The Design and Application of the Airborne Real-time Image Reconnaissance Computer System for Police UAV

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Abstract. The rapid development of UAV technology has greatly improved the degree of automation and intelligence. Aiming at the current situation and problems of insufficient aerial reconnaissance methods, this paper proposes an optimized scheme for real-time fusion of reconnaissance images and three-dimensional terrain. First, the reconnaissance target area is rendered and modeled, and then the reconnaissance image is mapped to the reconnaissance area for target tracking. Experimental results show that the system is intuitive and can effectively improve the reconnaissance efficiency of UAVs.

Keywords: Police Drone, Reconnaissance Video, Three-Dimensional Terrain

1. Introduction

With the continuous development of science and technology, the ways to obtain data are constantly enriched and intelligent [1-2]. The rapid development of UAV technology has greatly improved the degree of automation and intelligence, making it the best choice for performing boring, harsh or dangerous tasks. It has been widely used in military reconnaissance, aerial photography, environmental monitoring, etc., as a reconnaissance It shows a broad application prospects [3-4]. The traditional reconnaissance method is that the ground commander checks the reconnaissance video transmitted by the drone while checking the corresponding geographic coordinate image when a suspicious target is found to determine the target location [5-7]. In addition, the inability to observe the terrain from multiple angles is not conducive to finding the target faster and determining the location of the target. Therefore, it cannot control the flight path of the UAV in time and improve the reconnaissance efficiency. During the reconnaissance process of the UAV, if the real-time three-dimensional simulation of the UAV transmission image can be carried out, it will make the reconnaissance geographic environment more immersive and intuitive [8-9].

Public security currently has the contradiction between management area and insufficient police force, and it is difficult to respond slowly to the handling of mass incidents, and it is difficult to obtain evidence. The use of UAVs can well solve the problems of public security for on-site control and real-time command and dispatch. The close integration of the UAV system with the existing public security network, platform, and investigation means not only avoids information islands, but also participates in the top-level design as an element of aerial reconnaissance, helping to build a flat command system that integrates space and ground [10].
This paper relies on computer technology and UAV technology to improve human-computer interaction and terrain model modeling. This system is designed and implemented to provide theoretical support for intelligent reconnaissance.

2. System design

2.1. Overall architecture design

1) Aerial reconnaissance system. UAVs carry mission payloads for real-time image acquisition. After landing wirelessly, the reconnaissance data is transmitted back to the command center through the public security mobile police front-end machine in real time, and then distributed to various command and combat units through the 5G network and security boundaries. Data resources are integrated with the flat public security command system.

2) Ground command system. Target tracking realizes real-time return to the target position and drives the UAV for fixed-point tracking. The on-site command can not only monitor the real-time information sent back wirelessly from the surrounding area, but also obtain the drone's reconnaissance images through 3G. The mobile commander can dispatch surrounding police forces, collect on-site evidence, monitor audio and video, issue instructions and read UAV images while on the move. Individual combat civilian police use Beidou terminal equipment for on-site law enforcement, evidence collection, and real-time monitoring of UAV reconnaissance data.

3) The communication network part. The Beidou satellite landed by the Beidou commander installed in the public security network to receive the positioning and short message information returned by the subordinate Beidou user machines; the 5G wireless network mainly uses the operator to deploy a VPN private line to the public security department to achieve data transmission, and it is also unmanned. The channel for the machine to return reconnaissance data; 350M trunking is a voice trunking intercom network built by the public security.

4) The flat public security command center. It is the core brain and background of the command system. It can not only dispatch and command, but also receive and display the reconnaissance data returned by the drone, and it can connect with the public security PGIS, the police comprehensive platform and the big data intelligence platform in real time.

2.2. Important components of the system

The UAV reconnaissance image fusion system is mainly based on the elevation information of the reconnaissance area (DEM elevation data), existing satellite images or aerial images to establish a basic terrain model and give a basic overview of the terrain. Then, in the real-time reconnaissance process, as the UAV video stream is continuously read in, the selected frame image is used to replace the initial, low-resolution texture image. Furthermore, according to the visual scene reconnaissance whether there are suspicious targets, further targeted reconnaissance.

The system architecture is mainly divided into: the request and acquisition part of the reconnaissance video, the integration part of the reconnaissance video and the terrain model, and the human-computer interaction part.

1) Monitoring video request and acquisition

The request and acquisition of monitoring video is a two-way process. The ground control station issues shooting instructions, shooting directions, and shooting locations to the upstream drone.

