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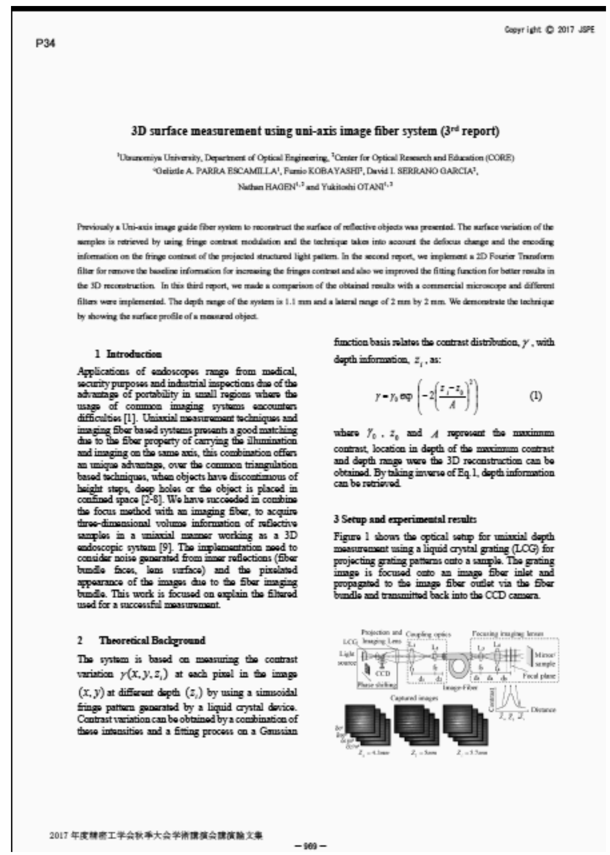
オーガナイズドセッション「光応用技術・計測」講演
3D surface measurement using uni-axis image fiber system (3rd report), 2017年精密工学会秋季大会, P34.

内視鏡を用いたユニアクシス3次元表面測定システムとして，構造化照明による投影パターンとその検出を同一にして投影された縞パターンのコントラストから高さ情報を検出することでパイプや人体内部計測を可能なイメージングファイバーを用いた計測システムの構築に対して贈賞。



P34

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3D surface measurement using uni-axis image fiber system (3rd report)

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Previously a Uni-axis image guide fiber system to reconstruct the surface of reflective objects was presented. The surface variation of the samples is retrieved by using fringe contrast modulation and the technique takes into account the defocus change and the encoding information on the fringe contrast of the projected structured light pattern. In the second report, we implement a 2D Fourier Transform filter for remove the baseline information for increasing the fringes contrast and also we improved the fitting function for better results in the 3D reconstruction. In this third report, we made a comparison of the obtained results with a commercial microscope and different filters were implemented. The depth range of the system is 1.1 mm and a lateral range of 2 mm by 2 mm. We demonstrate the technique by showing the surface profile of a measured object.

1 Introduction

Applications of endoscopes range from medical, security purposes and industrial inspections due of the advantage of portability in small regions where the usage of common imaging systems encounters difficulties [1]. Uniaxial measurement techniques and imaging fiber based systems presents a good matching due to the fiber property of carrying the illumination and imaging on the same axis, this combination offers an unique advantage, over the common triangulation based techniques, when objects have discontinuous of height steps, deep holes or the object is placed in confined space [2-8]. We have succeeded in combine the focus method with an imaging fiber, to acquire three-dimensional volume information of reflective samples in a uniaxial manner working as a 3D endoscopic system [9]. The implementation need to consider noise generated from inner reflections (fiber bundle faces, lens surface) and the pixelated appearance of the images due to the fiber imaging bundle. This work is focused on explain the filtered used for a successful measurement.

2 Theoretical Background

The system is based on measuring the contrast variation $\gamma(x,y,z_i)$ at each pixel in the image (x,y) at different depth (z_i) by using a sinusoidal fringe pattern generated by a liquid crystal device. Contrast variation can be obtained by a combination of these intensities and a fitting process on a Gaussian function basis relates the contrast distribution, γ, with depth information, z_i, as:

$$\gamma = \gamma_0 \exp\left(-2\left(\frac{z_i - z_0}{A}\right)^2\right) \quad (1)$$

where γ_0, z_0 and A represent the maximum contrast, location in depth of the maximum contrast and depth range were the 3D reconstruction can be obtained. By taking inverse of Eq.1, depth information can be retrieved.

3 Setup and experimental results

Figure 1 shows the optical setup for uniaxial depth measurement using a liquid crystal grating (LCG) for projecting grating patterns onto a sample. The grating image is focused onto an image fiber inlet and propagated to the image fiber outlet via the fiber bundle and transmitted back into the CCD camera.

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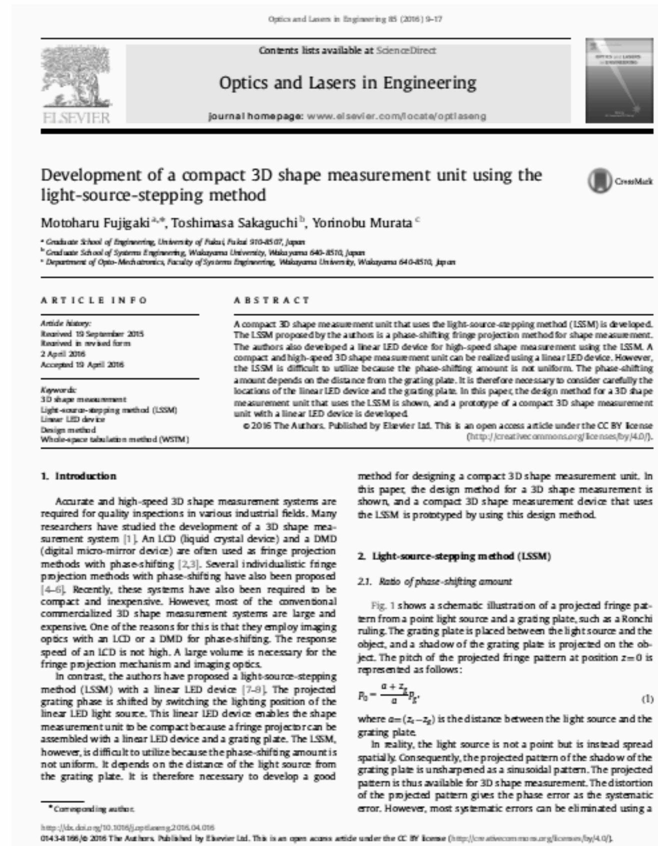
吉澤論文賞

