Camera Position Estimation and Feature Extraction from Incomplete Image of Landmark

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Abstract: On the autonomous unmanned helicopter landing problem, the position of the unmanned helicopter relative to the landmark is very important. A camera carried on the unmanned helicopter could capture the image of the landmark. In the earlier researches, the camera position could be estimated by the extracted features of the landmark image. However, it is necessary that the landmark image should be complete or with slight deficiency in order for the estimation process. In this paper, the innovated method is designed for camera position estimation from single image with incomplete landmark. An ANFIS is utilized for constructing the mapping relation between the features of complete and incomplete landmark image. It will be verified that it is possible to estimate the camera position from a landmark image with defects more than half via the proposed method.

Keywords: Camera position estimation, Incomplete landmark image, Feature extraction, ANFIS.

I. INTRODUCTION

Unmanned helicopters are very useful vehicles for aerial photography or investigation in hazardous locations. The research of autonomous unmanned helicopter control has been ongoing for several years. GPS (Global Positioning System) is the most commonly used sensor for position control of unmanned helicopters. Unfortunately, GPS error can range up to 6 meters [1]. Greater accuracy can be achieved by incorporating image-guided methods in conjunction with a GPS system.

In earlier researches, image servo control systems for a small scale autonomous unmanned helicopter are discussed in [2] and [3]. In these two references, two marks are used for assisting unmanned helicopter positioning. However, in practice when an unmanned helicopter is landing, the landmark constitutes a single reference on the ground. Consequently, image-guided methods are proposed for locating the landmark [4] and estimating the position information [5-6].

Image-guided methods are usually employed to guide an unmanned helicopter on close approach to a target. The distance between the vehicle and target is usually smaller than the range of GPS error while the vehicle is landing. Fig. 1 shows the situation concerned in [5-6] that an unmanned helicopter is approaching the landmark. The position of an unmanned helicopter can be described by θ and R. The θ and R can be estimated from the captured landmark image with the method proposed in [6].

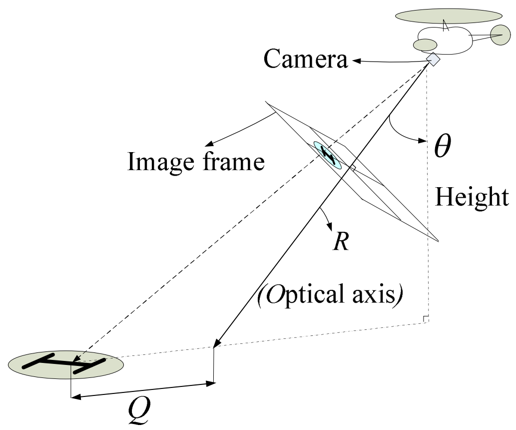


Fig.1. Situation of an unmanned helicopter approaching a landmark

In [5], it is necessary that the captured landmark image must be complete. Since the helicopter may yaw due to the effect of wind or the image size of the landmark may be larger than the image available to the camera this restriction has to be overcome. The case in which more than half the landmark image is available, called "*Case 1*", has been discussed in [6].

In this paper, we will focus on the case in which more than half of the landmark image is defective, called "*Case 2*". This scenario presents serious problems for extracting useful features. A feature extraction method is developed for extracting the features from the incomplete image of landmark in which more than half of the landmark image is defective. We use ANFIS to capture and estimate the useful features from an incomplete landmark image.

Simulation results verify that under some conditions it is possible to estimate the camera position from a landmark image in which less the than half the total image is available.

II. MAPPING RELATIONS AND CAMERA POSITION ESTIMATING METHOD

1. Projective geometry of landmark image

The five quantities, as defined in (1-5), obtained via geometric projection [7] are the projection of the features of the landmark image. We defined (6) for estimating the camera position [5].