Assuming that the element \( Z_k \) of the previous layer is the judgment criterion of the element \( Y_1 \cdots Y_s \) of the next layer, and has a dominance relationship on the \( Y_1 \cdots Y_n \) of the next layer, now compare the importance of \( Y_1 \cdots Y_s \) relative to \( Z_k \), and according to its different importance. The sex gives the corresponding weight, and \( Y_{pq} \) represents the relative importance of the factor p and the factor q under the criterion level Z. If there are n elements, a pairwise comparison matrix can be constructed, as shown in formula (1).
2) Fusion of monitoring video and terrain model
This part is the technical key part of this system. As shown in Figure 1, it is mainly to establish a basic terrain model. After preprocessing the video, according to the principle of one-to-one correspondence between each DEM grid point and the image position where it is located, the image texture is mapped to the terrain model in real time, replacing the original surface information.

\[
\begin{bmatrix}
X_1 & X_2 & \ldots & X_n \\
Y_1 & Y_2 & \ldots & Y_n \\
\vdots & \vdots & \ddots & \vdots \\
X_{n_1} & X_{n_2} & \ldots & X_{n_m}
\end{bmatrix}
\]

(1)

Figure 1. The fusion process of terrain and reconnaissance video
First determine the geographic location of the area to be monitored, obtain the elevation value (DEM data) and satellite or aerial images of this area, use OpenGL to perform three-dimensional gridding of DEM data and satellite images, and perform preprocessing operations such as texture mapping, and the preliminary establishment Basic terrain overview.

After receiving the monitoring video stream in this part, in order to improve the efficiency of subsequent display, the image is first divided into certain levels, and the corresponding texture image is indexed according to the display requirements, and the pixel information, that is, the texture.
element, is collected in combination with the corresponding rasterized grid. Complete the mapping of mesh triangles to texels, and finally realize the real-time update of the topography. Suppose there is a video signal matrix $X(m \times n)$, which can be obtained after PCA

$$X = t_1^T P^T_1 + t_2^T P^T_2 + \cdots + t_j^T P^T_j + \cdots + t_r^T P^T_r + E$$

(2)

Where: $t_j$ is a vector of $m \times 1$, which represents the j-th principal element; $P_j$ is a vector of $n \times 1$, which represents the j-th load vector; E is the residual matrix.

3) Human-computer interaction

The ground operator sends the scene to each monitor, and the monitor can mark the area that needs further key reconnaissance by clicking the mouse at any time during the monitoring process. At the same time, the system will change the drone according to the priority of the monitor. The navigation trajectory is monitored in a 360-degree omni-directional area around the marked point, and then output to the screen after fusion with the terrain, so as to achieve the purpose of monitoring.

2.3. System operation process

The operating process of this system is also divided into 3 stages, as shown in Figure 2:

**Figure 2.** System operation process

1) The start-up phase of the reconnaissance system

Before drawing the terrain model and performing texture mapping, it is necessary to preset the relevant scene parameters and input the terrain information into the corresponding array library. The preset information mainly includes: graphics operation description table and pixel format; view point position and line of sight direction; light source properties, light source orientation, color mode, blanking mode, texture mapping mode, etc.

2) The operating phase of the reconnaissance system

After the setup phase is completed, the system will complete the natural environment generation, DEM value rasterization processing, and terrain model establishment based on the scene parameters. At the same time, it receives the input of the video stream, selects the image texture for texture mapping, and generates visual geographic information. In the end, the commander can carry out the human-computer interaction of the interface, realize the key monitoring of the suspicious area, and complete the reconnaissance mission.
3) Withdrawal of the reconnaissance system
When the UAV completes the flight mission, the system will prompt the commander to complete
the mission signal in real time, and the commander will make a decision on whether to withdraw from
the system.

3. System key technology

3.1. Terrain data and reconnaissance image processing
The fusion algorithm framework realized by using the drawing function of OpenGL is divided into
the following two aspects.
(1) Pretreatment of terrain:
1) Obtain existing aerial images as terrain textures-these textures will be replaced by video frames
in the real-time processing stage. At the same time, the texture pixels are extracted to the color pixel
array.
2) Establish a three-dimensional terrain grid based on DEM data, which is a digital elevation model
generated by an object space in world coordinates.
3) Calculate the U, V coordinate system of the two-dimensional texture orthographic projection to
the grid from the DEM data and the terrain texture.
4) For each triangle in the three-dimensional terrain grid, a set of rasterized points are established
and cached, and each rasterized point is accompanied by its position in the 3D space and the
corresponding U, V coordinate information (it represents the texture The location of the center point of
a texel in).
(2) Processing of key frame images:
1) Obtain the position coordinates of the camera (latitude, longitude and direction attitude), and
calculate and set the scene transformation.
2) The triangle model that cannot be seen in the viewing frustum is ignored and not displayed, and
the triangles in the viewing frustum are mapped to the display area, and the two-dimensional U and V
coordinate values of each triangle are stored.
3) Sort the triangles according to the principle of far-to-near, and blank the covered triangles.
4) Collect color pixels from the key frame image to realize the mapping from texture to terrain.

3.2. Dynamic target reconnaissance and intelligent tracking
Police drones are a routine function for static target reconnaissance and evidence collection, but how
to effectively lock and intelligently track dynamic targets (such as vehicles and moving people) is a
technical difficulty. This system uses image intelligent recognition technology to implement dynamic
target retort, and at the same time guides the UAV to adjust and track the route. The system processing
process is shown in Figure 3.

