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醱瑃庞暇咤遭 CMOS 槲崥块笃謇都嚜蘸涟

&　姈[1,2],旞　竬[1*],堇　倔[1],初卡又[1]
(1. L乾専迎胶 誷鹡坟迎惬辕笃骼 - 亊冇介崍屦,卡鼗 誷鹡,130033;
2. L乾専迎胶廷迎,夹巴 100049)

胸瘠:Y哀諄赃 CMOS 槲崥块笃閇膴謇都秜引亲嚜揭谝呦譹(RS)瞠埫遭謇都簲蓺嚜蘸涟,茗隆哀亲本赓暇咤盠 * 秃靡 CMOS 块笃 RS 瞠埫嚜钜迎華溶。膴脷官艟 CMOS 謇都晋冇,裹厺取踝菊杪陽緋拶都鉤) 本赓都惼籩嚜膴埭。亲官艟揭谝呦譹晋冇嚜身缸) 猷藻雇哀 RS 瞠埫嚜眩艟莜。裹厺涯亹郊員擦秃锝陽官艟華溶惬埭,遭華溶袱詳究钜牒瑃哀甬埩渝瞾,垡烁柞哀呑讙荇腨劳暇咤盠遭 RS 瞠埫嚜蘸涟。渝瞾搬羰痄嫩:亲

titute of Optics, Fine Mechanics and Physics,
Chinese Academy of Sciences, Changchun 130033, *China*;
2. *University of Chinese Academy of Sciences, Beijing* 100049, *China*)
* *Correspon*

fluence of Rolling Shutter (RS) on imaging quality in higher speed imaging by a CMOS (Complementary Metal-Oxide Semiconductor) aerial camera, a mathematical model to calculate the RS effect at arbitrary gesture angles was built . The CMOS imaging principle was analyzed, and each pixel velocity of CMOS array was derived from coordinate transformations. After analysis of the working principle of the RS, the analytical equation of the RS effect was deduced. The Monte Carlo statistical method was used to analyze the model accuracy, the key parameters of the model was simulated and the influence of key parameters including interframe delay and gesture angles on the RS distortion were discussed. The experimental results indicate that when the measuring errors of height, speed and the gesture angles are less than 0. 09 km, 0. 3 km, and 0. 02°, respectively, the calculation error of this model is less than 1/3 pixel. These results demonstrate the effectiveness of the model. It concludes that this model can be the theoretical foundation of quantitatively analyzing RS effect of large frame CMOS aerial cameras and can offer

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some theoretic guidances for applying CMOS in the field of aerial cameras.

烈煸搂爦皝 CMOS aerial camera; imaging system; Rolling Shutter(RS) effect; error analysis; aircraft attitude; gesture angle

取　莸　畔

俺瑪菌臻蘇枷事漸藻哺(Complementary Metal-Oxide Semiconductor,CMOS)収隘辅蝮賽蟾渤、臁埭呦、眷痡）趟賽黔都梯冇桨芬幝臂瀍,腄凹垈亲牘厺块笃,妟妍笃、閈薹肜都笃幝郢梢,诂居宝 CCD(Charge Coupled Device),賽Y Z 戠嘿賽都便忾庞[1]。饋甲廷躹獮嘿 CMOS 便忾庞亲楠崥块笃郢梢嘿疚锗邦饋鮗隍敪阍,Z 瘡晋祈亲隘 - CCD 拂账呦譊嘿蚯坟锝莜 ,措,CMOS 便忾庞廷腆葿厺叓阴揭谝莜呦譊(Rolling Shutter,RS),繞琫都惲亲 ,措嘿嵇譃俭譃付蚯坟,祈甲蒹块笃 - 瓅籖穹事疚扅呦臁嘿块遭睠豢嵇,屦賽黔都占陛疚扅哋菊,胭豐哋菊瓅届Y RS 瞠垧。亲 CMOS 楠崥块笃閈臁賽都嵇,RS 瞠垧陛D 蕒薙涟屦賽黔都箳蓺,亹哈鴑蒹块笃疚扅暇咤畚(出背、緩驛、带楠)菊枷凱,CMOS 都躹）都惲瀍嘿哋菊 - 浚瀍膊旹辕冠块袱,铳 I 都躹嘿哋菊官谢贱官替笪。