$$k = \left(\tan(\gamma+\sigma) - \tan\gamma\right) * \overline{R} \tag{1}$$

$$h = \left(\tan(\gamma+\sigma+\omega) - \tan(\gamma+\sigma)\right) * \overline{R} \tag{2}$$

$$\overline{Q} = \tan(\gamma+\sigma) * \overline{R} \tag{3}$$

$$d = \sqrt{\left(\tan\lambda * \overline{R}\right)^2 + \left(\tan\delta * \overline{R}\right)^2} \tag{4}$$

$$\overline{r} = \frac{r \times \sqrt{\left(\overline{S}\right)^2 + \left(\overline{R}\right)^2}}{\sqrt{\left(\cos\theta \times \overline{R} + T\right)^2 - \left(\sin\theta * \overline{R}\right)^2}} \tag{5}$$

$$\begin{cases} Ratio_{project} = h/k \\ Ratio_{height} = \overline{r}/d \\ Ratio_{angle} = h/\overline{r} \\ Ratio_{position} = k/\overline{Q} \end{cases} \tag{6}$$

We further consider the cases of incomplete landmark images, specifically, the case of the landmark image in which more than half of the image is available [6]. The four quantities: *k*, $\overline{r}$, *x*, and *y*, related to the completed landmark image, are selected for estimating the approximate *h*. The estimated *h* is called $\hat{h}$. Here *k* and $\overline{r}$ have been derived from (1) and (2), respectively.

Consider the case in which more than half the landmark image is defective, as shown in Fig.2. The five quantities: I_1, I_2, I_3, I_4 and I_5 which are related to the complete landmark image are selected for estimating the approximate *h and k*, called $\hat{h}$ and $\hat{k}$, respectively.

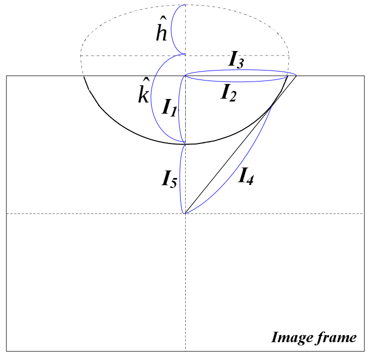


Fig.2. Incomplete landmark image and features

The projective relation between the landmark and camera position is shown in Fig. 3. Definitions of θ_α, θ_α and θ_e are provided as

$$\begin{cases} \theta_\alpha = \tan^{-1}\left(\dfrac{f+b+e+r}{h}\right) - \tan^{-1}\left(\dfrac{f+b+e}{h}\right) \\ \theta_\beta = \tan^{-1}\left(\dfrac{f+b+e}{h}\right) - \tan^{-1}\left(\dfrac{f+b+e-r}{h}\right) \\ \theta_e = \tan^{-1}\left(\dfrac{f+b+e}{h}\right) - \tan^{-1}\left(\dfrac{f+b}{h}\right) \end{cases} \tag{7}$$

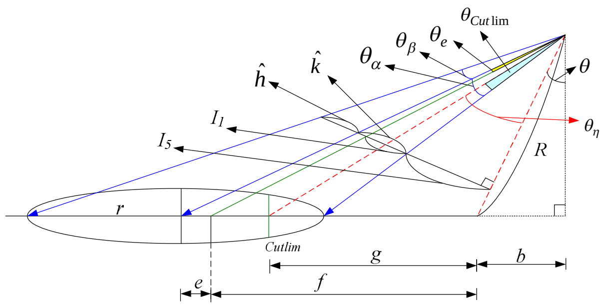


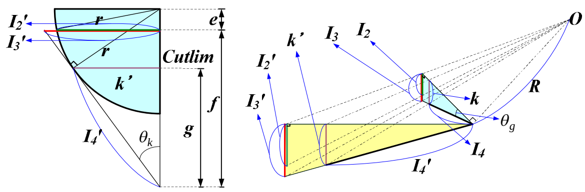
Fig.3. Projective geometry of landmark features

Fig. 4 illustrates the projective relations of features I_2, I_3 and I_4. From Fig.3 and Fig.4, the derivations of $\hat{h}$, $\hat{k}$, I_1, I_2, I_3, I_4 and I_5 can be obtained as shown in (8-13) and the estimated $\hat{h}$ and $\hat{k}$ in (14).

$$I_5 = \tan\left[\eta + \left(\theta_\beta - \theta_e\right)\right]R \tag{8}$$

$$I_1 = \left(\tan\eta\right)R - I_5 \tag{9}$$

$$I_2 = \frac{\sqrt{\left(r^2 - e^2\right)}\sqrt{\left(I_1 - I_5\right)^2 + R^2}}{\sqrt{H^2 + \left(b+f\right)^2}} \tag{10}$$



