Research on regional intrusion prevention and control system based on target tracking

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Abstract: In view of the fact that China's border is very long and the border prevention and control measures are single, we designed a regional intrusion prevention and control system which based on target-tracking. The system consists of four parts: solar panel, radar, electro-optical equipment, unmanned aerial vehicle and intelligent tracking platform. The solar panel provides independent power for the entire system. The radar detects the target in real time and realizes the high precision positioning of suspicious targets, then through the linkage of electro-optical equipment, it can achieve full-time automatic precise tracking of targets. When the target appears within the range of detection, the drone will be launched to continue the tracking. The system is mainly to realize the full time, full coverage, whole process integration and active real-time control of the border area.

1. Introduction
Due to the long country's border line and complex terrain, the management and control is very difficult, the protection is more difficult, Current means of protection cannot effectively prevent the suspicious personnel from entering the country illegally. The system is established in this context. Through inspection and tracking, we can identify suspicious persons on the border line on the first time, and then take effective measures to prevent illegal immigration of suspected persons. This system saves us a lot of manpower, material and financial resources, and is conducive to the management and control of China's border lines, and also conducive to China's security and stability.

2. Overall Design Scheme of the System
The system intends to detect and track suspicious persons on the border, and transmit the acquired information to the command center in real time. The command center makes decisions on this basis. This system consists of three parts: fixed nodes, mobile nodes, data centers. As shown in Fig. 1.

![Figure 1. Overall structure drawing of the system](image)

Fixed nodes are mainly composed of camera pan head, radar, wireless devices (data transmission, picture transmission) and solar panels. It mainly realizes the preliminary detection and recognition of suspicious personnel.

First, the radar equipment finds suspicious personnel and transmits the location signals of suspicious persons to the control panel. The control panel controls the camera pan head, which can
realize the shooting and tracking of the suspicious personnel. The recorded video signals will be transmitted to the command center as the basis for the decision making.

The mobile node is mainly composed of a foldable unmanned aerial vehicle, a four rotor unmanned aerial vehicle, a camera pan head and wireless devices. When suspicious personnel appear in the tracking range of the fixed nodes, the mobile node continues to track the target personnel, and transmits the location, image and other signals of suspicious persons to the command center in real time.

The data center mainly completes the acceptance and delivery of target data. Through large data analysis, the data center determines whether the target is suspicious, and then proceed to the next decision deployment.

3. System Hardware Composition

3.1. Fixed Node Part

The system is composed of the power supply system and target tracking system. The hardware structure of the power supply system points includes: solar panel module, 24V power module, voltage conversion module; target tracking system’s hardware structure mainly includes: PTZ motor module, servo drive module, camera module, serial communication module and millimeter wave radar module. Their connection diagrams are shown in Fig. 2 and Fig. 3:

![Figure 2. Power supply system hardware connection diagram](image)

![Figure 3. Hardware diagram of target tracking subsystem](image)
3.2. Mobile Node Section
In this system, the mobile node is composed of folding wing UAV. The folding wing UAV is shown in Fig. 4.

![Figure 4. Folding wing UAV](image)

With the help of profili airfoil analysis software, we analyzed the resistance characteristics of open hundreds of airfoil, and choose the airfoil with the highest lift drag ratio, and then use CAD to design the fuselage and the folding mechanism. The structural assembly drawing of the folding wing is shown in Fig.5.

![Figure 5. Folding wing structure assembly diagram](image)

4. The Design of System’s Software Algorithm

4.1. The Design of Radar Ranging Precision Algorithm
The essence of increasing the number of FFT points is to increase the sampling points in frequency domain uniformly in the whole unit circle (that is, the whole distance spectrum), thus increasing the amount of computing. To improve the ranging accuracy of radar, it is only necessary to use FFT to determine the main lobe position of the echo distance spectrum, and then to increase the sampling points of the main lobe in the distance spectrum locally. The commonly methods used are ZOOM-FFT, direct selection method, several cascade FFT and so on, they are all the methods to increase the sampling points in frequency domain, this paper adopts a method which is more direct and fast, that is, use the Chirp-Z transform for equal interval sampling on a spiral line in the Z plane, The Chirp-Z transform of N point x(n) is

\[ X(z_k) = \sum_{n=0}^{N-1} x(n)z_k^{-n}, z_k = AW^{-k} \]  (1)

