DEVELOPING A SOLUTION TO AUTOMATIC CALCULATION OF NAVIGATION FOR SU-30MK2 FIGHTER AIRCRAFT TO INTERCEPT AIRBORNE TARGETS

XÂY DỰNG GIẢI PHÁP TỰ ĐỘNG TÍNH TOÁN DẪN ĐƯỜNG ĐÁNH CHẶN MỤC TIÊU TRÊN KHÔNG CHO MÁY BAY TIÊM KÍCH SU30MK2

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ABSTRACT

This paper introduces a solution to automatically calculate the navigation process at the headquarters for fighter interceptors of the Air Force to intercept airborne targets. Concretely, the solution is applied to SU-30 MK2 fighter aircraft. The main goal of this solution is to identify tactical air routes, intercepting options, and probabilities to intercept the targets. The solution could be applied in combat readiness training, combat support, and contribute to developing an automated air combat system.

Keywords: *Interceping airborne target, air combat, navigation at the headquaters, automated air combat system.*

TÓM TẮT

Bài báo mô tả giải pháp tự động tính toán dẫn đường đánh chặn mục tiêu trên không tại Sở Chỉ huy cho các loại máy bay tiêm kích của Quân chủng Phòng không - Không quân, phần tính toán chi tiết được áp dụng cho máy bay SU30MK2. Trong đó mục tiêu của giải pháp là tính các tuyến chiến thuật, phương án đánh chặn và khả năng đánh chặn mục tiêu của tiêm kích. Kết quả của giải pháp có thể áp dụng trong huấn luyện săn sàng chiến đấu, hỗ trợ trong chiến đấu và là nền tảng để xây dựng hệ thống tự động hóa tác chiến không quân.

Từ khóa: *Đánh chặn mục tiêu trên không, tác chiến không quân, dẫn bay trên bàn tròn sở chỉ huy, tự động hóa tác chiến không quân.*

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1. GENERAL INTRODUCTION

Interception is a tactical form of using a fighter or a squadron of fighter aircraft, scrambling from the airfield or from the air duty area, to detect, approach and destroy an airborne target on the designated route, then escape, fly back to land on the airbase with assistance of ground navigation [7].

Navigation for interception is a process in which navigation units constantly interact with the interceptor (pilot) through air-to-air systems, from the moment of upgrading combat readiness level to taking-off, approaching the target and then escaping and landing [4].

Currently, navigation calculation for airborne target interception (intercept navigation) is carried out by two basic methods: Direct navigation from radar stations and navigation at the Air Force Headquarters (HQ) [6, 9]. This paper deals with the second one.

The current manual calculation method for navigation faces certain difficulties in producing an optimal, fast and accurate intercepting option because it requires a combination of relevant experience, professional knowledge, and various extra calculations.

Given the district characteristics and requirements of the above interception method, it is necessary to develop an alternative solution, with the help of computer systems, to automatically calculate the navigation process for intercepting airborne moving targets in order to have optimal, fast, and accurate results.

In this paper, the authors will concentrate on examining the navigation method for intercepting hostile airborne targets from the HQ. Issues will be discussed include: Reviewing contents and calculating method of the traditional navigation for interception from the HQ; developing an automatic calculation solution to interception navigation. The goal of this solution is to identify tactical air routes, propose interception options and identify probabilities to intercept the air moving target for the interceptor. Results of this automatic calculation could be applied to assist the interception navigation via air-to-air systems or provide parameters for the automatic flight program in building an automated air combat system.

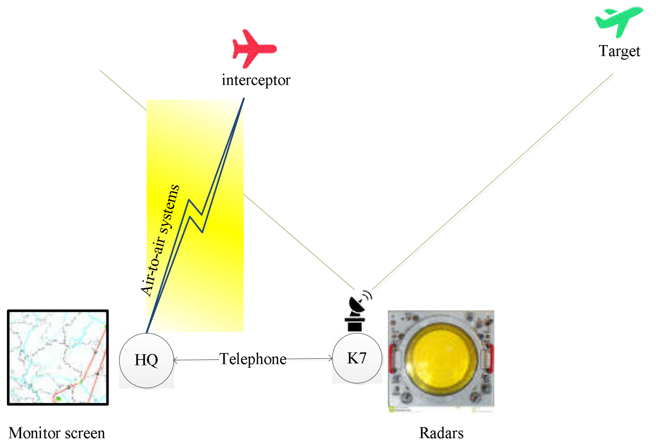


Figure 1. Model of navigation for interception at the Headquarters

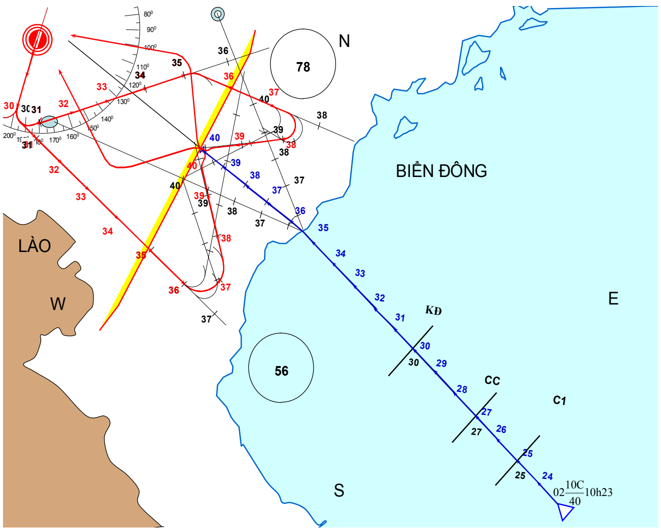


Figure 2. Map of calculation results and data of navigation for target interception at the command post

