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CONSTRUCTION MODIFICATION OF DATA-PROJECTOR FOR OPTICAL 3D MEASUREMENT

KONSTRUKČNÍ ÚPRAVY DATAPROJEKTORU PRO OPTICKÁ 3D MĚŘENÍ

Abstract

Optical profilometric and topographic non-coherence measurements have a great use today, for example in deformation measurement, product quality control, total arthroplasty wear measurement and many others. These measurements are based on using optical structure, which is projected on the measured object and is deformed by its surface. Good projector of such optical structure is data-projector. Its imperfection is too large zoom of serial objective, so measurement of small objects is influenced by quite big measurement error. This is caused by projecting only small part of optical structure is projected on measured object and that negative influences resolution of measurement method. For the measurement of small objects is necessary replace the serial objective by objective, whom parameters allow the measurement of this object influenced by the measurement error as small as possible. The contribution describes calculation procedure of new objective parameters a several examples of its usage in optical 3D methods.

Abstrakt

Optická profilometrická a topografická nekoherentní měření mají dnes široké uplatnění, jako například měření deformace předmětů, ověřování kvality výrobků, měření otěru endoprotéz a mnoho jiných. Tato měření používají ve svém principu optickou strukturu, která je promítána na předmět a jeho povrchem je deformována. Dobrým projektorem takovéto promítané optické struktury je dataprojektor. Jeho výrazným nedostatkem je ovšem příliš velké zvětšení sériového objektivu, takže měření předmětů menších rozměrů je zatíženo příliš velkou chybou. Ta je způsobena tím, že pouze malá plocha promítané optické struktury je zobrazena na měřený předmět, což negativně ovlivňuje rozlišení měřící metody. Pro měření těchto předmětů je vhodné nahradit tovární objektiv takovým objektivem, jehož vlastnosti umožní měření objektu daných rozměrů zatížené co možná nejmenší chybou měření. Příspěvek popisuje postup výpočtu parametrů nového objektivu a několik příkladů jeho použití v optických 3D metodách.

1 INTRODUCTION

Data-projector can be used in many non-coherence optical 3D methods, like Fourier profilometry, phase-shifting profilometry, Moiré topography and others. All these methods are using the same principle, some defined optical structure is projected on the measured object and this optical structure deformed by the shape of the measured object is observed from an angle. Because of

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obtained size of that deformation and because the observation angle is known, it is possible to enumerate a high variation of measured object surface. It is a good advantage to use data-projector, because it is able to project any necessary optical structure. Of course, it is necessary to take into consideration the size of measured object, because the resolution of the projected optical structure should be at least as high as the resolution of observation camera. If this condition couldn't be satisfied, it is necessary to use other objective with higher focal distance in the data-projector, so the zoom is lower and the same number of pixels is projected onto smaller area.

2 PARAMETERS OF DATA-PROJECTOR

For example, it is used a DLP (digital light processing) data-projector. There is a so-called DLP chip inside, which is very small (1,4 cm diagonal) rectangle area with about 2 millions microscopic mirrors, all of them rotary mounted. With a light source and an objective, it is able to reflect a digital image from a graphic signal. A simple scheme of such projector is shown in fig.1.

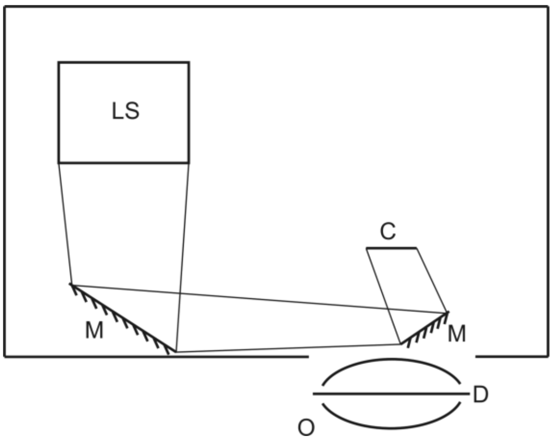

Fig. 1 Scheme of DLP projector

where:

LS - light source

M - mirrors

C - DLP chip

O - scheme of objective

D - principal plain of objective

3 EQUATIONS OF OPTICAL IMAGING

Objective displays DLP chip in distance and with zoom given by its focal distance. In the case, that we use a simple objective (lens doublet) instead of serial objective (zoom lens), we can approximate lens doublet by simple positive lens and compute with only one principal plain in relations. A simple positive lens imaging is shown in fig.2.