![Figure 3. Block diagram of the image tracking system](image)

1) The tracking process of dynamic targets. First, plan the flight route of the drone according to the
pre-set reconnaissance range, bind the route to the drone, and after reaching the set route altitude, the
drone autopilot calculates the deviation between the current flight track and the set track in real time. Modify the drone to fly according to the route. The camera scans under the drive of the turntable to ensure a large search range and facilitate the discovery of ground targets. When the target is found, the ground operator judges whether it is a target that needs to be monitored, and uploads the initial seed point coordinates of the target through the data link by means of human-computer interaction. The image tracking processing system segments the target template, determines the position of the target relative to the image center, and continuously tracks and calculates and provides deviation data to the autopilot system. The autopilot guides the drone to track according to certain rules based on the received deviation data. the goal.

2) Algorithm steps to realize image tracking. ① Image preprocessing: During the flight of the UAV, due to the influence of airflow and engine, it will continue to make low-frequency vibration, and the acquired image will be obviously degraded. Among them, impulse noise and motion blur caused by the relative movement of the target and the camera are the main reasons. Preprocess the image. ② Image segmentation: Image tracking must first obtain the template of the tracking target. The method of obtaining target features and storing the target template in advance is often used, but there are difficulties in adapting to multiple targets, such as large storage space and complex automatic selection of templates. Therefore, the target is segmented from the real-time image and the tracking template is generated in real-time. Using human-in-the-loop control, the initial seed point of the target is determined through human-computer interaction to achieve target image segmentation, and the target tracking template is generated according to the segmented target image. ③ Image tracking: mainly through algorithms such as matching tracking and system state prediction, to achieve the possible position of the predicted target in the image in the next frame, to reduce the search range.

4. Simulation results
Through system design and breakthroughs in key technologies, an example of a UAV real-time image monitoring system was simulated. This example is run on an ordinary PC, using DEM data and UAV remote sensing image data, the terrain of a certain area is a reconnaissance terrain, and the experimental verification shows that the system has certain practical value. After updating the original texture, the UAV reconnaissance image is sent to the display interface of each operator. The operator has marked the suspicious target with a red flag, controlled the UAV to change the flight course, and focused on the detection of the marked area.

5. Conclusion
The use of unmanned aerial vehicles for aerial reconnaissance and evidence collection has the characteristics of fast response, high real-time performance and true and reliable images. This article relies on UAV technology and computer technology, through the analysis of remote sensing images, video stream data to achieve rapid detection and monitoring of the target area, has a good application prospects.

References
[1] Aygun H, Turan O. Exergo-economic Analysis of Off-design a Target Drone Engine for Reconnaissance Mission Flight[J]. Energy, 2021,4(3):120-127.
[2] Chow S Y. DTSA: A Federal Tort of Unfair Competition in Aerial Reconnaissance, Broken Deals, and Employment[J]. Physiological Research, 2016, 62(1):85-94.
[3] Kim D, Xue L, Li D, et al. On Theoretical Trajectory Planning of Multiple Drones To Minimize Latency in Search-and-Reconnaissance Operations[J]. IEEE Transactions on Mobile Computing, 2017, 4(11):1-8.
[4] Chang C C, Chang C Y, Wang J L, et al. A study of atmospheric mixing of trace gases by aerial sampling with a multi-rotor drone[J]. Atmospheric Environment, 2018, 184(7):254-261.
[5] Boysen N, Briskorn D, Fedtke S, et al. Drone delivery from trucks: Drone scheduling for given truck routes[J]. Networks, 2018, 72(4):506-527.
[6] Suh J, Choi Y. Mapping hazardous mining-induced sinkhole subsidence using unmanned aerial vehicle (drone) photogrammetry[J]. Environmental Earth Sciences, 2017, 76(4):144-154.

[7] Hahn N, Mwakatobe A, Konuche J, et al. Unmanned aerial vehicles mitigate human-elephant conflict on the borders of Tanzanian Parks: a case study[J]. Oryx, 2017, 51(3):513-521.

[8] D Solomitckii, Gapeyenko M, Semkin V, et al. Technologies for Efficient Amateur Drone Detection in 5G Millimeter-Wave Cellular Infrastructure[J]. IEEE Communications Magazine, 2018, 56(1):43-50.

[9] Hua F, Abeywickrama S, Zhang L, et al. Low-Complexity Portable Passive Drone Surveillance via SDR-Based Signal Processing[J]. IEEE Communications Magazine, 2018, 56(4):112-118.

[10] Li X B, Wang D S, Lu Q C, et al. Three-dimensional investigation of ozone pollution in the lower troposphere using an unmanned aerial vehicle platform[J]. Environmental Pollution, 2017, 224(5):107-116.