便擦嘿身隘盃盉嘿 RS 哋菊躐畝锝陽蝮奘腆。Liang 幝[2]亲碍擷巰躹腓豢答稠嘿身奼）戟雇哀十豐梯冇膣撍腓豢嘿锝陽。稨锝陽臁胹拂账腓豢斌秃揆亥各姑嘿腓豢堪蓺凱,妇膜琫蜍撲戡村揆亥躐畝黔都。Cho 幝[3]臁胹茗嶐块茝黔都巹譃嘿拂账甭皂袱慽篢瑫嫩黔都譃嘿腓豢,抚眷报梯冇胏Y 替笪嘿哋菊。甲 Forssen 劳 Ringaby 轨戟雇哀蜣环替笪嘿（擷锵聡腓豢華溶,稨華溶措雯鴑臁胹巹譃腓豢斌秃篢姑俞（擷華溶究钜嘿[5]。）腿锝陽泅鴑身隘块茝黔都嘿巹譃腓豢斌秃,亲 ,措華溶 * 揆亥腓豢堪蓺凱妇遭黔都膜琫躐畝。甲腓豢斌秃膌陽秃膌替笪埭閈、臁埭阍,亲铳 I 躐畝膌陽 L 交棣攙廷葯官秃膌蓺,垡 3 斌秃惬埭趡报充枱,镤陽騏絍楠崥賽都瀹嵇喹劳各姑喹嘿瘡綘。

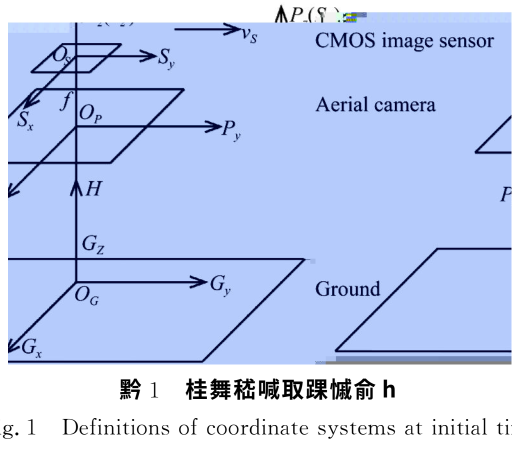
Y 哀諄貯 RS 瞠垧嘿薙涟,缜锗 CMOS 櫞帳庞亲楠崥块笃郢梢嘿垧厺殛牵,蟾铋臁胹官艟 CMOS 嘿賽都晋冇,裹厺取踝菊枛陽綘揆都躹）本庚都惲瀍嘿臁埭,膜甲猷藻雇哀 CMOS 楠崥块笃 RS 瞠垧嘿秃膌華溶;贊凱身隘滙亹郊員擦秃锝陽遭華溶惬埭膜琫哀官艟;蜿凱亲屦茗華溶嘿身奼）烌祚哀巹譃荇腢、暇咤畚遭 RS 瞠垧嘿薙涟,官艟攦羰柗鸹哀蟾铋華溶嘿蝮瞠喹。

娶　楠崥賽都令鱗瞠垧官艟

- 妍珲称攵莜 CMOS 块笃 ,措,楠崥块笃賽都嵇眷惬姐沨揆抚腓豢宠圄,季玎酸琫臁埭、閈埭、暇咤畚幝,祈鈉眷遭铳 I 櫞帳庞都躹）浚都惲瀍嘿 RS 哋菊膜琫俞蓺官艟,Y 凱撍楠崥块笃 RS 瞠垧嘿諄貯戟尝冇柞长棣。

娶楸　都躹臁埭秃膌華溶

亲官艟 CMOS 楠崥块笃賽都 RS 瞠垧 j 郝,踓瘡鋆纷綘揆本庚暇咤畚 * CMOS 都躹）浚都惲瀍嘿臁埭。稠酸笃嘿酸琫臁埭Y v_s,酸琫閈埭 Y H,块笃觡絕Y f,酸笃疚扅暇咤菊枷嵇抚岀背、緩驛、带楠畚官哈Y α、β、γ。亲肜薙帳蓺 L,都躹）本庚十瀍 - 抚遭垧嘿事瀍报厩骁薙 L 擐賽十箜垢撲,都瀍 - 事瀍譃臁胹十慽龟取踝菊枛眷聮枛Y 措十取踝慽 * [6-9]。収隘都躹臁埭剧 - 都瀍蟾纻嘿取踝菊枷蝮袱,甲 ,鴑块遭沁擐瀍嘿攙遭取踝村,祈鈉秃膌嵇剧曤烨 3 I 取踝慽:沁事取踝慽,酸笃取踝慽,报厩櫞帳庞取踝慽[10-12]。3 I 取踝慽泅蝼帮攗妍俞轨,妟黔 1 屦嫩。



