学位論文の要旨

題　目　A Study on Fast Three-Dimensional Shape Measurement for Moving Objects
（運動物体の高速三次元形状計測の研究）

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With the development of digital technology, real-time three-dimensional (3D) shape measurement is becoming increasingly important for applications in many fields. When the camera view includes fast motion, the extraction of a depth image has to be sufficiently fast to allow more information to be obtained. To measure a moving object effectively, coded structure light illumination, a well-known active 3D shape measurement approach, is widely used. Based on this approach, many scanning systems implemented with a one-shot or sequential projection technique have been reported over the past decades. Systems based on one-shot projection are realized by using a complicated image processing algorithm; however, acceleration of the process presents a challenge. It is feasible that a system based on sequential projection can be effective at a high frame rate (HFR); however, the synchronization errors caused by the light patterns projected at different points being misread as those projected at the same one limit the measurement accuracy.

To overcome the restrictions of conventional systems, I developed two methods: a sparse blink-spot projection method without synchronization errors and a density motion-compensated stripe projection method with reduced synchronization errors. The contributions of my previous studies can be summarized as follows:

A) Blink-spot projection method can reduce the synchronization errors of the sequential structured light illumination, which are caused by multiple light patterns projected with different timings when fast-moving objects are observed. In this method, a series of spot array patterns, whose spot sizes change at different timings corresponding to their identification number, is projected onto scenes to be measured by a high-speed projector. Based on simultaneous and robust frame-to-frame tracking of the projected spots using their ID numbers, the 3D shape of the measuring scene can be obtained without misalignments, even when there are fast movements in the camera view. I implemented our method with an HFR projector-camera system that can process 512×512 pixel images in real-time at 500 fps to track and recognize 16×16 spots in the images.

B) An HFR structured light vision is developed that can simultaneously obtain depth images of 512 ×512 pixels at 500 fps by implementing a motion-compensated coded structured light method on an HFR camera-projector platform; the 3D computation is accelerated using the parallel processing on a GPU board. This method can remarkably reduce the synchronization errors in the structured-light-based measurement.

C) A projection-mapping system is developed that can project RGB light patterns that are enhanced for 3D scenes using a graphics processing unit (GPU) based HFR vision system synchronized with HFR projectors. This system can acquire 512×512 depth-images in real time at 500 fps. The depth-images processing is accelerated by installing a GPU board for parallel processing of Gray-code structured light illumination using infrared light patterns projected from an IR projector. Using the computed depth-image, suitable RGB light patterns to be projected are generated in real time for enhanced application tasks. They are projected from an RGB projector as augmented information onto a 3D scene with pixel-wise correspondence even when the 3D scene is time-varied.

D) A fast 3D shape scanner is developed that can output 3D video at 250 fps using two HFR camera-projector systems with an implementation of 10-bit Gray code light pattern encoded in both horizontal and vertical. The 3D data, which is extracted by the two camera-projector systems, are registered together to obtain an entire shape. To avoid the interference of projection patterns, the high-speed vision platform used in this system is dedicated and improved for dual-camera frame-straddling by developing a hardware logics for the time delay control between the two cameras.