藤垣 元治（福井大学）

Development of a Compact 3D Shape Measurement Unit Using the Light-source-stepping Method : Fujigaki,M., Sakaguchi,T., Murata,Y. ,Optics and Lasers in Engineering, Vol. 85, 9-17(2016)

　高速でかつ高精度に三次元計測をするため光源切替位相シフト法と全空間テーブル化手法において，高速に格子パターンの位相シフトを行うことができる光源切替位相シフト法とそれを実現するためのラインLEDデバイス，光源切替位相シフト法における位誤差の伝播が検討により小型の三次元計測装置の開発に対しての贈賞。



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Development of a compact 3D shape measurement unit using the light-source-stepping method

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ABSTRACT

A compact 3D shape measurement unit that uses the light-source-stepping method (LSSM) is developed. The LSSM proposed by the authors is a phase-shifting fringe projection method for shape measurement. The authors also developed a linear LED device for high-speed shape measurement using the LSSM. A compact and high-speed 3D shape measurement unit can be realized using a linear LED device. However, the LSSM is difficult to utilize because the phase-shifting amount is not uniform. The phase-shifting amount depends on the distance from the grating plate. It is therefore necessary to consider carefully the locations of the linear LED device and the grating plate. In this paper, the design method for a 3D shape measurement unit that uses the LSSM is shown, and a prototype of a compact 3D shape measurement unit with a linear LED device is developed.

1. Introduction

Accurate and high-speed 3D shape measurement systems are required for quality inspections in various industrial fields. Many researchers have studied the development of a 3D shape measurement system [1]. An LCD (liquid crystal device) and a DMD (digital micro-mirror device) are often used as fringe projection methods with phase-shifting [2,3]. Several individualistic fringe projection methods with phase-shifting have also been proposed [4–6]. Recently, these systems have also been required to be compact and inexpensive. However, most of the conventional commercialized 3D shape measurement systems are large and expensive. One of the reasons for this is that they employ imaging optics with an LCD or a DMD for phase-shifting. The response speed of an LCD is not high. A large volume is necessary for the fringe projection mechanism and imaging optics.

In contrast, the authors have proposed a light-source-stepping method (LSSM) with a linear LED device [7–9]. The projected grating phase is shifted by switching the lighting position of the linear LED light source. This linear LED device enables the shape measurement unit to be compact because a fringe projector can be assembled with a linear LED device and a grating plate. The LSSM, however, is difficult to utilize because the phase-shifting amount is not uniform. It depends on the distance of the light source from the grating plate. It is therefore necessary to develop a good method for designing a compact 3D shape measurement unit. In this paper, the design method for a 3D shape measurement is shown, and a compact 3D shape measurement device that uses the LSSM is prototyped by using this design method.

2. Light-source-stepping method (LSSM)

2.1. Ratio of phase-shifting amount

Fig. 1 shows a schematic illustration of a projected fringe pattern from a point light source and a grating plate, such as a Ronchi ruling. The grating plate is placed between the light source and the object, and a shadow of the grating plate is projected on the object. The pitch of the projected fringe pattern at position $z=0$ is represented as follows:

$$P_0 = \frac{a + z_g}{a} p_g, \qquad (1)$$

where $a = (z_s - z_g)$ is the distance between the light source and the grating plate.

In reality, the light source is not a point but is instead spread spatially. Consequently, the projected pattern of the shadow of the grating plate is unsharpened as a sinusoidal pattern. The projected pattern is thus available for 3D shape measurement. The distortion of the projected pattern gives the phase error as the systematic error. However, most systematic errors can be eliminated using a

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吉澤業績賞

武田 光夫（宇都宮大学）

現在まで幅広く用いられている縞解析手法「フーリエ変換法」の開発による光計測分野に多大な貢献，およびメカノフォトニクス専門委員会においては，Senspec2016の「三次元光計測の基礎」の講演を通して光計測における縞解析の原理を企業若手技術者への教育活動への貢献による「フーリエ変換法」の開発並びに若手技術者への啓蒙活動に対しての贈賞。

2018年
吉澤奨励賞

ヘリステル・パラ・エスカミーラ　殿

3D surface measurement using uni-axis image fiber system

2018年6月14日

公益社団法人精密工学会
メカノフォトニクス専門委員会
委員長　新井泰彦

2018年
吉澤論文賞

藤垣 元治　殿

Development of a Compact 3D Shape Measurement Using the Light-source-stepping Method

2018年6月14日

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メカノフォトニクス専門委員会
委員長　新井泰彦

2018年
吉澤賞

武田 光夫　殿

「フーリエ変換法」の開発並びにSenspec2016における「三次元光計測の基礎」に関する講演を通した企業若手技術者への光計測啓蒙活動

2018年6月14日

公益社団法人精密工学会
メカノフォトニクス専門委員会
委員長　新井泰彦