論 文 の 要 旨

題 目　A Study on Motion-blur-free High-frame-rate Video Camera Using High-speed Mirror Actuator

（高速ミラーアクチュエータを用いたモーションブラーフリー高速度カメラに関する研究）

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Motion blur caused by relative motion between a camera and a scene is a well-known problem that occurs when fast-moving scenes are captured in various applications, such as factory inspection, biomedicine, multimedia, and civil engineering. When high-quality images of objects are required, such as pattern recognition, this problem becomes more acute. To reduce motion blur in videos of fast-moving objects, the camera's exposure time should be lowered as the apparent speeds of the target scenes increase. However, it is difficult to obtain bright images because of the insufficient intensity of the light projected on the image sensor. In chapter 1, we introduced a background of the motion-blur and an overview of a motion-blur-free HFR video camera using a high-speed mirror actuator. The background has discussions of demands in a general situation included an onsite team project in the TAOYAKA program. In chapter 2, we discussed related works regarding motion-blur compensation. It can compensate for the motion-blur in a limited situation and includes a software-based-approach of motion-deblurring, an image stabilization, an HFR camera tracking, and a TDI camera.

In this study, to overcome these limitations, we proposed new methods for real-time motion-blur compensation and developed a motion-blur-free high-frame-rate (HFR) video camera using a high-speed mirror actuator. Our proposed method controls the viewpoint velocity of the camera system during the exposure time by the movement of the high-speed mirror, which reflected the moving objects. The developed camera system can capture non-blurred and brightness images without decreasing the motion-blur and uses for real-time in various applications where video shooting with high magnification is strongly required for unidirectionally fast-moving scenes, and the apparent speed of the target scene can be given by an external speed measurement device or a blur degree of captured images for a visual-feedback. In chapter 3, to overcome the limitations of current works, we introduced basic concepts of a camera-driven frame-by-frame intermittent tracking method with a high-speed mirror actuator, an actuator-driven frame-by-frame intermittent tracking method, and a blur-index-based visual-feedback control for a viewpoint velocity. These concepts need to capture a clear HFR image without decreasing the exposure time of the camera and relying on their patterns. In chapter 4, a motion-blur-free high-frame-rate video camera using a 2-DOF piezo mirror was developed to verify the effectiveness of the camera-driven frame-by-frame intermittent tracking method for shooting non-blur and bright images of fast-moving objects. Its effectiveness was investigated by several experiments using a liner-slider and a table tennis ball shooter. In chapter 5, the developed motion-blur-free HFR camera, which includes a high-speed vision and a resonant mirror, is described. It shows the effectiveness of the actuator-driven frame-by-frame intermittent tracking method for capturing clear and high-brightness images of fast-moving objects. The results of several verification experiments using a high-speed conveyor system are showed. The high-speed conveyor system can control the speed of its belt in a range of 0.0~7.5 m/s. The printed belts of the conveyor system are dot, checkered, and electrical board patterns. In chapter 6, the developed motion-blur-free HFR camera uses an actuator-driven frame-by-frame intermittent tracking method and a blur-index-based visual-feedback control for a frame-capture-event of the HFR camera and an amplitude of the resonant mirror. It has a robust and controllability to capture motion-blur-free HFR image sequences even when relative motion occurs between high-speed shooting complicated objects and the camera. The verification experiments using the similar high-speed conveyor system in the previous chapter was described. The printed belts of the conveyor system are checkered, cracked walls, and electrical board patterns. As a practical experiment, the video capturing experiments by applying the developed system in a vehicle to verify the effectiveness in the situation of capturing the real concrete surface from a running vehicle was conducted. In chapter 7, thesis contributions were summarized, and the scope for future work was discussed.