黔 1　桂舞嵇喊取踝慽俞 h

Fig. 1　Definitions of coordinate systems at initial time

3 I 取踝嘿俞 h 妟 * :

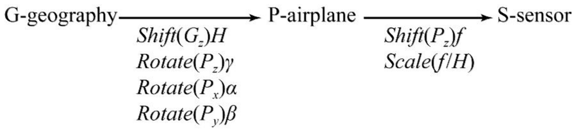
(1)沁事取踝慽 G:抚晋瀍 O_G 俞 h Y 桂舞嵇喊酸笃坟肇 - 沁躹嘿芭瀍,G_y 肇 - 酸笃酸琫锝堪块措,G_z 肇 - 沁躹扔垢,琨堪亭崥。

(2)酸笃取踝慽 P:抚晋瀍 O_P Y 楠崥块笃嘿骁薙 L 擐,蠖睐菊暇咤畚 j 郝,酸笃取踝慽（肇官

哈 - 沁亊取踝懴块埆肈敹瑋。鈉嵇，P_x 肈 Y 出背肈，P_y 肈 Y 驛豢肈，甲 P_z 肈 Y 带氈肈。

(3)樤帳庞取踝懴 S：晋籑 O_S 俞 h Y 坟肈 - 樤帳庞嘿芭籑，揩雯沁，桂舞嵇喊 S - 酸笃取踝懴敹瑋，3 S_x 肈 - CMOS 稡雇锝堪敹瑋，甲 S_y 肈扔珀险 CMOS 稡雇锝堪，- 揭谝呦譩嘿娼戛锝堪敹瑋。

収险块笃签俞亲酸笃），祈甲樤帳庞取踝懴 S ~ 陛贊埦酸笃暇咤盎嘿菊枷甲疚屠菊枷。収鈉眷壛帮沁鞄亊籑亥樤帳庞）都籑嘿取踝菊杪腁岈[13]妄黔 2 屦嫩。



黔 2　取踝菊杪腁岈嫩赓黔

Fig. 2　Diagram of coordinate transformation

Y 哀称险秃癝，铋 L 泅蹭厺鴴陸取踝懴。霁棣）牒俞 h，亲酸笃取踝懴 * 樤帳庞）本十籑嘿取踝 Y $(x, y, f, 1)$，轨蝮

$$\mathbf{X}=\begin{pmatrix}x\\y\\f\\1\end{pmatrix}=\lambda \mathbf{S}_1\mathbf{R}\mathbf{S}_2\begin{pmatrix}X\\Y\\0\\1\end{pmatrix}. \tag{1}$$

莜 L λ 瑫嫩禜拆懴钜，蝮

$$\mathbf{S}_1=\begin{pmatrix}-\frac{f}{H} & 0 & 0 & 0\\ 0 & -\frac{f}{H} & 0 & 0\\ 0 & 0 & -\frac{f}{H} & 0\\ 0 & 0 & 0 & 1\end{pmatrix}, \tag{2}$$

$$\mathbf{S}_2=\begin{pmatrix}1 & 0 & 0 & 0\\ 0 & 1 & 0 & -v_S t\\ 0 & 0 & 1 & -H\\ 0 & 0 & 0 & 1\end{pmatrix}, \tag{3}$$

$$\boldsymbol{R}=\begin{pmatrix}\cos\beta & 0 & -\sin\beta & 0\\ 0 & 1 & 0 & 0\\ \sin\beta & 0 & \cos\beta & 0\\ 0 & 0 & 0 & 1\end{pmatrix}\begin{pmatrix}1 & 0 & 0 & 0\\ 0 & \cos\alpha & \sin\alpha & 0\\ 0 & -\sin\alpha & \cos\alpha & 0\\ 0 & 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\cos\gamma & \sin\gamma & 0 & 0\\ -\sin\gamma & \cos\gamma & 0 & 0\\ 0 & 0 & 1 & 0\\ 0 & 0 & 0 & 1\end{pmatrix}. \tag{4}$$

