

doi: 10.11857/j.issn.1674-5124.2018.09.007



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: 1674-5124(2018)09-0035-04

Dynamic 3D measurement method based on raster binocular stereo vision sensor

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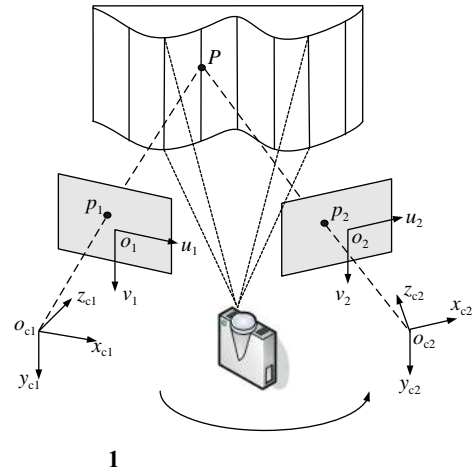
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Abstract: Based on the rectangular grating structure light and binocular vision measuring technology, a method for dynamically measuring 3D topography on the object surface is proposed. A matching method of high-density grating light stripes based on the guidance of light plane is adopted to complete matching of the left and right camera light-strip images, in which correspondence of the left and right image points can be firstly realized by homography matrix corresponding to each light plane, and then the optimal overall matching of the center points on the left and right light strips can be achieved by combining the limit constraint and the space point distance constraint. As a result, the matching problem in the grating structured light measuring system that is composed of two cameras and projectors is solved. Finally, the 3D reconstruction on the object surface is completed according to the binocular stereo vision measuring principles. In the physical experiment, the measurement of a moving arm is carried out, and the results prove that it only needs to project a single grating image to measure its 3D topography, thus, effectiveness of such method is verified.

Keywords: stereo vision; dynamic 3D measurement; raster structure light; light matching

0

[1-4]



R_{12}, t_{12}

$$\begin{cases} \rho_1 p_1 = K_1 [I & 0] P \\ \rho_2 p_2 = K_2 [R_{12} & t_{12}] P \end{cases} \quad (1)$$

$K_1 \quad K_2$

[5-6]

[7-8]

[9-10]

2

2.1

Steger [13]
Hessian

[11]

Hessian

σ_0

$$H(u, v) = \begin{bmatrix} r_{uu} & r_{uv} \\ r_{uv} & r_{vv} \end{bmatrix} \quad (2)$$

r_{uu}, r_{uv}, r_{vv}

$I(u, v)$

$g_{uu} \quad g_{uv} \quad g_{vv}$

$H(u, v)$

$$n(t) = (n_u, n_v)^T \quad (u_i, v_i)$$

1

1

P
[12]

P

$p_1 \quad p_2$

P

$O_{c1} x_{c1} y_{c1} z_{c1}$

$O_{c2} x_{c2} y_{c2} z_{c2}$

$$\begin{cases} u'_i = u_i - \frac{n_u r_u + n_v r_v}{n_u^2 r_{uu} + 2n_u n_v r_{uv} + n_v^2 r_{vv}} n_u \\ v'_i = v_i - \frac{n_u r_u + n_v r_v}{n_u^2 r_{uu} + 2n_u n_v r_{uv} + n_v^2 r_{vv}} n_v \end{cases} \quad (3)$$

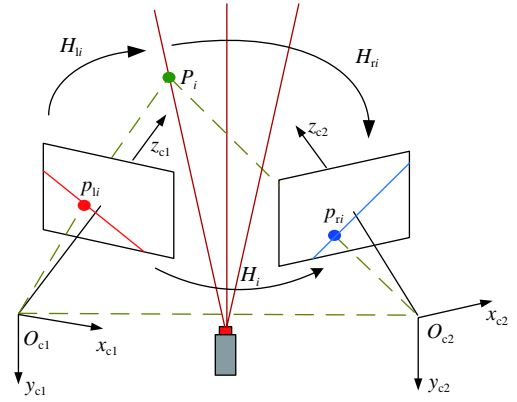
$$(tn_u, tn_v) \in \left[-\frac{1}{2}, \frac{1}{2}\right] \times \left[-\frac{1}{2}, \frac{1}{2}\right] \quad (t = -$$

