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VISION IMPROVEMENT OF CCTV CAMERA USING VARI-FOCAL LENS FOR SURVEILANCE ACTIVITIES

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Abstract

Most recent Lens operates using extended zooming technique, in surveillance system of security operation, a clearer viewing of image recording and capturing is required of a Close Circuit Television (CCTV) cameras. Most recent camera have been developed to improve on vision. Vari-focal Lens camera provides a robust way to capture either spatial or angular images within a single shot. The essential factor of this camera is in 3D depth sensing, which can extract depth information from the acquired scene. However, other CCTV conventional light field cameras suffered from shallow depth of field (DoF). Here, a Vari-focal light field camera (VF-LFC) with an extended DoF is a new innovation for mid-range 3D depth sensing applications as a main lens of the system, a Vari-focal lens with four different focal lengths is adopted to extend the DoF up to 15 m. The focal length of the Micro-Lens Array (MLA) is optimized by considering the DoF both in the image plane and in the object plane for each focal length. This is by dividing measurement regions with each focal length, depth estimation with high reliability which is available within the entire DoF. The VF-LFC is evaluated by the disparity data extracted from images with different distances. Moreover, the depth measurement in an outdoor environment demonstrates that VF-LFC could be applied in various fields such as delivery Robots, various surveillance applications, autonomous Vehicles, and remote sensing Drones, poor vision of recorded image can be eliminated using Vari focal lens and advance vision definition.

Keywords: Depth of Field, Micro-Lens Array, CCTV, Surveillance

1. Introduction

Camera systems have advanced to mimic the mechanism and function of the sight biological organ (eyes) [1–4]. However, conventional 2D imaging systems are limited in capturing the real world because of the lack of in-depth image clarity. A vari-focal lens incorporated in a security camera with an adjustable focal length, angle of view and level of zoom improves camera performance [2]. This type of lens is often used in facilities like airports, hospitals, government offices and warehouses [3-4]. And other surveillance activities.

They are designed for uses that require multiple angles of view that a standard camera cannot achieve, this new camera contains four 5MP vari-focal lenses that provide separate video streams (capturing). A single device can be deployed with capability of capturing a wider scene [4]. The vari-focal lenses can be positioned in infinite configurations to allow end users to view and record what is most important. The Multi-Imager is equipped with WDR, audio and alarm for enhanced video capture [2]. "The ability to configure each of the four lenses allows a vari-focal multi-imager (VMI) camera to cover virtually any security footprint," according to Bill Hobbs, Vice President of Global Sales for 3xLOGIC. "Because the camera provides wider view.

However, conventional 2D imaging systems are limited in capturing the real world because of the lack of depth-of-information [DoI] [4]. A light field camera (Vari-focal Cameras) provides a facile way to capture 3D information (light field or preoptic function) of an object with only a single image sensor and micro-lens array without any external light source, so it has attracted considerable interest in both academia and industry. Vari-focal camera consists of a micro-lens array (MLA), a core optical component, acting like a multi-camera array and acquires light field data which can be adjusted in depth estimation, multi-viewing imaging, digital refocusing, and 3D reconstruction [5].

The initial light field cameras were proposed with two different approaches: placing a pinhole grating inside the camera and placing a micro-lens in front of the image plane [5,6]. Based on these concepts, Ng et al introduced the first hand-held plenoptic camera called the standard light field camera (plenoptic 1.0) in 2005 [**7**], and a focused light field camera (plenoptic 2.0) was proposed by Lumsdaine and Georgiev in 2009 [8]. Since then, numerous studies have flourished based on these two types of light field camera and various applications have been explored by utilizing the light field data. For instance, the development of Micro-Lens Array (MLA) fabrication in a large area facilitates the integration of customized light field cameras for all-in focus imaging from a single exposure [9], and geometrical calibration and depth estimation algorithms have been developed to extract depth information from the lens-let light field camera [10,11].

In particular, 3D depth sensing is one of the major concerns in modern security and automation systems, and the light field camera could be a vital technique for depth sensing vision systems [**12**]. To realize 3D imaging equivalent to human vision, near- (~1 m) to mid-range (~10 m) depth sensing is required in the artificial vision system including the light field camera

2. Methodology

Figure 1 shows a configuration process of CCTV camera for surveillance activities, indicating various steps taken during the activity, when attached with vari focal lens. The visibility improved and clearer images are verified and surveillance activities are determined.