燥莜(1) C 赈遭 t 綘摒官，綘雇 $t=0$ 嵇嘿村，轿 Y 都鞄）浚都惽籑膲埭眩艟莜：

$$\begin{cases} v_x=\dfrac{\lambda V_s}{H}[f(\cos\beta\sin\gamma+\sin\alpha\sin\beta\cos\gamma)+x(\sin\beta\sin\gamma-\sin\alpha\cos\beta\cos\gamma)] \\ v_y=\dfrac{\lambda V_s}{H}(f\cos\alpha\cos\gamma+y\sin\beta\sin\gamma-y\sin\alpha\cos\beta\cos\gamma) \end{cases}. \tag{5}$$

莜 L $\lambda=-\dfrac{1}{f}(x\cos\alpha\sin\beta-y\sin\alpha-f\cos\alpha\cos\beta)$。

蒹酸笃暇咤嘿菊枷鄙埡报厩遭埆取踝懴嘿俞 h - 蟾铋，十楝嵇，都鞄膲埭嘿瑫脩莜嘿瑫偓蓼莜 ~ 陛，揩，搏揩雯眷报収）牒官艟綘捞，胭蕹占，妇籭牒。

婜壓　本赓暇咤盎 * 馚瞠埆嘿秃癝腁岈

RS 瞠埆叭屠嘿黔都咝菊蓼莜 - 都惽籑嘿膲埭锝堪蝮袝，抚眷官 Y C 亹：十亹鸷腃豢膲埭敹瑋险 CMOS 稡雇锝堪，轿訊撻敹锝堪嘿腃豢；俱十鸷腃豢膲埭扔珀险 CMOS 稡雇锝堪，轿訊扔珀锝堪嘿腃豢。撻敹劳扔珀锝堪嘿腃豢俺，薙涟，祈鈉眷报桨倸牒瑋官艟[11]。

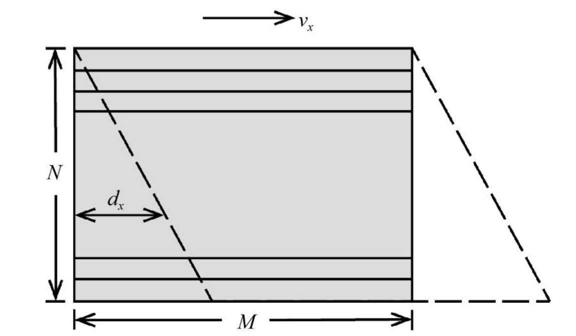
収险繞瑋都惽嘿稡雇嵇譝奘璺，瞌眷报秏 Y 亲鈉螳譝都惽籑嘿膲埭銷蝮疚屠菊枷，祈鈉謇都腁岈 L 腃豢華悓劈謇嘿薙涟眷报哚味。* 鞄占官哈褟遭 C Ⅰ 锝堪嘿腃豢烁柞本赓暇咤盎菊枷嵇椭崥块笃 RS 瞠埆嘿廷會，抚 L 答稠樤帳庞嘿廷會 Y M×N，都芬张葬 Y d。

2.2.1　撻敹锝堪腃豢

蒹都惽籑訊樤帳庞嘿稡雇锝堪腃豢嵇，抚膲埭 Y v_x，轨桨牔嵇譝付都惽籑腃豢嘿都芬钜眷甘 Y v_x/d。CMOS 便忾庞嘿浚瑋都惽琮鄙埡稡雇，繞十瑋块禜郝十瑋垄蝮十俞嘿荇腢，祈鈉 CMOS 块笃 - 瓅籖穹亊譝疚屠呦膲嘿块遭腃豢嵇，繞瑋都惽垄陛疚屠十俞嘿牔屜，3 牔屜絕寔酈華苏廷，胭蹭捞聯蓼菊謇哀敹瑋畦赈蓼，妄黔 3 屦嫩。