$$\frac{n_u r_u + n_v r_v}{n_u^2 r_{uu} + 2n_u n_v r_{uv} + n_v^2 r_{vv}}$$

$p = (u, v)$

$n(t)^\perp \quad -n(t)^\perp$

$n(t)^\perp \quad -n(t)^\perp$



$H_i = H_{ri} H_{li} \tag{5}$

i

H_i

1

$[-22.5^\circ, 22.5^\circ] \quad 2$

$\begin{bmatrix} u_{ri} \\ v_{ri} \\ 1 \end{bmatrix} = H_i \begin{bmatrix} u_{li} \\ v_{li} \\ 1 \end{bmatrix} \tag{6}$

n

H_1, \dots, H_n

H_i

j

n

2.2

[14]

$B\{b_1, b_2, \dots, b_k\}$
 $C\{c_1, c_2, \dots, c_n\}$

(3)

p_{ri}

p_{ri}

2

$H_{ri} \quad H_{li}$

H_i

$i = 1, 2, \dots, n$

$p_{li} = [u_{li}, v_{li}, 1]^T \quad p_{ri} = [u_{ri}, v_{ri}, 1]^T$

L

m

$B \quad C$

$P_{vi} = [x_{vi}, y_{vi}, z_{vi}, 1]^T$

R_i

m

$P_{si} = [x_{si}, y_{si}, 0, 1]^T$

m

R

L

$\begin{bmatrix} x_{si} \\ y_{si} \\ 1 \end{bmatrix} = H_{li} \begin{bmatrix} u_{li} \\ v_{li} \\ 1 \end{bmatrix} p_{li} \tag{4}$

3

H_{ri}

H_i

17 mm GigE 4(a)
 1 628 pixel×1 236 pixel 600 mm×
 500 mm Dell M110 1 280 pixel×
 800 pixel 4(b)

1)

2)

3.1

3.1.1

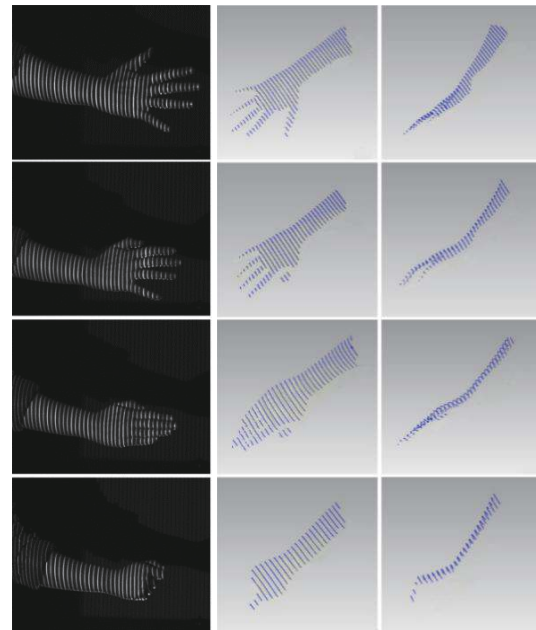
[15]

12

3



3



(a)

(b)

$$f_x=3\ 985.76\ f_y=3\ 985.84\ \gamma=5\times 10^{-5}\ u_0=816.65\ v_0=637.10\ k_1=-0.23\ k_2=0.51$$

$$f_x=3\ 986.48\ f_y=3\ 986.76\ \gamma=6\times 10^{-5}\ u_0=828.39\ v_0=603.13\ k_1=-0.23\ k_2=0.47$$

$$R = \begin{bmatrix} 0.876 & -0.063 & 0.485 \\ 0.0623 & 0.998 & 0.018 \\ -0.485 & 0.014 & 0.875 \end{bmatrix}$$

$$t = [-562.404\ -17.082\ 154.492]$$

3.1.2

2

10×10 12 mm

0.02 mm

d_t d_m d_i

RMS

RMS 0.05 mm

3.2

1 024 pixel×768 pixel

16 pixel

64

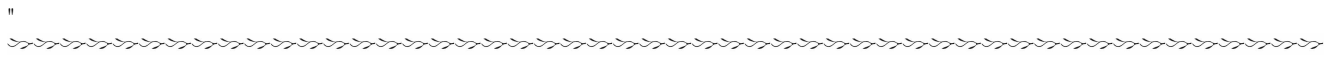
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[1] SHIRMOHAMMADI S, FERRERO A. Camera as the instrument: the rising trend of vision based measurement[J]. IEEE Transactions on Instrument Measure, 2014, 17(3): 41-47. (下转第 50 页)