The current calculating process of navigation for airbone target interception from the HQ is carried out as follows:

Information on the interceptor and the target is transmitted to the HQ via intelligence channels of target. Basing on the relative positions between the interceptor, the target, and his assignment, the navigation officer will calculate flight parameters that follow (by using specialty rulers, lookup tables, computers...) in support of destroying it before the possible interception route. After finishing the calculation, the navigation officer will communicate with the pilot via air-to-air systems to help him control the interceptor.

- Blue line: flying path of the target;
- Red line: flying trajectory of the interceptor;
- C1: Route Level 1;
- CC: Take-off Route;
- TCTĐC: Possible route to intercept.

The navigation for intercepting the target needs to calculate the following key metrics:

- Take-off Route: The interceptor will take off when the target approaches this route to make sure that it can intercept the target before the possible interception route;

- Probability to intercept: Available data (position, speed) of the target and the interceptor makes it possible to determine the probability (the farthest position) where interceptor can approach and destroy the target;

- Interception option: Calculating an optimal trajectory and providing relevant flight data for the interceptor to reach the target at a desired position.

The above-mentioned process uses approximate calculations. In order to have optimal results, calculations must be done repeatedly and flight paths must be adjusted accordingly. In the case of highly maneuvering targets, it is impossible to do this way without the assistance of computer systems. To meet requirements of the intercept navigation under new circumstances, particularly in response to highly maneuvering targets, the authors of this paper will present a solution to automatically calculate the navigation process for interception associated with complex parameters as follows:

- Identifying the Take-off Route and Route Level 1 in a fast and accurate manner basing on the interceptor's dynamics;

- Calculating the optimal interception option (on the interception route, before the interception route);

- Assessing the probability of interception for the interceptor and adjusting the option and navigation parameters accordingly.

2. PROPOSED SOLUTION

After reviewing the navigation method for intercepting airbone targets from the HQ as presented in Section 2 and taking its assiciated problems into account, the authors propose a new calculation solution for navigation as shown in Figure 3 and the implementation algorithms as shown in Figure 4.

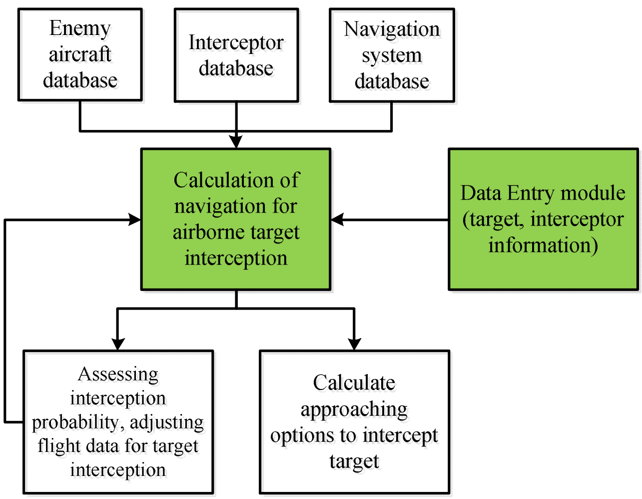


Figure 3. Model of automatic calculation of navigation process for intercepting airborne targets

When the target information is relayed to the HQ for the second or third time, a tactical route (Level 1 Route, Take-off Route) is defined basing on calculation of the interceptor's dynamic characteristics, the target speed and other available interception data. Once the tactical route is identified, the interceptor scrambles, the navigation officer will assess the probability of interception from its current position. If interception is possible, an interception option is calculated and the interceptor is controlled accordingly. The calculation process will be repeated every time the target information is transmitted until the interceptor approaches and destroys the target.