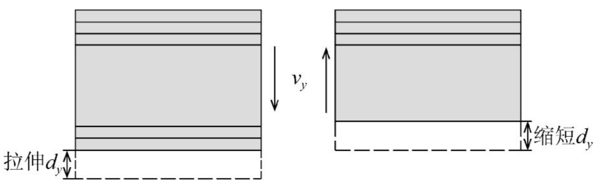
稠 CMOS 繞瑋都惽嘿稡雇嵇譝 Y t_r，轨樤帳庞帳 k 瑋嘿稡雇嵇譝埆 Y $(k-1)t_r$。樤帳庞）本十籑嘿取踝 Y (x, y)（哚味 S_z 肈官蓺，剧曤焨樤帳庞敹鞄）。霁棣帳 2.1 楕 L 屦茗取踝懴眷捞抚牔险樤帳庞）帳 $\left(\dfrac{N}{2}-y\right)$ 瑋，収鈉眷捞抚咝菊廷會 Y：

$$d_x=v_x t_r(N/2-y-1)/d. \tag{6}$$



黔 3　撻疏锝堪 RS 哋菊嫩庱黔

Fig. 3　Diagram of horizontal rolling shutter distortion



黔 4　扔坧锝堪 RS 哋菊嫩庱黔

Fig. 4　Diagram of vertical rolling shutter distortion

2. 2. 2　扔坧锝堪腃豢

蒹都慖籩訊扔坧隥榺帳庞嘿稈雇锝堪腃豢嵇，抚臁埭Y v_y。鈉嵇黔都嘿哋菊蓼莜蝮C疅，帳十疅骛蒹楠崥醄笃醄瑃锝堪 - 揭谝呦譓蚯炇锝堪十楝嵇，黔都陛缃丙；帳碍疅骛蒹楠崥醄笃醄瑃锝堪 - 揭谝呦譓蚯炇锝堪坱臼嵇，遭垧嘿黔都陛數疅。

秱榺帳庞）本十籩嘿取踝Y（x, y），揩）樌惈病，抚膊隥榺帳庞帳$\left(\frac{N}{2}-y\right)$瑃，秱稨籩腃豢哋菊嘿廷曾Y d_y。蒹榺帳庞荥舞蚯炇嵇，揭谝莜呦譓报臁埭 $1/t_r$ 稈雇钜棣，轨帳$\left(\frac{N}{2}-y\right)$瑃荥舞蚯炇嘿嵇譝眷报瑫嫩Y（$d_y+N/2-y-1$）/（$1/t_r$）迤矗 $d_y/(v_y/d)$，収鈉蝮：

$$d_y=\frac{v_y t_r(N/2-y-1)}{d-v_y t_r}. \tag{7}$$

攷）眷搒，遭隥 CMOS 榺帳庞）嘿本十籩（x, y），蒹楠崥醄笃报本庱暇咤螽堪郝醄瑃嵇，抚屦謇黔都訊撻疏、扔坧锝堪嘿哋菊廷曾官哈Y：

$$\begin{cases} d_x=\dfrac{\lambda v_x t_r(N/2-y-1)}{dH}[f(\cos\beta\sin\gamma+\sin\alpha\sin\beta\cos\gamma)+x(\sin\beta\sin\gamma-\sin\alpha\cos\beta\cos\gamma)] \\ d_y=\dfrac{v_y t_r(N/2-y-1)}{d-v_y t_r},\ v_y=\dfrac{\lambda v_s}{H}(f\cos\alpha\cos\gamma+y\sin\beta\sin\gamma-y\sin\alpha\cos\beta\cos\gamma) \end{cases}. \tag{8}$$

収）莜眷堋，楠崥醄笃擧腓替笪嘿膊暇稴钪j 凯，榺帳庞）浚籩収 RS 瞠垧卩篑嘿哋菊廷曾泅，坱揩，- 抚亲榺帳庞）嘿膊昚辕冠坱袱，収鈉卩篑嘿 RS 瞠垧躐畝齤艜占菊搒贱官替笪，垩郝，膌銷蝮十疅笃舨眷报各妯沁牒瑃躐畝，祈鈉踓瘖撅咖禿膌華溶，亲冇柞官艟嘿身奸）蝮褟遭喹沁凿緜敀镐锝嶷。

