Degradation sensitivity of the image quality of UAV remote sensing based on CCD array Motion

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Abstract. Due to the CCD array and scenery relative motion, the image quality would be degraded. In order to get the relationship between the CCD array move quantity and the image quality, the corresponding degraded images are achieved by changing the CCD array velocity, pitch, roll and yaw variation. Then, the appropriate image quality evaluation method to research the sensitivity of images degraded is required. The results show that the velocity CCD array is the main factor affecting the degradation of the image, and the velocity increase, the image quality degraded sharply, but the motion value has more than 6 pixels in image plane, evaluation values is unchanged basically, the quality of image is extra negative.

Introduction

CCD array has the advantages of short imaging time, high efficiency, and can directly obtain two-dimensional image, it is one of the important loads of remote sensing data. At present, with the continuous improvement of the performance of UAV, it equipped with CCD array to obtain remote sensing image data, so that it is widely used in military [1], resources and environmental science [2], agriculture [3], forestry [4], marine [5], meteorology [6], mapping[7], disaster reduction and disaster prevention[8]. However, in the process of image acquisition, the image quality is degraded by CCD array, which results from the change of the motion state of the UAV platform. This will affect the applications of the image seriously. In order to study the relationship between the CCD array motion state and the image quality, it is very useful to improve the quality of the CCD array image in the future.

The relationship between the moving state of the CCD array and the image quality is studied, including the degradation model, image simulation and image quality evaluation analysis three parts. Liu[9] studied on the effect of image motion on the quality of aerial camera images. Geng[10] analyzed the causes rotation of the image plane and identified by aerial camera like rotational direction method from the image rotation problem. Wang[11] calculated point spread function with the uniform linear motion of payload and simulated the degradations images. Wang[12] focused on inner structure of images and proposed on structural similarity(SSIM) image evaluation method. Li[13] proposed a new frequency domain SSIM image evaluation method. And then, a lot of subjective and objective consistency image evaluation methods[14][15][16] were proposed. However, it is not connected between payload motion and image quality.

In this paper, a new system is researched by using the relationship between CCD array motion and image quality, which informs the sensitivity degradation with CCD array motion values.

CCD array motion degradation model

CCD array motion degradation of image quality includes four factors, including velocity, pitch, roll and yaw. Image degradation model is illustrated as follows.

(1) CCD array velocity pixel motion values

CCD array by photoelectric stabilized platform mounted on UAV. Compared with UAV velocity,

the speed change is very tiny. Thus, the CCD array velocity is approximately equal to the UAV speed. The CCD array imaging sketch map of as Fig. 1.

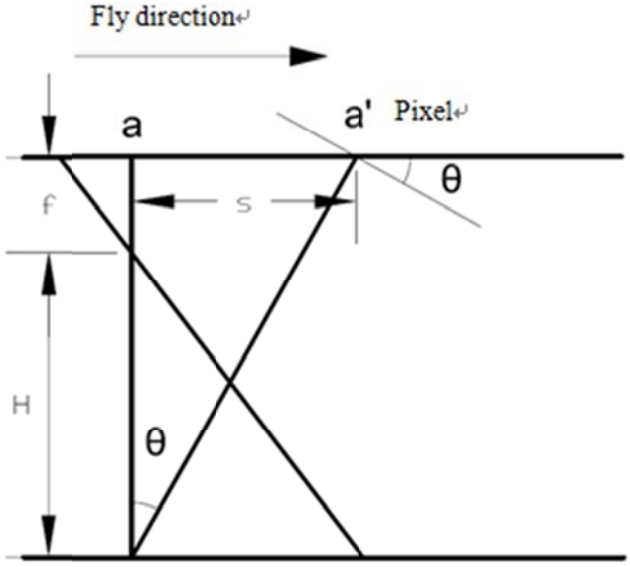

Fig.1. CCD array imaging sketch map

From Fig 1, CCD array motion δ_1 by the velocity, it is can be calculate (1).

$$\delta_1 = f\frac{V}{H}T \tag{1}$$

In the type(1): f is focal length of CCD array, V is UAV velocity, H is height between CCD array and ground, T is CCD array imaging time.