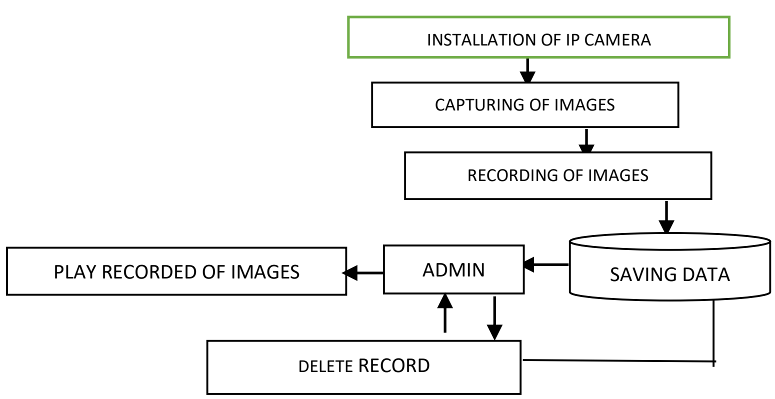

Figure1. Flowchart of conventional camera for surveillance activities

Conventional light field cameras consist of a fixed focal lens as a main lens, the micro-lens arrays (MLA), and image sensor as shown in figure (2). Each micro-lens of the micro-lens array (MLA) acts as a single camera by focusing the image from the main lens on the image sensor with slightly different perspectives, so that it is possible to capture light field data including disparity. The disparity should be adjusted to have a sufficient slope to extract depth information within the distance (coverage) range, but it quickly converges as the distance increases out of the depth of focus (DoF) of the light field camera, as shown in figure (2). Therefore, to extract depth information from far objects, a light field camera should have a large depth of focus (DoF). However, in the conventional light field camera system with fixed focal lens, the micro-lens array (MLA) has a fundamentally limited depth of focus (DoF), so the conventional light field camera suffers from a shallow depth of focus (DoF) according to Hsieh et al., [18].

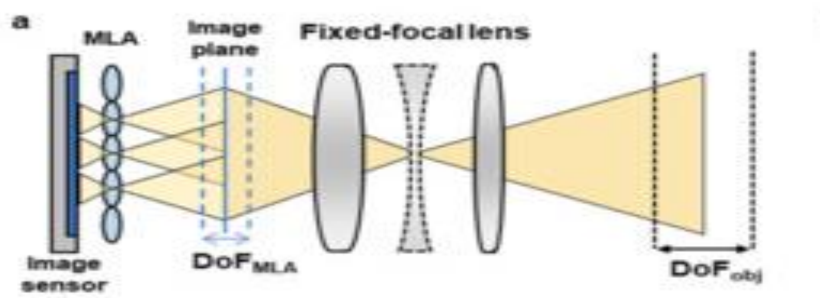

Figure 2. Micro-Lens Arrays (MLA)

The VF-LFC consists of a vari-focal lens as main lens, a micro-lens array, and an image sensor as shown in figure 3a. Based on plenoptic camera 2.0, an image of an object located at a_L is formed by the main lens at the position of b_L. The micro-lens array (MLA) is located behind the image plane with a distance of a, and the image sensor is located behind the MLA with a distance of b. The MLA focuses the image of the main lens, as an object, on the image sensor. The depth estimation principle of the VF-LFC is as follows. The distance a_L from the main lens to the object can be calculated by the thin lens equation using the focal length of the main lensf_L and b_L, which is expressed by:

$$\frac{1}{f_L} = \frac{1}{a_L} + \frac{1}{b_L} \qquad (1)$$

Where:

f_L = focal length of the main lens

a_L= image of an object location

b_L = object location

Each micro-image formed on the image sensor shows the main lens image with a slightly different point of view. figure 3b describes the triangulation scheme based on the projection of two micro-images. $p_{x,1,2}$ is the distance between the image point to the principal point of the respective micro-image, and $d_{1,2}$ is the distance from the intersection point of the image plane and a baseline that is an optical axis of the respective micro-lens. In figure 3a, b, an up-pointing arrow and a down-pointing arrow of distance present positive and negative values, respectively. Triangles which have equal angles are similar, and thus, the following relation is validated:

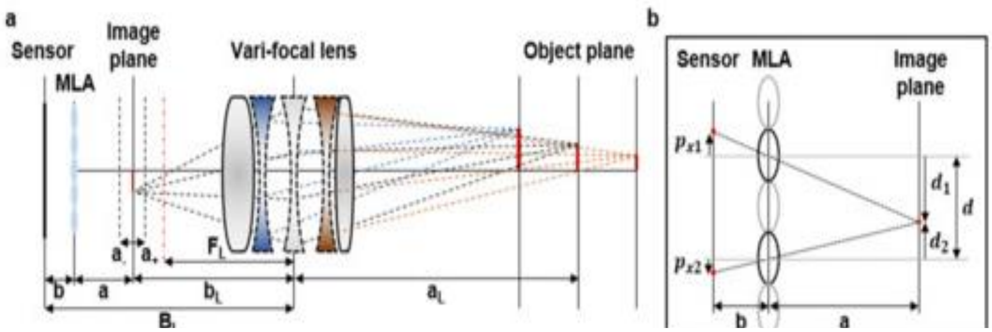

Figure 3. a and b design parameters and optical path through the Micro-Lens Array

$$p_{xi} = \frac{d_i \times b}{a} \quad (2)$$

Where d_i is the baseline distance between two micro-lenses.