(a) (b)

Fig.4. (a) Top view of the landmark features
(b) Projections of the landmark features

$$I_3 = \frac{[f \cdot \tan(\theta_k)]\sqrt{(I_1 - I_5)^2 + R^2}}{\sqrt{H^2 + (b+f)^2}} \quad (11)$$

$$I_4 = \frac{\tan(\eta + \theta_e - \theta_\beta + \theta_{cut\lim})R}{\tan^{-1}\left[\frac{I_3}{I_1 + I_5}\right]} \quad (12)$$

$$\theta_g = \tan^{-1}\left(\frac{g+b}{h}\right) - \theta - (\eta + \theta_e - \theta_\beta) \quad (13)$$

$$\begin{cases} \hat{k} = \tan(\eta + \theta_\beta)R - I_5 \\ \hat{h} = \tan(\eta + \theta_e + \theta_\alpha)R - I_1 - I_5 \end{cases} \quad (14)$$

Obviously, from Fig. 2, I_4 is an important quantity for estimating $\hat{h}$ and $\hat{k}$. Therefore the restriction of this method is that the tangent I_4 must be available, i.e., $I_1 + I_5$ has to be less than *Cutlim* defined by

$$Cutlim = \sqrt{r^2 - s^2} \quad (15)$$

where $s = (\sin\theta_k)\sqrt{(f+e)^2 - r^2}$.

2. Camera position estimation method

The proposed method is illustrated in Fig.5. There are two major parts in this method. The first part is "*Landmark image detection algorithm*". The algorithm is designed for computing the landmark image and detecting:

1. Is the landmark image complete?
2. Is more than half of the image defective?
3. Is the landmark image beyond sensor range?

The basic rectangle is employed not only for executing efficient detection but also for fast computation of the features.

The second part is "*Image feature based camera position estimation* method". The incomplete landmark image features database could be constructed by (1-15). The ANFIS is employed for recognizing the mapping relations between the image features and the camera positions. Furthermore, the camera positions can be estimated quickly via the established mapping model.

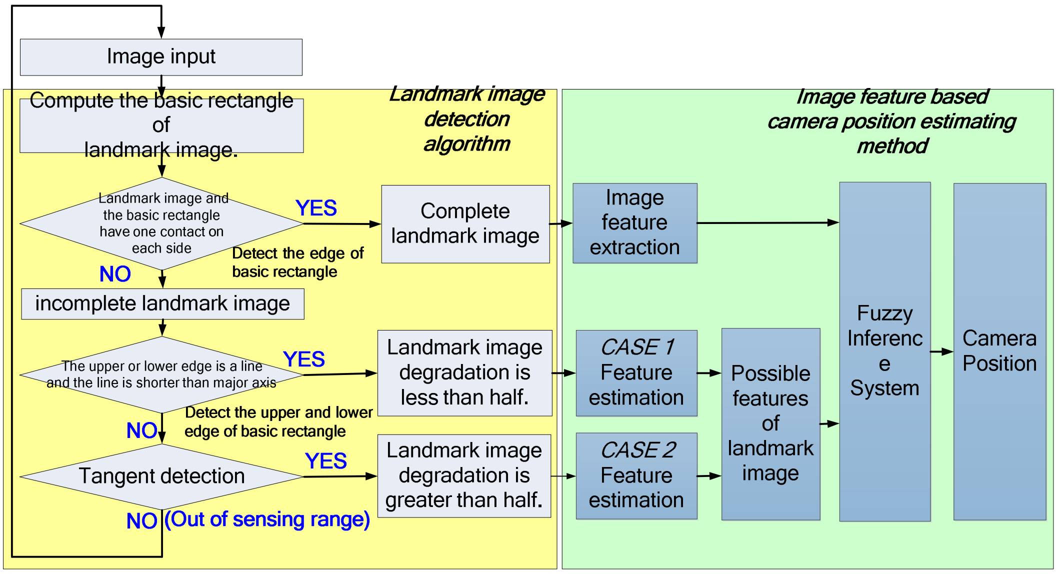


Fig.5. Flow chart of camera position estimation method

3. ANFIS training

The model for "Case 1" has been established and confirmed in [6]. We only discuss "Case 2" in this paper. Two ANFIS are provided for estimating the $\hat{h}$, and $\hat{k}$. In addition, the database is established by (7-15), and the network is illustrated in Fig. 6.