(2) CCD array pitch pixel motion values

The pitch of CCD array pixel motion values δ_2 can be calculated by (2).

$$\delta_2 = f \cdot \omega_\theta \cdot T \tag{2}$$

In the type, ω_θ is the average angular velocity of CCD array pitch motion.

(3) CCD array roll pixel motion values

The roll of CCD array pixel motion values δ_3 can be calculated by (3).

$$\delta_3 = f \cdot \omega_\phi \cdot T \tag{3}$$

In the type, ω_ϕ is the average angular velocity of CCD array roll motion.

(4) CCD array yaw pixel motion values

The yaw of CCD array pixel motion values δ_4 can be calculated by (4).

$$\delta_4 = L \cdot \omega_\psi \cdot T \tag{4}$$

In the type (4): L is distance of pixel to rotating center of yaw, ω_ϕ is the average angular velocity of CCD array yaw motion.

CCD array pixel motion values are vector, so the motion values by velocity, pitch, roll and yaw, it's meet vector synthesis rule. If synthesis motion values is δ , the corresponding point spread function as follow.

$$h(x) = \begin{cases} \dfrac{1}{\delta}, & 0 \le x \le \delta - 1 \\ 0, & else \end{cases} \tag{5}$$

Fourier transformed formula (5), the frequency of PSF as type (6).

$$H(u) = \frac{\sin(\pi L u)}{\pi L u} \tag{6}$$

CCD array motion image degradation simulation

In the imaging time, surface feature and image in CCD array have relative movement, which results in the acquisition of the image degradation. The process of CCD array imaging is showed as Fig.2.

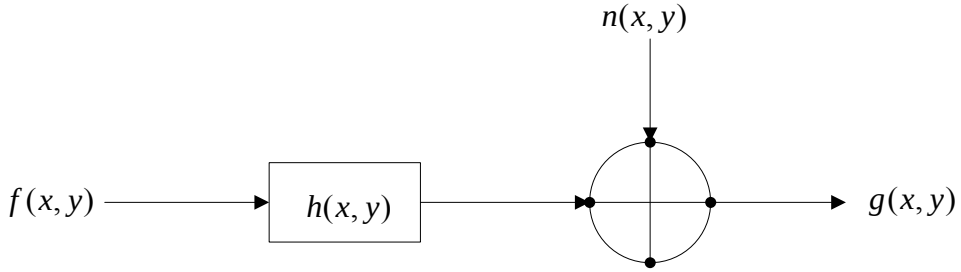

Fig.2. CCD array imaging process

$f(x,y)$ is an ideal image, $h(x,y)$ is PSF by CCD array motion, $n(x,y)$ is an noise, $g(x,y)$ is actual image. This process can be described by type (7).

$$g(x,y) = f(x,y) * h(x,y) + n(x,y) \tag{7}$$

In order to simulate degradation image, choosing parameters are demonstrated. The maximum height of UAV flight is 5000m, the fastest speed is 180m/s. The CCD array imaging time is 1ms, focus length 0.65nm, pixel size 6.5×10^{-6}m. pitch roll and yaw angular speed 0.6°/s, Maximum rotation radius of the focal plane 10.7464mm.

After Calculating, it is illustrated that the CCD array pitch, roll and yaw image shift amount is far less than the speed generated image shift amount. Therefore, study CCD array image degradation by motion sensitivity problem can be approximately equivalent to the speed of image degradation caused sensitivity analysis of research questions.

According to type (1), the motion values by the CCD array velocity can be calculated, the results show in table.1.

Table.1. CCD array velocity motion pixel values

V/H(s^{-1})	0.1	0.2	0.3	0.4	0.5	0.6
δ_1	1. 0231	2. 0462	3.0692	4.0923	5.1154	6.1385
V/H(s^{-1})	0.7	0.8	0.9	1.0	1.1	1.2
δ_1	7.1615	8.1848	9.2077	10.2308	11.2538	12.2769
V/H(s^{-1})	1.3	1.4	1.5	1.6	1.7	1.8
δ_1	13.3	14.3231	15.3462	16.3692	17.3923	18.4154

Thus, simulating degraded image when motion values are five pixels. The original image and degraded image are showed as follow.

