公益財団法人 セコム科学技術振興財団
研究成果報告書

研究課題名
次世代画像入力システムを実現する高速パンチルト・リフォーカスカメラの研究

Developments of High-Speed Pan-Tilt and Refocus Camera
for Next-Generation Image Capture System

研究期間
平成２８年１０月　～　令和３年５月

報告年月
平成３年６月

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Abstract

Cameras are important to ensure the safety of nowadays life of people. The recent advances of the image recognition using artificial intelligence has also increased the importance of cameras. Recently, the performances of cameras have been improved, such as resolution and frame rate. However, the movement of the gaze direction of cameras (pan-tilt function) has so far been performed using the mechanical system so the cameras cannot follow fast movements of target objects. The focus of the camera has also been altered using the mechanical system so the cameras cannot quickly change the focus position. This study proposes the high-speed pan-tilt refocus camera to address the remaining issues of the present cameras. The experimental verification of the proposed technique is shown and the applications of the proposed technique are discussed.

The high-speed pan-tilt refocus camera consists of the pan-tilt part consisted of micro-lens arrays and the refocus part which performs numerical image focusing using a computer (refocus process). In the pan-tilt part, two parallelly aligned micro-lens arrays are used, which are shifted each other to change the direction of the optical axis so the pan-tilt function is realized. When the lens arrays are shifted with an amount of the pitch of lenses of the lens arrays, the maximum pan-tilt angle is achieved. Therefore, when the lens arrays with a lens pitch of approximately 100 μm are used and piezo actuators are used to displace the lens arrays, the high-speed pan-tilt action is achieved. The aperture array is used to extract partial images from images produced by the first lens array and the extracted images are magnified by the second lens array to produce elementary images on the image sensor. The parallax images are synthesized from the elementary images and the numerical focusing is performed by synthesizing the parallax images. Because the parallelism of this refocusing calculation is quite high, this study utilizes GPUs to enable the fast numerical focusing.

The experimental system was constructed to verify the proposed technique. The micro-lens arrays with a lens pitch of 103.5 μm and a size of 15.0 mm×11.0 mm were designed and fabricated. The image sensor with a resolution of 4,096×3,000 and the piezo actuators with a maximum stroke of 100 mm were combined to build the experimental system. The experimental system had a maximum pan-tilt angle of 25^0 and an operating frequency of 1 kHz. The multiple GPU system was constructed for the refocusing process and the calculation time of 3.8 ms was achieved using two GPUs. The above results show the validation of the proposed technique.

Then, the reduction of blurs of the refocused images was explored. When the conventional technique is used, the parallax images are distorted due to the lens aberration of the lens arrays and the synthesis of the distorted parallax images causes blurs in the refocus images. This study proposes a new algorithm which generate refocus images directly from the elementary images without the generation of the parallax images. This algorithm reduced the blurs of the refocus images. Because the parallax images are not generated, the calculation time and the memory usage are reduced.

The applications of the proposed high-speed pan-tilt refocus camera were developed, such as, the resolution increased image capturing technique by use of the pan-tilt function, and the 3D image capturing system for 3D displays by use of the refocusing function.

Finally, the future improvements of the performances of the high-speed pan-tilt refocus camera and its applications are discussed.