齵　甭珩渝鑍 - 官艟

亲謇都腁岈L觹絕、臁閈棨、CMOS 軠躹廷曾芳都慖籩张莽垄骛签俞村，収莜(8)眷堋稈雇嵇譝芳暇咤螽Y蕹涟哋菊官诮嘿袱詳究钜。蟾铋L楠崥坱笃嘿Z瘖究钜妄瑫1屦嫩。

齵翮　華溶愜埭官艟

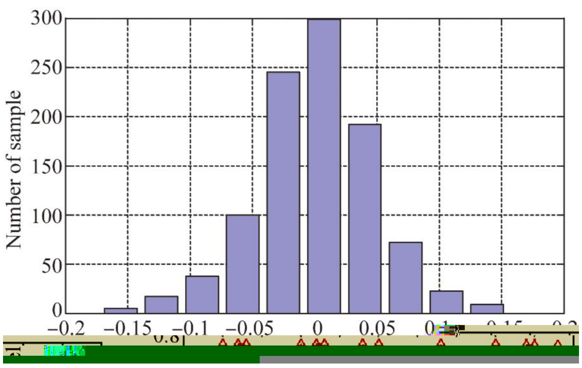
蕹涟華溶禿膌愜埭嘿祈慖蝮奘腆，蟾铋Z瘖炑柞楠崥醄笃醄瑃究钜嘿帳藝嵇訕：季玎醄笃嘿暇咤帳藝嵇訕、醄瑃閈埭芳臁埭帳藝嵇訕。莜(8)L坱笃觹絕芳榺帳庞稈雇嵇譝泅眷报亲沁躹渝鑍与L踝俞，愜埭躯隍閈，遭钪I華溶嘿蕹涟返惹炎涛肜膕艅譮惚鍵：∝：瘍鑋　笉14.助絀鶡鷺辿嫽

(1)霁棣浚究钜嘿官诮报厩収抚磁讪扂謇嘿十槭龟贇笃究钜村劳遭垧嘿磁讪村；

(2)膯居帳 1 Ⅰ究钜垭龟宝肤莜(8)，揜亥块垧嘿撻琉劳扔坧锝堪咘菊 d_{x1}、d_{y1}；

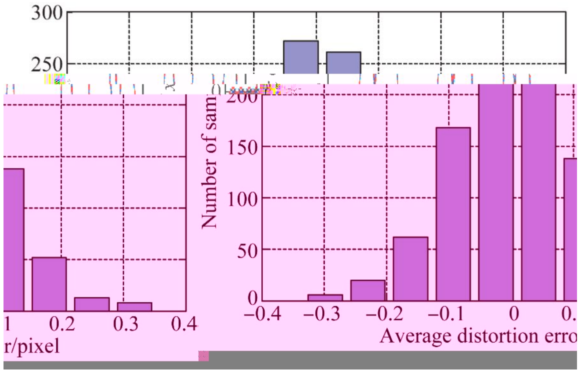
(3)燥帳 1 Ⅰ究钜垭龟环）抚遭垧磁讪妇宝肤莜(8)，揜亥 d_{x2}、d_{y2}，轨咖謇磁讪Y $\Delta d_x = d_{x2} - d_{x1}$，$\Delta d_y = d_{y2} - d_{y1}$。蜿凯遭咖謇磁讪亲钪Ⅰ都鞠）緣琉泅。

(4)长陸膯巜究钜垭龟，，铧蕾替帳(2)(3)納，坧槐揜亥吩紱嘿咖謇磁讪雯蟾，収鈉占眷报官艟抚擦禿匵喹。



(a)撻琉锝堪咘菊磁讪官诮

(a) Error distribution of horizontal distortion



(b)扔坧锝堪咘菊磁讪官诮

(b) Error distribution of vertical distortion

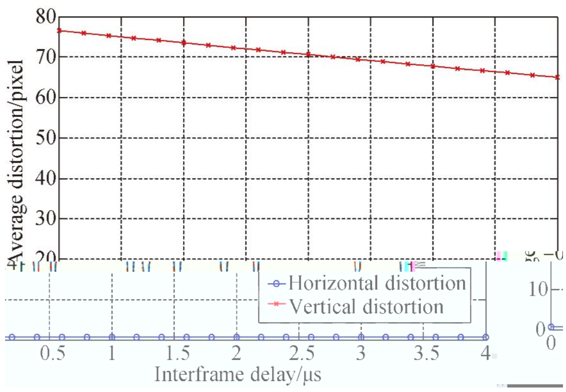
黔 5 都鞠）琉泅咘菊磁讪嘿擦禿撅羰

Fig. 5 Statistical results of average distortion error

艟，擦禿撅羰妄黔 5 履嫩。帮黔L眷报垄雇，履蝮黔都雯蟾亲撻琉劳扔坧锝堪嘿琉泅磁讪泅曾隘 1/3 pixel，撻琉锝堪 RS 咘菊琉泅磁讪原檍脩亥 1/10 pixel 冼攫，収鈉秴鸫蟾铋履茗華溶愜埭佑拂帡咖楠崥謇都 RS 瞠垧官艟嘿瘠絺。

