速アクティブカメラプロジェクターシステムを用いた移動物体の 3D 再構築に関する研究）

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The 3D measurement of moving objects has garnered significant interest in various fields, including online industrial production inspection, robotic arm grasping for moving object navigation, motion analysis, high-precision positioning in medical robotics, and dynamic 3D data acquisition for virtual reality. Methods for 3D reconstruction of moving objects include Time of Flight (TOF), Stereo Vision, and Camera-Projector techniques. Among these, the Camera-Projector technique stands out for its superior accuracy and speed. These methods use point, line, or plane-structured light to project unique patterns onto the object, with depth information derived through triangulation in the captured images.

However, existing Camera-Projector methods face significant challenges with 3D reconstruction of high-speed moving objects due to two primary reasons: the static nature of the system, with fixed cameras and projectors, which limits the 3D imaging range, and the lack of dynamic feedback on the target's motion, making it difficult to address reconstruction errors caused by the object's movement. To overcome the first issue, researchers have proposed various active 3D reconstruction systems. One approach mounts the projector on the end of a robotic arm to improve scanning flexibility; however, its accuracy is limited by the precision of the robotic arm. Another system employs gimbals to drive the projector and camera for scanning, however, the system size was significant, and its scanning speed was slow. For the issue of target motion, some researchers have used high-speed projectors for quicker pattern projection and capture. However, the projection speed of multi-tone patterns remains a limiting factor, affecting effectiveness. The fixed field of view (FOV) of both the camera and projector further limits the reconstruction range, making it difficult to accurately reconstruct high-speed moving objects. Other approaches have focused on algorithmic solutions to compensate for measurement errors due to object motion. Although these methods correct some inaccuracies caused by movement, they generally assume uniform motion and are computationally intensive, limiting their utility in real-time applications.

To address these issues, this research proposes a novel active 3D reconstruction method for wide-range sensing, which is further combined with a visual feedback-based approach to achieve 3D reconstruction of moving objects. This approach integrates a galvanometer-based tracking system with a dual-galvanometer-based active light-section 3D reconstruction system. Our strategy ensures synchronization between laser scanning, adjustment of the tracking camera’s FOV, and modification of the 3D reconstruction camera’s FOV. Additionally, we have devised a joint calibration technique for both the tracking and active 3D reconstruction systems and introduced a 3D motion error compensation method. Experiments indicate the effectiveness of the proposed method for high-quality 3D reconstruction of moving objects. This thesis is organized as six chapters. Chapter 1 is the introduction. Chapter 2 summarizes related works on active 3D reconstruction and calibration methods. Chapter 3 describes the concept of the high-speed active camera-projector method. Chapter 4 proposes a novel active light-section 3D reconstruction method for wide-range sensing. Chapter 5 introduces a visual feedback-based active light-section 3D reconstruction method for moving objects. Chapter 6 summarizes the contributions of this study and discusses future work.