The baseline distance between two micro-lenses is defined as follows:

$$d_i = d_2 - d_1 \quad (3)$$

Similarly, if we define the parallax of the image point, p_x, as the difference between p_{x1} and p_{x2}, it can be defined as follows from Equations (2) and (3).

$$p_x = p_{x1} - p_{x2} = \frac{d_2 - d_1}{a} \quad (4)$$

The distance between the image plane and the MLA, a, is described as a function of the baseline distance d, the distance between the MLA and sensor, b, and the estimated parallax,(p_x)

$$a = \frac{d \times b}{p_x} \quad (5)$$

In addition, the distance between the image plane and main lens, b_L, can be calculated by a known parameters B_L and b.

$$b_L = B_L - b - a \quad (6)$$

The object plane distance from the main lens, a_L, is calculated by substituting Equation (5)
into the Equation (1), which is expressed by:

$$a_L = \left\{\frac{1}{f_L} - \frac{1}{B_{L-b-a}}\right\}^{-1} \quad (7)$$

Consequently, the depth can be estimated from a point which is simultaneously focused on at least two micro-images.

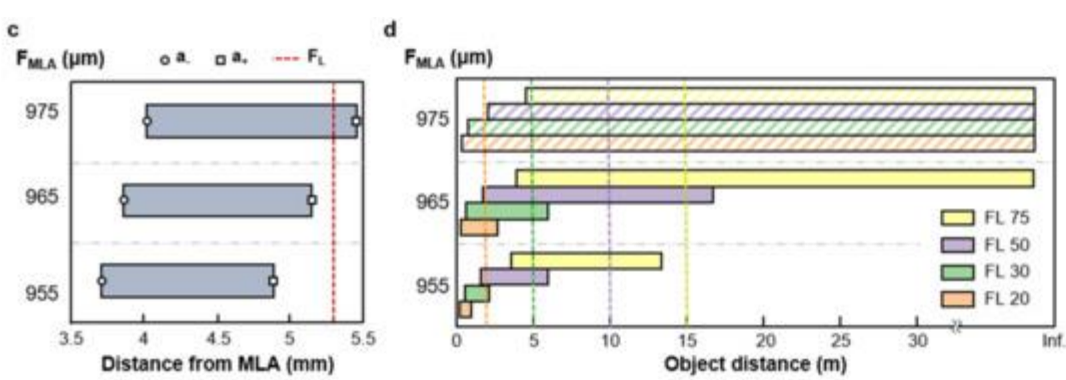

Figure 4. c and d are optical path through the Micro-Lens Array and the image side of depth of focus.

In figure 3. (a) the VF-LFC system with main design parameters is sketched. (b) Shows the optical path through the Micro-Lens Array (MLA) between the image sensor and the image plane of the main lens. (c) The image side of depth of focus (DoF), a_+ and a_- are calculated from the thin lens equation for a focal length of MLA. (**d**) The object side depth of focus (DoF) for each focal length of a vari-focal lens according to the Micro-Lens Array (MLA) focal length, the dotted lines are the boundaries between measurement regions of each focal length.

Figure 3.c shows the image side depth of focus (DoF) according to the micro-lens array (MLA) focal length. (F_L) is a focal length of the main lens when the object is at infinity. If the image side DoF exceeds the F_L, the image becomes blurred because it is out of the focal range. Therefore, the MLA focal lengths of 955m and 965m are more desirable than 975m for the selected vari-focal lens. For the depth estimation with high accuracy, the object should be located within the DoF of the light field camera system. Since the image side and object side Depth of Focus (DoFs) are correlated with each other, the object side depth of focus is determined by the image side, region within the image side DoF.

Table 1. Parameters of MLA and image sensor.