\( z_k \) is the sampling point, \( N \) is the number of sampling point, \( A \) is the starting point position, and \( W \) determines the stretching rate and sampling interval of the helix. When \( A = W = 1 \), local refinement sampling can be realized on the unit circle, and the formula (1) is represented by the Chirp-Z transform.
In formula (2) \( g(n) = x(n)A^{-n}W^{-\frac{k^2}{2}}, h(n) = W^{-\frac{k^2}{2}} \), and the FFT algorithm is used in the implementation of circular convolution in the frequency domain, the algorithm of Chirp-Z transform is divided into seven steps. The Chirp-Z algorithm calculation is less than \( N \log_2 N + 2(N + M) + (N + M - 1) \log_2(N + M - 1) \), because of the need to conduct a FFT operation to determine if the radar echo from the far main lobe when use the Chirp-Z transform, the computation calculation is \( N \log_2 N \), so the total amount of computation of the algorithm is \( N \log_2 N + 2(N + M) + (N + M) \log_2(N + M) \). If the method of increasing FFT number is used to improve the ranging accuracy of radar directly, its computation is \( 2MN \log_2 NM \). When \( N=256 \), \( M=256 \), FFT calculation only using N algorithm for 2048 computation using FFT combining with Chirp-Z transform is 7680, using direct increase of computation of FFT points to 10485760 it can be seen that using FFT method combining with Chirp-Z transform, the computation uses only 3.75 times FFT however, the measurement accuracy is improved by 256 times. The method of increasing the number of FFT points directly can achieve the same precision, and the computation will be only 512 times of FFT.

The parameters of the radar are \( T = 2.56 \text{ms}, B = 500 \text{MHz} \) (corresponding to the distance resolution of 0.30 m), \( f_s = 100 \text{KHz}, A = 4.0V, N = M = 256 \) (corresponding to the distance of the sampling interval is 0.0012m), the target from the radar distance is 12.0-12.3 m (step 5cm), the target is a single object. The range of local refinement is between the largest sampling point and the second largest sampling point in the echo intermediate frequency spectrum obtained by FFT. Its computer simulation results are shown in table 1.

**Table 1. The simulation results of radar ranging accuracy improvement by using Chirp-Z transform**

| Actual distance | 12.0000 | 12.0500 | 12.1000 | 12.1500 | 12.2000 | 12.2500 | 12.3000 | maximum error |
|-----------------|---------|---------|---------|---------|---------|---------|---------|---------------|
| Maximum sampling point method | 12.0000 | 12.0000 | 12.0000 | 12.3000 | 12.3000 | 12.3000 | 12.3000 | 0.1500         |
| Chirp-Z transform | 12.0012 | 12.0506 | 12.1000 | 12.1506 | 12.2012 | 12.2494 | 12.3000 | 0.0012         |

**4.2. Target Tracking Algorithm**

The system adopts the modified KCF algorithm, KCF tracking algorithm is one of the fastest and most stable tracking algorithms at the moment, but the traditional KCF algorithm does not have long-term tracking ability. Once the target is lost, it is difficult to find again. The lack of target detection mechanism is one of the major drawbacks of KCF tracking algorithms. Kalal et al. Proposed TLD tracking algorithm, which can make the tracking, learning and detection simultaneously, detect and track targets throughout the process, and constantly correct the template, but this method of testing target has seriously affected the speed of tracking. Therefore, in order to achieve long-term tracking, this paper adds the detection and localization mechanism based on the KCF tracking algorithm. Only when the target is lost can the restart detection mechanism be started, so that the tracking can be ensured, and the detection is taken as the second step, so as to ensure that the tracking speed is not affected greatly. The anew detection method used in this paper is to divide the whole image in the sampling window, respectively, calculated the sampling window peak response by KCF algorithm, the peak of the window, the peak is the largest window containing the target, this re positioning the target detection.

The overall process of the improved algorithm is shown in Fig. 6, when the peak does not appear abnormal, the algorithm will be in accordance with the way the KCF tracker to track the target frame;
when the peak is abnormal, stop immediately update the target template, re-start the detection mechanism, upon detection of target positioning, reload the KCF tracker, continue to update the target template. To track the target according to the KCF tracker frame mode.

![Flow Chart](chart.png)

**Figure 6.** Overall flow chart of the improved algorithm

Fig.7 is the 4 properties: non-rigid deformation, fast motion and illumination changes, occlusion success rate, it can be seen from the figure of this algorithm in 4 properties, the success rate of figure are ranked first, compared with the traditional KCF tracking algorithm performance were improved by 19.96%, 19.81%, 15.39%, 11.13%. It shows that the improved algorithm has good tracking effect in deformation, fast motion, illumination change, target occlusion and so on.
5. Conclusion
Aiming at some problems existing in border control, this paper designs a target tracking system based on Intrusion Prevention and control, the system can meet the real-time and all-weather requirements in radar target tracking, the two algorithms are improved, a good solution to the radar in the distance accuracy. The performance of target tracking algorithm is better than other algorithms.

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