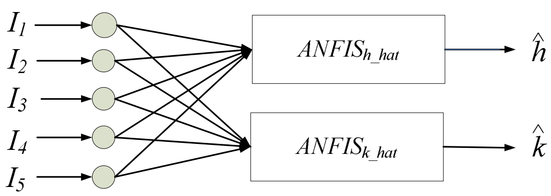


Fig.6. Illustration of $\hat{h}$ and $\hat{k}$ computation with dual ANFIS

III. SIMULATION RESULTS

In this section, we will demonstrate the estimation results of the $\hat{h}$ and $\hat{k}$ from the incomplete landmark features I_1, I_2, I_3, I_4 and I_5 via ANFIS. The simulation is based on the following qualities:

1. The image size of the camera is 320×240 pixels.
2. The diameter of the circular landmark is 3 cm.
3. The range of R is 20 ~ 300 cm.
4. The range of θ is 0 ~ 62 degrees.

The estimation results of features $\hat{h}$ and $\hat{k}$ are illustrated in Table 1. There are 10 sets of data utilized for testing the ANFIS training results. In Table 1 the

RMSE of $\hat{h}$ and $\hat{k}$ are 0.000615 and 0.000471, respectively. The $\hat{h}$ and $\hat{k}$ are utilized to approximate the complete landmark image features. Table 2 illustrates the estimation results of camera position with the features $\hat{h}$ and $\hat{k}$. The RMSE of the θ, R and Q are 0.45868, 0.506617 and 0.240798, respectively.

IV. CONCLUSION

In this paper, a scenario in which more that half of a landmark image is defective has been analyzed. The method for estimating the approximate features of incomplete landmark images is provided. From simulation results, it is clear that the approximate features can be very closely estimated via the known quantities. Moreover, we have shown that the approximate features can be used for camera position estimation. The inherent camera position estimation error range is acceptable for practical applications. The method proposed in this paper is a functional tool for camera position estimation.

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Table 1. The estimation results of features $\hat{h}$ and $\hat{k}$

No.	θ	R (cm)	k	$\hat{k}$	Error of feature k	h	$\hat{h}$	Error of feature h
1	32°	31	1.58891	1.58823	0.00068	1.70474	1.70463	0.00011
2	21°	44	2.87088	2.87023	0.00065	2.73393	2.73451	-0.00058
3	42°	78	2.06710	2.06790	-0.00080	1.96832	1.96786	0.00046
4	53°	113	0.16088	0.16187	-0.00099	0.15886	0.15934	-0.00048
5	19°	157	1.78014	1.78001	0.00013	1.76272	1.76347	-0.00075
6	60°	163	0.77189	0.77171	0.00018	0.74055	0.73976	0.00079
7	10°	173	2.78694	2.78656	0.00038	2.77071	2.77091	-0.00020
8	35°	201	0.92258	0.92308	-0.00050	0.91298	0.91274	0.00024
9	13°	240	3.22209	3.22278	-0.00069	3.22209	3.22176	0.00033
10	29°	289	2.92995	2.92951	0.00044	2.91630	2.91611	0.00019

Table 2. The estimation results of camera position with the features $\hat{h}$ and $\hat{k}$

No.	θ	R (cm)	Q (cm)	Error of estimated θ	Error of estimated R	Error of estimated Q
1	32°	31	10	-0.619	0.421	-0.174
2	21°	44	23	-0.354	-0.572	0.243
3	42°	78	189	0.475	-0.435	0.314
4	53°	113	78	-0.487	-0.376	-0.197
5	19°	157	63	0.221	0.636	0.231
6	60°	163	284	-0.334	0.551	0.299
7	10°	173	174	-0.531	-0.417	-0.143
8	35°	201	124	0.437	0.623	0.354
9	13°	240	254	-0.634	-0.581	-0.208
10	29°	289	365	-0.312	0.352	0.146