Application of differential countermeasure machine learning model in the field of UAV circuit inspection

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Abstract. In this paper, we establish one-objective differential game equations for one-to-one attack and defense in a two-dimensional plane. Through calculation and visual analysis, obtain the optimal pursuit path movement trajectory, and through machine learning method to training UAV, using cycle process of simulation, output with time growth each cycle pursuit path results, by comparing the movement trajectory image of the pursuit results and find the sheep just escape critical point exit. After that, the angle difference between the two initial positions was changed and tested again to enable the UAV to learn the optimal escape strategy more comprehensively, thus making a more precise path selection. Finally, this method can be reasonably evaluated.

Keywords: differential game machine learning simulation.

1. Introduction
The proposal of the differential game stems from the need for military strategy during World War II to R. (USADr. Isaccs) led research on the pursuit of each other to plan each other. This paper restricts restrictive on the basis of confrontation, studies how to avoid when drones encounter a tornado during circuit inspection, and uses machine learning to find intelligent and effective avoidance schemes. Within a given circle range, the drone attempts to escape at a constant rate, and the tornadoes chase along the circle at a constant rate. The drone aims to run out of the circle as much as possible by a tornado, which approaches around the circle. Through the analysis of the pursuit path and ability, the pursuit strategy of the UAV is developed, and the UAV is trained through machine learning methods, so that it can be successfully escape after continuous training. Finally, this method is reasonably evaluated.

2. Model establishment and solution
2.1. Determine tracking trajectory of tornadoes and drones

2.1.1. Optimal containment strategy for tornadoes. To investigate whether the drone can successfully escape, first plan the optimal path of the tornado. When the drone can still escape successfully under the assumption of the optimal path, it shows that it must surely escape successfully in real situations. Assuming that the escape start of the drone is fixed with the exit position, the escape path determines the drone, connecting the center to the exit and extending to the circle where the tornado motion route is located. When the tornado and the UAV start on the same side of this connection, the containment
path of the tornado and the escape path of the UAV, when the tornado and the UAV start, the tornado starts in the opposite direction of the UAV's escape path. That is, when the exit is determined, the optimal containment strategy adopted by the tornado is always a bad arc from the tornado starting point to the circle at the exit.

2.1.2. UAVs are based on successful escape conditions under a tornado optimal containment strategy. Due to the uncertainty in the drone start and exit, the direct analysis is so complex that it is rare to draw conclusions of high credibility. Let's fix the drone's start and exit before we analyze its shortest path. We follow a given constraint according to the title stem: the UAV has a constant rate in a circle with a radius and the distance between each point on the escape path and the center is monotonous with time, and then the UAV must choose the shortest path that meets the prescribed conditions. As shown in Figure 1, the UAV start point and exit point C, acquisition were determined. $BC \perp OB$.

![Figure 1. Escape situation of the UAV](image)

From the triangle, we can see that $AB + AC > BC \ \text{}\Rightarrow AB + AC > BC$

Let every point on the escape path and the distance from the center is monotonous with time, namely the drone can only escape to the direction away from the center of the circle, and the shortest line between the two points can escape the optimal path: first do uniform circular motion to the cut point position, then by the cut point position start to do uniform straight motion until reach the exit successfully escape.

After analyzing the optimal paths of drones and tornadoes, we make four possible assumptions about the relative initial position and the two pursuit path, and the four pursuit models are shown in Figure 2.
2.1.3. A pursuit model that does not consider the specific motion trajectory of the UAV. Before building the model, both are first assumed to start simultaneously and start motion.

- \( x_{s0} \): The initial position transverse coordinate of the UAV
- \( y_{s0} \): Initial position ordinate of the UAV
- \( r_s \): \( r_s = \sqrt{x_{s0}^2 + y_{s0}^2} \)
- \( t \): Total time of drone movement

In order to more comprehensively discuss the relative position relationship and sum trajectories of the pursuit game, we combine the characteristics of the neural network guidance law to focus on analyzing the pursuit game problem in the two-dimensional plane environment. Drones and tornadoes are considered as ideal manipulable points, and the focus of discussion is the real-time online numerical solution of the guidance law of the pursuit game and the motion law of the center of mass in the plane, that is, the optimization of the motion trajectory of the pursuit is studied. [1]

To simplify the model to make the subsequent optimization solution smoothly, we ignore the response to the manipulation mechanism deflection and various external disturbances during the modeling process. Under this condition, the kinetic model of the two-dimensional intraplane tornado UAV pursuit game can be expressed in the following form:

\[
\dot{x} = \begin{bmatrix} \dot{x}_1 \\ \dot{y}_1 \\ \dot{x}_2 \\ \dot{y}_2 \end{bmatrix} = \begin{bmatrix} v_1 \cos \theta_1 \\ v_1 \sin \theta_1 \\ v_2 \cos \theta_2 \\ v_2 \sin \theta_2 \end{bmatrix}
\] (1)

Among them:
- \( x_1, y_1 \): Location coordinates of the tornado in a two-dimensional plane (m);
- \( x_2, y_2 \): Position coordinates of drones in the 2-dim ensional plane (m);
- \( \theta \): Angle of movement direction and coordinate axis (r ad);
- \( v \): Motor speed (m/s)

In the pursuit game, the state variable is \( i=1,2 \) and the control variable is \( i =1,2 \). \( x_i = (x_i, y_i, \phi_i, v_i) u_i = (u_i, \phi_i) \)