Micro-lens Array	Image Sensor
Pitch 240m	Model IMX178 (Sony, Tokyo, Japan)
Focal-length 965m	Pixel size 2.4m
Array-type Hexagonal	Number of pixels 3096 (H) x 2080 (V)

Table 2. Intrinsic parameters for vari-focal light field camera.

b(mm)	b(μm)	F_L(mm)	b_L(mm)
1.235	101.8	20, 30, 50, 75	$5.3 - b + f_L$

In this regard, the MLA of VF-LFC design to have a focal length of 965 m considering the DoF of both the image side and the object side. a_+ and a_- becomes appropriate . The object side DoF was calculated for focal lengths of 20 mm, 30 mm, 50 mm, and 75mm, respectively (figure 3d). The dotted lines indicate the boundaries between measurement regions of each focal length. In case of the focal length 955m, the object side DoF does not cover the target object distance of 15m, even though there is no blurred a+ and a_-. The dotted lines indicate the boundaries between measurement regions of each focal length. In case of the focal length 955m, the object side DoF does not cover the target object distance of 15 m, even though there is no blurred region within the image side DoF. In this regard, the MLA of VF-LFC design to have a focal length of 965m considering the DoF of both the image side and the object side was used.

Table 3. Light field camera classification.

Light Field Type	**Objective Lens**	**Depth of Field**	**Main Characteristics**
Unfocused LFC (1.0)	Zoom lens	0.05–2m	Lytro 1st generation
Unfocused LFC (1.0)	Zoom lens	0.5–0.9 m	-
Focused	3.04 mm	0.05 –	Small form

LFC (2.0)		0.25 m	factor
Focused LFC (2.0)	35 mm	0.7–5.2 m	Raytrix camera
Focused LFC (2.0)	39.8 mm	~0.59m	LC MLA (tunable)
Focused LFC (2.0)	Zoom lens	0.5–15m	Vari-focal lens

3. Results Discussion

In security surveillance, closed circuit television (CCTV) is a system of video cameras, display devices and data networks used to detect and deter sensitive and criminal activities. Video surveillance systems are used in public and private sectors, such as schools, homes or public spaces for crime prevention purposes. A vari-focal security camera is a special sets of cameras that improved in performance quality over all other conventional cameras in used depicted in the various images clarification - its mode of adjustment, operating, and mode of operation make this camera appropriate for offices, schools, businesses or home security architecture. Vari-focal lenses have greater flexibility and the zooming is essential for commercial premises which is the most important architectural system in coverage when it comes to video security in surveillance.

In complex situations, getting a vari-focal security camera is the best option. As it can easily be adjusted since it possesses multiple focal length and the level of zoom with a vari-focal camera is tremendous, you can also decide afterward what area wants monitoring. Moreover, the process of adjusting the field of view in the vari-focal setting is not complicated. High-quality images and videos with motorized lenses: Most static security cameras use digital zoom, which reduces the quality of an image or video when enlarged. Digital zoom uses fewer pixels to give you a closer view of objects or particular areas, which can be problematic, especially if you need to see clear details of these objects or areas. With vari-focal cameras, image and video quality is preserved, even if you adjust the depth of field. For example, a fully zoomed-in 4MP veri-focal camera will provide the same image quality, regardless of whether it is zoomed-in or not.

Easy installation process: In an event of having fixed cameras, reinstalling them can be costly and time-consuming, especially if situation of relocation or in the process of renovating a certain facility area. When these types of security cameras are relocated, it becomes completely necessary to remove it from its original place. If your camera is wired, this means that you need to install new wiring in your location surveillance location. With vari-focal IP cameras or vari-focal fixed IP cameras, the installation process is simple and straightforward and connects via Ethernet, both wireless and wired, less wiring needed.

4. Conclusions

In summary, we proposed the VF-LFC with an extended DoF by introducing a vari-focal lens as a main lens. Unlike conventional light field cameras, which suffer from an inherently limited DoF, the proposed VF-LFC successfully extends its DoF up to ~15 m. We divided the four measurement regions according to the focal lengths of a vari-focal lens (20 mm, 30 mm, 50 mm, and 75 mm) to achieve the target DoF. Each measurement region contains the partially overlapping area with its adjacent region for continuity. By considering both the DoF (image side) of MLA and the DoF (object side) of the main lens, the focal length of MLA was adjusted to be 965 μm.

For mechanical robustness, a light field module is considered to meet an optical alignment, and the module adaptable to a C-mount lens, which is generally used for machine vision. The disparity data extracted from the object images according to each measurement region are compared with the non-vari-focal values and indicate that the VF-LFC can provide depth information with the range of the extended DoF. In addition, the outdoor measurement demonstrations revealed that VF-LFC can be implemented for various circumstances such as autonomous vehicles, delivery robots, and remote sensing drones that require 3D information acquisition from short to medium distances other than just security alone.

5. Recommendations

Having good security cameras in place can help detect intruders and protect the premises from physical threats. Security cameras are critical player in physical security, and investing in the right equipment can go a long way. Considering the importance of the vari-focal security cameras for surveillance activities, the camera efficiency has been analysed over the fixed lens types to determine the camera DoF, this quality is a major decision to choose Vari focal equipment which is best for any organization security architecture.

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