Optik 126 (2015) 1909–1913

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Indirect target recognition method for overhead infrared image sequences

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ARTICLE INFO

Article history:
Received 20 March 2014
Accepted 5 May 2015

Keywords:
Target recognition
Perspective transformation
Position prediction
Target localization

ABSTRACT

Target recognition in infrared imagery is a challenging problem due to the complexity of real-world, especially in the cases that the target is occluded or hided completely, and that there exist lots of objects which are similar to the target. For these cases, an indirect target recognition method is proposed to recognize the target for the overhead image sequences. The proposed method mainly includes four steps: preparing template image of landmark, extracting the real-time scene image, matching landmark and locating the target. Several key technologies used in the proposed method are presented, such as perspective transformation used to prepare the template image for matching it with the overhead scene image, position prediction which is proposed to improve the real-time performance, and target localization used for locating the target's position. Experimental results are shown to demonstrate the robustness and efficiency of the proposed method under the condition that the target is occluded and that there exist lots of objects which are similar to the target.

1. Introduction

Infrared (IR) images captured by an aerial camera have extremely low resolution, low signal-to-noise ratios, obscurity and poor target visibility. Target recognition in infrared IR images is a fundamental and challenging task in computer vision. Many researchers have investigated various approaches of ATR from IR images. The classical approaches involve background suppression [1] and feature matching [2,3], correlation measures [4], Fourier transform [5], and edge match [6–8]. Some algorithms using fast template matching to recognize targets have also been presented [9]. Other approaches based on known techniques, such as neural networks [10,11], morphology [12–15], wavelets [16,17], human visual system [18], and support vector machine-based methods [19,20] have also been presented for detection the target. However, when the target is occluded or hided completely, or that there exist lots of objects which are the same as or similar to the target, few of above methods have robust performance.

Aimed at above conditions, an indirect target recognition method is proposed to recognize the target for the overhead image sequences. The model of proposed method is designed. In the designed model, several key technologies such as perspective transformation, position prediction, and target localization technology are presented. The remainder of this paper is organized as follows. Section 2 introduces the target recognition methodology. In Section 3, experiments under different conditions are shown to demonstrate the effectiveness of the proposed method. Section 4 draws the final conclusions.

2. Target recognition methodology

Before the target recognition, it is important to make platform route planning and select an appropriate landmark. In general, in the satellite image, the target is known, and landmarks are selected near the target and can be recognized easily. According to the selected landmarks, the reference images of landmarks are extracted from the satellite image. Once the landmarks have been selected, the position relationships between the landmarks and the target in the satellite image can be known according to their geographic position and resolution of satellite image. It is worthy to mention that the platform route should be made to ensure the landmark and target within the field of view, and the camera is fixed to the platform, namely, the camera motion is the same as the platform.

The main work of this paper is to propose an indirect target recognition method to recognize the target from the overhead

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http://dx.doi.org/10.1016/j.ijleo.2015.05.015
0030-4026/

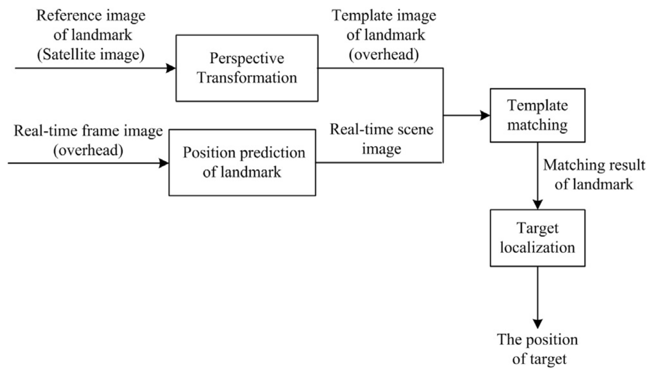

Fig. 1. The flow chart of the proposed method.

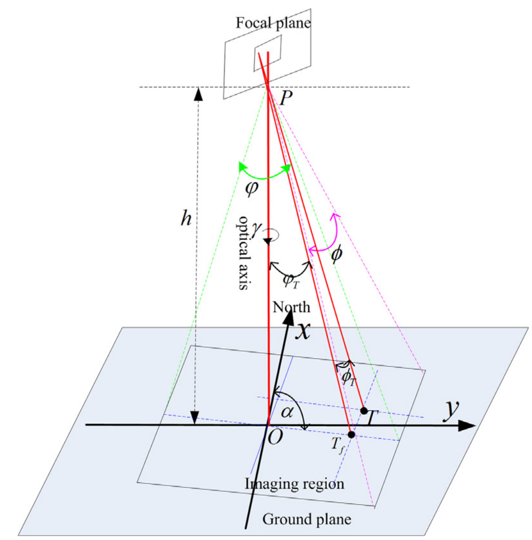

Fig. 2. Geometric model of perspective transformation.