Given the limitations of the physical capacity of the drone and the tornado, neither rotates the trajectory at any angle in a short period of time, so the control variables against both sides need to meet the following constraints: \( i=1,2 \), \( \phi_{i_{\text{min}}} \leq \phi_i \leq \phi_{i_{\text{max}}} \)

To facilitate model building and computational learning, we stipulate that tornadoes can successfully capture drones when the tornado is 0 apart from the drone:
In formula, when the distance between the UAV and the tornado is 0, we determine that the corresponding time is the termination time (s) of the pursuit game. The final form of the formula is:

\[
\begin{align*}
\phi(x(tf), tf) &= (x_1(tf) - x_2(tf))^2 + (y_1(tf) - y_2(tf))^2 > 0 \\
R - r_s &= \int_0^t v \cos(\theta(t)) \, dt \\
R + \int_0^t v \sin(\theta(t)) \, dt = \theta \\
R \arctan \frac{y_{s0}}{x_{s0}} + \frac{R \theta}{V} = t
\end{align*}
\]

Formula indicates the displacement size of the UAV in the radius direction, the total angle of the UAV and the total time of UAV motion. Simplified available:

\[
\theta(t) = \frac{V}{2R} t + \arccos \frac{V(R - r)}{2Rv \sin \frac{Vt}{2R}}
\]

Based on the existing conditions and known states, we plan to solve the pursuit game problem using a direct method.

The first step adopts the dual-layer planning idea to transform the original minimax problem into a maximum and a minimum one-sided optimal control problem. For the one-sided optimal control problem, in this paper, the orthogonal configuration method is used to perform the model discretization. The method is solved using the Longgekuta method with high order precision. For the initial state of each group of specific UAV tornado motion paths, we can obtain bilateral optimal control based on the orthogonal configuration method and the above optimization proposition. Then the iterative method is used to obtain the optimal control of the convergent bilateral open loop.

To sum up, the optimal path of the research UAV is to first move along the arc with a fixed radius, and then move along the tangent line until the escape of the UAV circle.

2.2. Establish a simulation machine learning method

1. Hypothesis

To perform machine learning and simulation simulations, we first assign reasonable hypothesis values to the initial conditions.

\[
R100r = 50V = k \times vt_1 R = 2rk = 2
\]

We set the circle size to, the initial position of the drone from the center of the circle, the speed of the tornado, the time of motion. Here, whether tornadoes could chase drones at the time was only related to their initial angle, regardless of movement time and cut location. Let the speed of the UAV, the movement time, to get a more general conclusion, take (between 1 and 2), then the speed of the tornado. Make the tornado and the drone have an initial angle of 0 to establish a polar frame, so that both people can move counterclockwise from the positive axial direction. \( v = 10t_2 k = 1.5V = 15 \)

\[
\frac{vt_1}{R} - \theta_0 = \arccos \frac{r}{R} + \frac{v_t - \sqrt{R^2 - r^2}}{r}
\]

The tornado happened to catch up with the drone. (Here, the initial clip angle) \( t_1 = t_2 \theta_0 = 0 \)

2. Machine learning process

To enable the UAV to achieve escape after learning and training, we establish a model system that can reference the UAV escape route by constraining the initial known conditions.

In this model, we establish a polar coordinate system and input the parameters of the current environment of the UAV: the UAV circle radius, the radius and angle of the location of the UAV relative...
center, the angular difference between the UAV and the tornado and the speed of the two. At the same time we specify the polar axis of the polar system, with all angles positive counter-clockwise. Therefore, each time, by changing the UAV and tornado motion time, judge whether the tornado is successfully pursued according to the obtained path simulation image, and whether the UAV can successfully escape.

The time for the drone to do the tangent movement, because the drone should go out and at least finish the tangent, and the length of the tangent is certain, so the tangent time is fixed here. That can directly increase the total time, let the UAV do uniform speed circular movement time slowly increases, when the UAV arc trajectory increases, the arc movement and tangent linear movement in the process of time change, using MATLAB write cycle program output each loop of UAV and tornado path results, by comparing the two trajectory image observe chase results and find the critical point exit.

It then changed the angular difference between the tornado and the initial position of the drone and was tested again. Figure 3 is a simulation of the pursuit process in three cases.

![Figure 3. Simulation and simulation of the UAV escape path](image)

The red path represents the tornado pursuit path, the blue path represents the escape path of the drone, and the analysis of both image trajectories yields the following results:

The initial Angle of 1. is 0, the speed of the tornado is 15, and the speed of the UAV is 10. Both move counterclockwise from the Angle of 0. The tornado can chase the drone within a certain time, and
not the drone after the critical time. As can be seen, through calculation, the critical time is \(20 \cdot (\sqrt{3} - \frac{\pi}{3})\).

2. We can change the initial clip angle according to the actual situation to obtain the optimal learning path.

3. Conclusion

In this paper, when the best path is solved. It is no need to solve the first-order necessity conditions, or to provide a good initial value and the control variable switching structure for the optimization proposition. The above features ensure that the method can effectively solve the pursuit game problem under complex constraints. The rand function is used to detect the utility index of the model, being more efficient, and yielding a corresponding escape range with a fixed velocity and initial position. Multiple sets of data can be trained simultaneously. This study can be used to simplify manual remote operation, and save more output costs for workers in the contemporary power industry. With the flexibility and convenience of UAV technology, the modern power grid system can achieve scientific and intelligent development.

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