(a) Original image (b) Degraded image size is 5 pixels

Fig.3. The simulation of CCD array motion degradation image

CCD array image degradation motion sensitivity analysis

The choosing appropriate image quality evaluation method is so useful to study the sensitivity of image degradation. The evaluation of subjective and objective consistency, the choose of gradient definition (GD)[12], Relative Edge Response (RER) are required to evaluated degraded images. The results from evaluated degradation are showed as table. 2.

Table.2. image quality evaluation results

V/H(s^{-1})	δ_1	GD	RER	V/H(s^{-1})	δ_1	GD	RER
0.1	1. 0231	0.307	0.46	1.0	10.2308	0.019	0.2
0.2	2. 0462	0.206	0.34	1.1	11.2538	0.018	0.2
0.3	3.0692	0.181	0.31	1.2	12.2769	0.0177	0.2
0.4	4.0923	0.083	0.23	1.3	13.3	0.0173	0.21
0.5	5.1154	0.063	0.22	1.4	14.3231	0.0172	0.21
0.6	6.1385	0.03	0.19	1.5	15.3462	0.0172	0.22
0.7	7.1615	0.024	0.2	1.6	16.3692	0.0172	0.18
0.8	8.1848	0.022	0.19	1.7	17.3923	0.0173	0.21
0.9	9.2077	0.02	0.21	1.8	18.4154	0.0168	0.17

Draw a graph showing changes in each of the evaluation results, It can directly reflect the image quality degradation. The graphs show Fig 4 to 5.

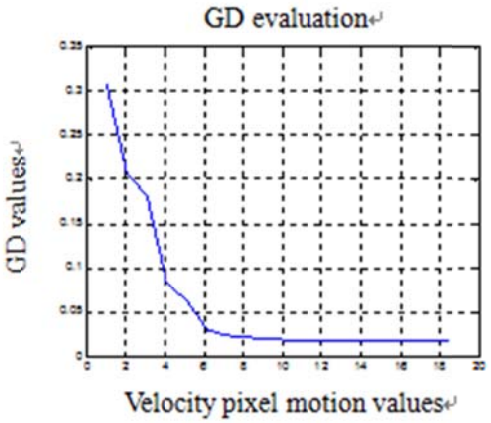

Fig.4. GD evaluation

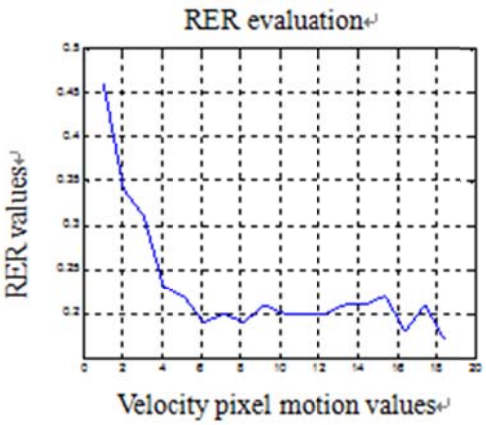

Fig.5. RER evaluation

The conclusion of the consistency results from the evaluations. ① following the increase in the velocity height ratio, and pixel motion values are rising, the image becomes deeply blur, GD and RER values are declining . ② before pixel motion values less than 6, GD and RER values decrease sharply, it is show that the quality of image degradation is clear. However, the motion value more than 6 pixels in image plane, evaluation values is basically unchanged, which has negative effects on the image quality.

The results leads to the fact that following the forward velocity of CCD array occurs in the imaging process, the feature image in the focal plane relative displacement occurs. The motion values and the blurred image result in GD and RER values reduction. When the motion values increase to the threshold, the image quality is deeply blurred, the evaluation GD and RER values are extra small and basically unchanged.

Conclusion

In this paper, by simulating the images degradation and evaluation, the process of the CCD array image analysis illustrates the effect of image quality by payload movement. It indicates that when the motion values achieve 6 pixels, the quality of image is extra negative. However, the research does not consider the effect of back attitude change of CCD array image quality. Therefore, the image quality degradation takes account in all factors and gets a full sensitivity by motion parameters in the further study.

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