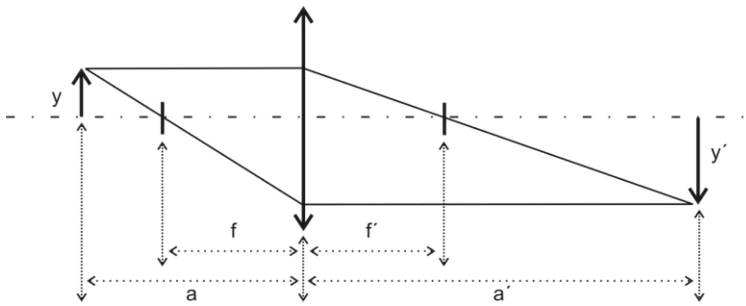

Fig. 2 Imaging of positive lens

where:

f, f´ - focal distance

a - object distance

a´ - real image distance

y - size of object

y´ - size of image

Basic equations, which will be used for computing of focal distance of the new objective and its distance from DLP chip, are Gauss imaging equation (eq.1) and equation for zoom of lens (eq.2).

$$\frac{1}{a}+\frac{1}{a'}=\frac{1}{f}\,, \qquad (1)$$

$$z=\frac{y'}{y}=\frac{a'}{a}\,, \qquad (2)$$

where all variables were described at fig.2. Zoom z is exactly set by an experimenter according to the size of measured object (to cover its entire surface by projected image) and image distance y' is approximately set according to satisfy the condition of projection from infinity. Defined variable is also y, because it is half of size of DLP chip (the centre of chip is in optical axis). It is possible to compute f by the substitution of a from eq.2 in eq.1. The problem is that f cannot take the arbitrary value, because there are several nominal values of focal distances of commercial objectives. Therefore, it is necessary to choose objective with as close value of focal distance as possible. It is profitable to choose several ones with nearest values of focal distance, and compute pair of variables a and a' for each one of them. If the value of zoom z has to be saved, the value of a' will change. It is necessary to choose such objective, which will change a' only a little. The condition of projection from infinity must be satisfied anyway, and the value of a' must also respect geometry of experimental setup. For computing values of a and a' can be used eq.3 and eq.4, which are derived from eq.1 and eq.2.

$$a'=f(1+z)\,, \qquad (3)$$

$$a=f(1+\frac{1}{z})\,. \qquad (4)$$

It is possible and profitable to construct a graph of values of a and a' depending on focal distance f, when zoom z is constant. This graph is shown in fig.3.

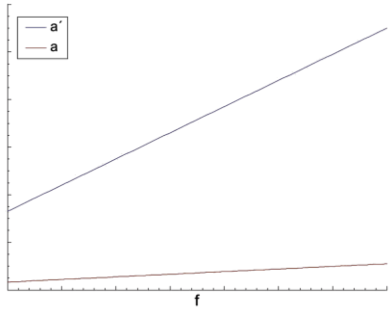

Fig. 3 Graph of object and image distances

In this graph, it is very simple to find objective, which will have focus distance as exact as possible, and to see values of object and image distances for constant zoom for each value of focal distance. Of course, it is necessary to take account of projector construction, because it allows some limit smallest distance between objective and DLP chip. Some examples of projected optical are shown below. Fig.4 shows 10 cm high sinusoidal pattern used for total knee arthroplasty wear measurement, fig.5 shows 20 cm high pattern used for face measurement. Both of them were reached by replacing objectives in data-projector in constant image distance.

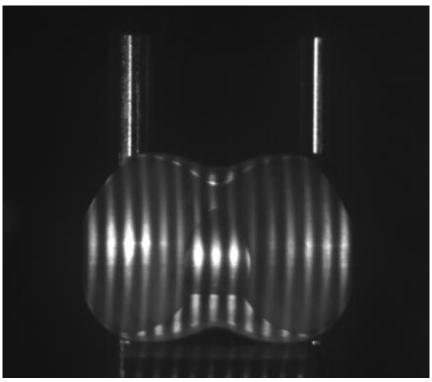

Fig. 4 Sinusoidal pattern 10 cm high

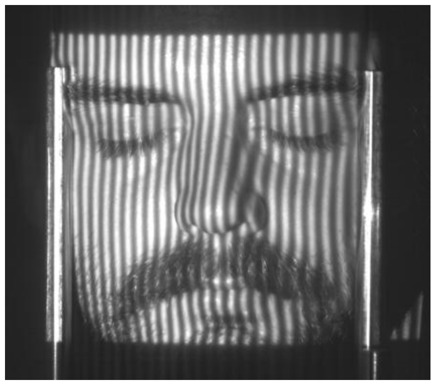

Fig. 5 Sinusoidal pattern 20 cm high

4 CONCLUSIONS

Data-projector is very good projector of sinusoidal structure for optical 3D measurement. Sometimes, its zoom is not suitable for given application, because it is too big and only its small part covers the measured object. Replacing serial objective by another one with suitable focal distance leads to cover the measured object by more pixels of projected image. This increases the resolution and the accuracy of chosen optical 3D measuring method.

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