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Quick-Response Control of Liquid Crystal Lens Cell based on Effective Voltage Control

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One of the most common ways to improve the safety of vehicles and drones is to use cameras to understand their surrounding environment. Such camera systems must be stable enough to operate in any environment, have low installation costs, and perform as a high-performance sensor capable of capturing a wide range of information. Therefore, the authors have focused on camera technology that realizes a wide field of view and high optical magnification at the centre, called the wide-angle fovea lens. The associated liquid crystal lens could be useful for a high-definition sensor that is very small like the human eye, but can flexibly and instantly magnify a specific viewpoint in a wide field of view. This study examines feasibility of a zoom lens system using liquid crystal lenses to realize it without any mechanical component. The zoom lens system using liquid crystal lenses was actually built by the authors, and experiments are carried out to capture magnified images. On the same time, its response time for changing a focal length of the liquid crystal lens is evaluated.

A liquid crystal material is sealed between two ITO glass plates. We call this optical device a liquid crystal lens cell. In this liquid crystal lens cell, the internal refractive index changes due to the molecular orientation effect in a liquid crystal layer when an AC voltage is applied externally to the upper and lower electrodes, and a single liquid crystal lens can achieve various focal lengths from a convex lens to concave one.

Hirai and et.al. proposed a zoom system designed based on the lens configuration of the Galilean telescope (Fig.1), which has no mechanical part and can be controlled entirely-electronically by small electric power of a few μW order. From left to right, the system consists of an obeject, two liquid crystal lenses, a convex glass lens, and a CMOS image sensor. Since the two liquid crystal lens cells have a very small electrode aperture of 2 mm, an image is projected darkly. Therefore, a glass convex lens with a focal length of f_0 = 30mm, which acts as an imaging lens, is placed between the liquid crystal lens cells and the imager. Define a focal length of liquid crystal lens1 as f_1, a focal length of liquid crystal lens2 as f_2, and a distance between the two liquid crystal lens cells as L. Then, magnification factor m when is $L = f_1 + f_2$, is denoted by

$$m = -f_2 / f_1 .$$

In this paper, the authors propose a system for realizing a zoom lens system using liquid crystal lenses, and conducts magnified image formation experiments of a zoom lens system without any mechanical part using two liquid crystal lens cells and one convex glass lens by combining our proposed method and existing methods.

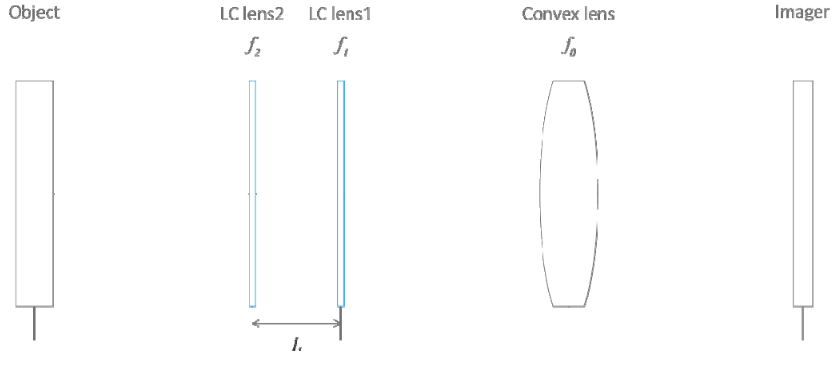

Fig.1 Non-Mechanical Zoom lens System Using Liquid Crystal Lenses