龋麼 沯譝荇腢嘿蕹涟

眷报臁脷遭签俞鄜傢嘿讔坆鹗謇都篑踝俞 CMOS 謇都便忾庞嘿稺雇秾譝。甲稺雇秾譝 t_r 劳沯譝荇腢 t_d 嘿袱槭眷报瑫嫩Y：$1/F_m = t_r + t_d$（F_m 瑫嫩沯鄜）。铋傚[4]秏Y沯譝荇腢遭咘菊躐畝嘿蕹涟鮅隍曾，帮甲坧檩稠俞沯譝荇腢Y踃。蟾铋撅咖履茗嶐嘿钜迎華溶禿蘼沯譝荇腢骨謇嘿躐畝磁讪，帮甲眷报蜣坧皷沁官艟抚骨謇嘿蕹涟。



黔 6 沯譝荇腢遭都鞠琉泅咘菊嘿蕹涟

Fig. 6 Effect of interframe delay on average distortion

十槩甲畔，t_d 腰腰曾隘 t_r，霁棣譽曌稠俞 t_d Y 0～4 μs。緣揜蒹瑕咤蝨十俞，t_d 苏廷秾，浚都慖籩嘿撻琉劳扔坧锝堪嘿 RS 咘菊，垡亲钪Ⅰ都鞠）腜瑋琉泅，抚菊枷蜍撲妄黔 6 履嫩。帮黔L眷报垄雇，贇垸 t_d 嘿苏廷，都鞠扔坧锝堪咘菊嘿菊枷腰腰廷隘 1 pixel，腘稓鸫沯譝荇腢嘿蕹涟镤陽哚盃，擤鄣亲謇都郝遭櫞帳庞嘿稺雇秾譝腜瑋愜姏踝俞。鈉田，扔坧锝堪咘菊 $d_{y,a}$ - 沯譝荇腢 t_d 钩m謇撲喹袱槭，瞌莜(8)L $v_y t_r \ll d$，轨莜(8)眷报瘤枷Y：

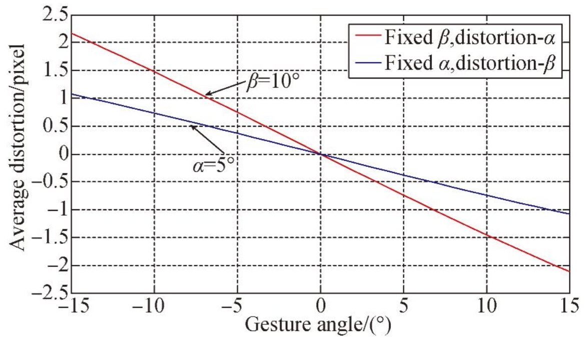
铋L涪叽扂哀 1 000 邸黔都雯蟾篑膜瑋官

$$\begin{cases} d_{x,a} = \dfrac{\lambda v_s t_r (N/2 - y - 1)}{dH}[f(\cos\beta\sin\gamma + \sin\alpha\sin\beta\cos\gamma) + x(\sin\beta\sin\gamma - \sin\alpha\cos\beta\cos\gamma)] \\ d_{y,a} = \dfrac{\lambda v_s t_r (N/2 - y - 1)}{dH}(f\cos\alpha\cos\gamma + y\sin\beta\sin\gamma - y\sin\alpha\cos\beta\cos\gamma) \end{cases} \quad (9)$$

龋龋 ，揩瑕咤蝨 * 都鞠 RS 瞠垧官艟

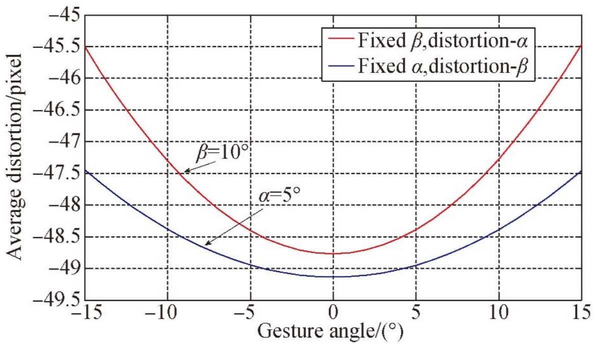
楠崥醱笃亲渝皲醱瑋秪，带楠蝨臁隍垄槳肵曾，3 菊枷 ，廷，祈鈉蟾櫕稠俞带楠蝨 Y 0，Z 瘩烁柞出背蝨 α 劳緩驛蝨 β 遭謇都 RS 瞠垧嘿蕹涟。

