論文の内容の要旨

A 3D Acquisition Technique in Dynamic Environments Using Structured Light Patterns
(構造光を用いた動的な環境における 3 次元形状取得手法に関する研究)

氏名　　ダオ　ヴィンニン

The main purpose of this research is to propose techniques that allow a mobile projector-camera system to be used freely in ubiquitous environments. This research concentrates on the geometrical aspect of a mobile projector when it displays images on an arbitrary surface. An advantage of a mobile projector is that its usage is no longer restricted to office environment; instead it can be used anywhere and can display on any surface. However, to display the contents on a 3D surface properly, geometry information of a surface is essential. There are 3D acquisition techniques using structured light pattern to measure surface geometry, but most of them cannot reconstruct 3D geometry of objects in dynamic environments or can produce only sparse data.

We proposed a novel one-shot 3D acquisition technique by using an image of a dense checkerboard pattern. The checkerboard pattern is displayed by the projector and captured by the camera, and only a single image of the checkerboard pattern is required to reconstruct 3D geometry structure. Our proposed technique can robustly recognize a dense checkerboard pattern under dynamic conditions. The recognition process is adaptive to different light conditions and objects' color. It is minimally affected by light intensity and surface's discontinuity thereby avoiding the need to set threshold values manually for different objects especially when the device is moving.

A checkerboard pattern is used widely in many computer vision processes, such as a camera calibration, or simple geometry registration process. The checkerboard pattern is preferred in many computer vision systems because the basic crossing feature points are robustly detected and refined to sub-pixel accuracy. A black-white checkerboard pattern is also convenient to be displayed as an imperceptible pattern. However, until now most of contemporary recognition process is usually sensitive to the pattern's distortion and noise. Our proposed technique can robustly recognize a checkerboard pattern by adaptively changing the threshold in the detection process. Their rich connection of checkerboard corners is utilized to eliminate noise and their constraints can be used to identify their corresponding positions.

This dissertation research proposes a technique to find corresponding positions for the checkerboard pattern displayed by a projector, without needing any position-encoding techniques. Most of contemporary correspondence matching techniques for structured light patterns require some positional coding by using time sequence or colors or spatial characteristics of the structured light pattern to distinguish the feature points from each others. These coding techniques are either complicated to create, sensitive to dynamic conditions or heavily affected by the surface condition of objects to be scanned. Our proposed technique enables the checkerboard pattern to be matched to a uniquely true solution even if parts of it are occluded, and the matching process is computationally efficient and can be carried out in real time. Our approach to solving the correspondence problem for a dense checkerboard pattern is by using the combination of epipolar geometry and topology constraints in the checkerboard pattern. Epipolar geometry is a common technique to search for corresponding positions in stereo camera systems, and it has been used widely in projector-camera system for 3D acquisition purposes. However, existing techniques either require heavy computation or cannot assure a unique correspondence position for a dense pattern.

Our proposed correspondence matching technique is not limited to a checkerboard pattern. It can also be applied in other kinds of grid patterns to solve ambiguity caused by epipolar geometry. However, the combination of our robust checkerboard pattern detection technique and checkerboard matching technique allows a mobile projector-camera system to acquire environment geometry information in dynamic environments.

We constructed a handheld projector--camera system to verify the feasibility of the proposed techniques. The system is portable, and can acquire 3D geometry of colorful and dynamic objects at the video capture frame rate (30fps). However, the contribution is not only by creating a real time scanner system. The simplicity of the structure light pattern, the assurance of a unique correspondence for matching a checkerboard pattern, the analysis of convergence conditions against noise and the robustness of the acquisition technique are the main contributions of this dissertation research.