image sequences, especially under the conditions that the target is occluded or hided completely, and that there exist lots of objects which are similar to the target. Based on the planned platform route and the selected landmark, the flow chart of the proposed method is shown as Fig. 1. The method mainly includes four steps. (1) Due to the disparity between the satellite image and the overhead image caused by the difference of geometric viewpoints, the template image of landmark must be prepared by transforming the reference image from the satellite image status to the overhead image status using perspective transformation. Then the landmark is recognized by matching the template image with the scene image. (2) From the second frame, the landmark's position in the overhead image of current frame can be predicted using position prediction technology. Then a small region near the predicted landmark's position can be extracted from the current image frame, which is used as the scene image to match template for improving the real-time performance. (3) The normalized cross correlation (NCC) template matching method is used here for matching landmark. (4) According to the matching result of landmark and the position relationship between the landmark and the target in the satellite image, the target can be located using target localization technology. The following parts will detail the proposed method step by step.

2.1. Perspective transformation

Since the reference image of landmark is selected from satellite image, the disparity between the satellite image and the overhead image makes landmark matching great difficult. Therefore, it is necessary to transform the reference image of landmark from the satellite image status to the overhead status. It is well known that the points in the satellite image and in the overhead image are one to one correspondence. Perspective transformation is proposed here to describe the corresponding relationship. Fig. 2 shows the geometric model of perspective transformation.

Let P denote the camera's position, φ and ϕ represent the longitudinal and horizontal imaging field of view angles, α, γ and h represent yaw, roll and height, respectively. From the principle of optical imaging, intersection point between the optical axis and ground plane is defined as the aiming point of optical axis O, whose position in overhead image is $\left(C/2, R/2\right)$, where R and C denote the number of rows and columns of each image frame in a video sequence, and the corresponding longitudinal and horizontal angle are $\phi/2$ and $\phi/2$. Since we just consider the overhead image here, the aiming point of optical axis O also is P's projection point on the ground plane. Assuming, for any point T in the field of view, whose position in the overhead image is (C_T,R_T), and T's projection point on the flight direction of aircraft is T_{f}. According to Fig. 2, we get

$$\begin{cases} \varphi_T = \left(R_T - R/2\right) \cdot \phi/R \\ \phi_T = \left(C_T - C/2\right) \cdot \varphi/C \end{cases} \tag{1}$$

where $\varphi_T = \angle OPT_{\mathrm{f}}$ and $\phi_T = \angle TPT_{\mathrm{f}}$, which are defined as T's longitudinal and horizontal angle. The perpendicular distance and horizontal distance between T and O can be calculated by

$$\begin{cases} OT_{\mathrm{f}} = h \cdot \tan\varphi_T \\ TT_{\mathrm{f}} = \sqrt{h^2 + OT'^2} \cdot \tan\phi_T \end{cases} \tag{2}$$

Then T's position (x_T,y_T) in geodetic coordinate system will be calculated by coordinate transformation,

$$\begin{cases} x_T = OT_{\mathrm{f}} \cdot \cos(\alpha+\gamma) - TT_{\mathrm{f}} \cdot \sin(\alpha+\gamma) \\ y_T = TT_{\mathrm{f}} \cdot \sin(\alpha+\gamma) + OT_{\mathrm{f}} \cdot \cos(\alpha+\gamma) \end{cases} \tag{3}$$

where the roll γ is considered. According above one to one corresponding relation, the grayscale value of any pixel in the overhead reference image can be calculated by using bilinear interpolation according to the grayscale value of the corresponding position in the satellite image.

2.2. Position prediction

In order to improve the real-time performance, from the second frame, the landmark's position in the current frame can be predicted using its position and flight parameters in the previous frame. Then a small region will be extracted around the predicted landmark's position which will be as the scene image to match template. The process of position prediction is derived as follows.

Let $\ldots I_{i-2}$, I_{i-1}, $I_i \ldots$ be the frames in a video sequence, the size of each frame is $R \times C$, and the corresponding aircraft's position are $\ldots P_{i-2}$, P_{i-1}, $P_i \ldots$, and the optical axis aiming points are $\ldots O_{i-2}$, O_{i-1}, $O_i \ldots$. The space position relationship diagram is shown as Fig. 3. Herein, imaging coordinate system is defined as: for the ith frame, O_i is origin, and the projection of the platform motion direction on ground is y axis and whose vertical direction is x axis. For simplicity, this imaging coordinate system is called coordinate system O_i in the following description.

Assuming, the flight parameters including height, pitch, yaw and roll of the ith frame are h_i, θ_i, α_i, γ_i. (x_{i-1},y_{i-1}) represents