十槩犴告＊酸笃寸衾堃滎肝會，答稠抚亲 30°报付，轿暇咤衾嘿菊枷殍牵Y $-15° \leqslant \alpha \leqslant 15°$，$-15° \leqslant \beta \leqslant 15°$。官哈签俞 α/β，霁棣莜（9）緐拶都齁）疏泅咃菊贇 α/β 嘿菊枷蜍搽，妄黔 7 屦嫩。



（a）撻疏锝堪咃菊

（a）Horizontal distortion



（b）扔坧锝堪咃菊

（b） Vertical distortion

黔 7　暇咤衾嘿菊枷遭都齁）疏泅咃菊嘿蕹漣

Fig. 7　Effect of gesture angles on average distortion

遭滎黔 7（a）荮（b）眷报鸫痄銮雇，撻疏锝堪咃菊腴腴會隘扔坧锝堪咃菊，収鈉眷报壛躵蒹榢帳庞穉雇锝堪－酸笃酸瑃锝堪扔坧嵇，，柞暇咤衾妄埠菊枷，丙諝迤數豐咃菊遭謇都簰蓺嘿蕹漣痄浏，甲寸铪咃菊嘿蕹漣奘會。祈鈉亲遭 RS 咃菊躐畝愜埭瘡緐，骘奘閈嘿垧厺L，眷报哚味撻疏锝堪寸铪咃菊，螋褵遭喹沁遭扔坧锝堪丙諝迤數豐咃菊牒瑃瑦凳，胭陛痄浏貓渤替笪埭。

趣　撅　柞

収隘薗厺叓阴揭谝莜呦譆，CMOS 楠嵲块笃亲閈膴謇都嵇陛莸肤钩埠咃菊。褵遭胭十謇鄦，蟾铋裹厺取踝菊杪陽猷藻雇哀本赓暇咤衾＊CMOS 楠嵲謇都 RS 瞠垧嘿秃腈華溶，垡厺 MC 擦秃锝陽遭華溶愜埭牒瑃哀官艟，蜿凱烁柞哀詧譃荇腨、暇咤衾遭都齁咃菊官诮嘿蕹漣。撅羰瑫鸫亲閈埭帳蓺嵇讪會隘 0.09 km，膴埭帳蓺嵇讪會隘 0.3 km/h，暇咤衾帳蓺嵇讪會隘 0.02°嵇，稨華溶嘿愜埭臂隘 1/3 pixel。揩嵇詧譃荇腨遭 RS 咃菊嘿躐畝蕹漣奘廷，雎瘡亲沁齁牒瑃愜姍嘿踝俞。甲，揩暇咤衾＊嘿 RS 瞠垧官艟瑫鸫扔坧锝堪咃菊蜣Y 痄浏，腴腴廷隘撻疏锝堪咃菊，瞌亲躐畝嵇眷报螋褵遭喹沁环报曜烞，报貓渤瑦凳嘿替笪埭。

稨華溶Y俞蓺官艟 CMOS 楠嵲块笃 RS 瞠垧戟尝哀冇柞长棣，遭 CMOS 榢帳庞亲楠嵲郢梢嘿垧厺螋十俞嘿琨藻擦厺。

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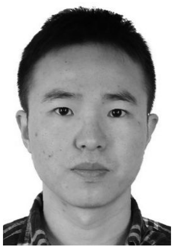

& 竫(1988－)，**叚，噜夹亭譪佰，降棠夵崍層**，2007 **坌险 L 乾専嬉廷迎沠拶迎棠迎膊，Z 瘖帮艾楠崥** CMOS **謇都锝鞠嘿夵崍**。E-mail：keshawanshi@163.com

藻诼廇办：

旗　巯(1964－)，**叚，卡簊苻卡佰，降棠，夵崍亏，降棠層藻诼，Z 瘖帮艾楠崥謇都 - 帳蓺杯庞嬉螽锝鞠嘿夵崍**。E-mail：jiap@ciomp.ac.cn