"V?42"oN ≤
 203 ' "42"oN
 72"oN
 K'

J3_ IDIV"79720"7 6
 4228JU_0" < "42280
 J4_ JL"823 ô 4233JU_0"
 "42330
 J5_ /
 JL6:4 ô 422;JU_0" "422;0
 J6_ "6/
 JL725 ô 422;"JU_0" "422;0
 J7_ [L]0"
 4239."2*5+<"529/5330
 J8_ " " 0"
 [L]0" "4237."9:*+<"7;/:850
 J9_ [L]0"
 "4234."97*32+<"74;/:780
 J:~ 0" ô
 [L]0" "4235."49*4+<"4;/:80

* < +



*上接第 5: 页+

J4_ " " 0"
 [L]0" "4236."62*7+<"32:/3320
 J5_ " " " 0"
 [L]0" "4237."63*9+<"43/450
 J6_ FW"S"L."UJK"Z."FCK"D."gv"cn0"Dkpwewnc"uytgq"Xkukq"u{uyg o
 hqt "c"jw ocpqkf "tqdaq[L]0"Kpvgtpcvkqpcn"Lqwtpcn"qh"Eq o rrwgt
 Cr rnkcvkqpu"kp"Vgejppnqi {"4235."68*6+<"538/5440
 J7_ NQJ T ["Y." \ J C P I "U0"Hqwtkt"vtcpuhqt o "rtqhkno gvt {"wukpi
 c"dkpct {"ctgc" o qfwncvqkq "vgejpkswg [L]0"Qrvkecn"Gpikpggtkpi.
 4234."73*33+<"5824/582;0
 J8_ " " " 0"
 [L]0" "422:."4:*9+<"34;3/34;70
 J9_ " " " 0"
 [L]0" "4238."55*4+<"473/
 4770
 J:~ HW "["L."NWQ"S0"Htkpig"rtqlgevkq"rtqhkno gvt {"dcugf"qp"c
 pqxgn"rjcug"ujkhv"ogvjqf [L]0"Qrvkeu"Gzrtguu."4233."3;*44+<
 4395;/439690
 J:~ " " 0"

[L]0" "422;."57*6+<"78;/7960
 J32_ LCPI "Y."LG"E."UGQ "[."gv"cn0"Uvtwewtgf/nkijv "uytgq<
 Eq o rctcvkxg"cpnc{uku"cpf"kpvgitcvkq"qh"uytwewtgf/nkijv"cpf
 cevkxg"uytgq"hqt"ogcuwtkpi" f{pc oke"ujcrg[L]0"Qrvkeu"cpf
 Ncugtu"kp"Gpikpggtkpi."4235."73*33+<"3477/34860
 J33_ YQPI "C"M"E."PKW"R "[."JG"Z0"Hcu"ceswkvkq"qh"fgpug
 fgrvj"fcvc"d{ "c"pgy "uytwewtgf"nkijv"uejgog[L]0"Eq o rrwgt
 Xkukq"cpf"Kocig"Wpfgtucpfpki."4227.";:*5+<"5;:/6440
 J34_ 0"]O_0" < "422:.<"48/620
 J35_ UVG IGT"E0"Cp"wpdkcugf"fgvgevt"qh"ewtXknkpgct"uytwewtgu [L]0
 KGGG "Vtcpucevqpu "qp "Rcwgt" "Cpcn{uku "cpf "Ocejkpg
 Kpvgnki gpeg."3; ; : "42*4+<"335/3470
 J36_ " " 0"
 [L]0" "4234."5:*7+<
 7;3/7;60
 J37_ \ J C P I " \ "[0 "C "hgzkdng "pgy "vgejpkswg "hqt "ec o gtc
 ecnkdtcvkq [L]0 "KGGG "Vtcpucevqpu "qp "Rcwgt" "Cpcn{uku "cpf
 Ocejkpg"Kpvgnki gpeg."4222."44*33+<"3552/35560

* < +