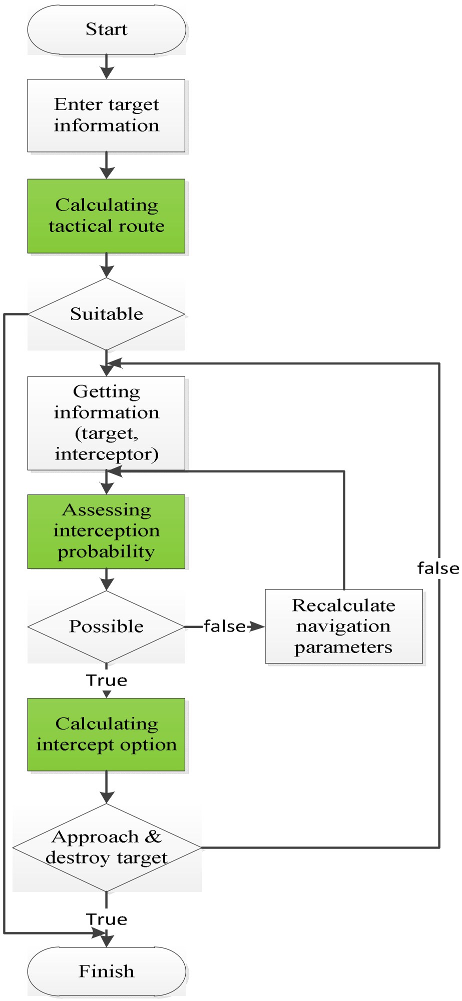
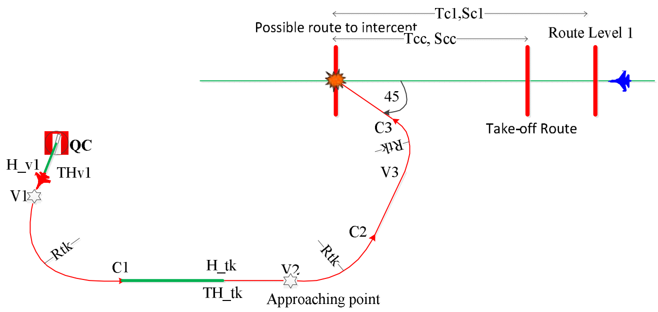


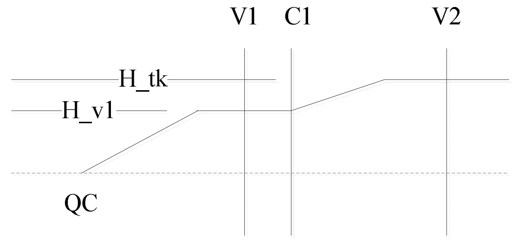
Figure 4. Algorithm flowchart describing steps in calculating navigation for target interception

2.1. Calculation to identify the tactical route (Level 1 Route, Take-off Route)

Identifying Level 1 Route (Take-off Route) requires accurate calculations. When the target reaches to Level 1 Route (Take-off Route), the interceptor scrambles to approach the target before the possible interception route. There are two steps in calculating the tactical route: Calculating a trajectory for the interceptor to approach the target; and calculating flight time for it to reach the interception route.



a) Straight flight trajectory



b) Cross section of flight path

Figure 5. Model of calculating the tactical route

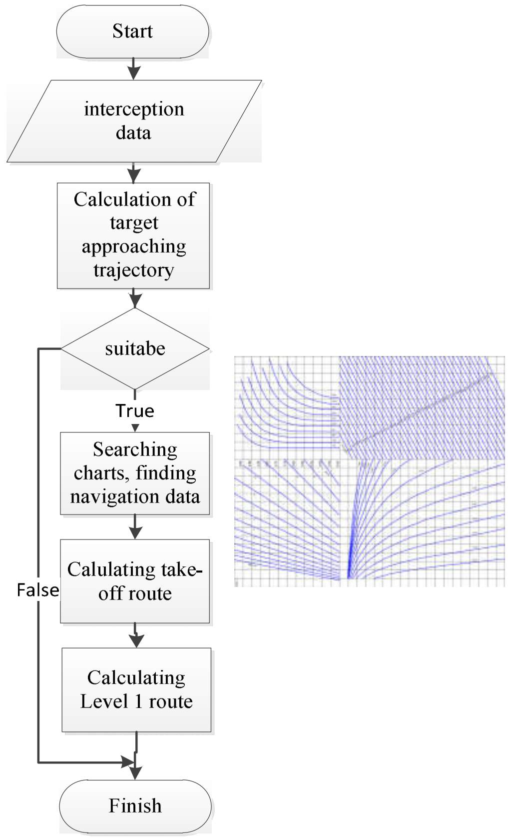


Figure 6. Algorithm flowchart for calculating the tactical route

The approaching trajectory is automatically calculated as shown in Figure 5a; cross-section of the flying path is shown as in Figure 5b. The approaching point and possible interception route are identified depending on the take-off airfield. The flying trajectory consists of 3 elements: the circling segment (v); straight flight segment (c); height reduction segment.

Time for the interceptor to reach the possible intercepting route includes: time to climb to point V1 (Thv1); time rising to the altitude to intercept (Thtk); time in Tbb (circle, straight flying).

$$T_{tk} = T_{hv1} + T_{htk} + T_{bb} \quad (1)$$

T_{hv1}, T_{htk} is automatically calculated according to charts 2.6.1, 2.6.2, 2.6.3 of the fighter aircraft SU30MK2 [1], of which data inputs include: flying glider n(m), flying speed (M), flying mode (cd), engine RPM (vqdc), drag force index (Lc), lap altitude 1 (hv1), ambient temperature (t), intercept altitude (htk); data outputs include: flying distance (L), flying time (T), fuel consumption (Q).

T_{bb} is calculated by the formula:

$$T_{bb} = S_{bb}/V_{tk} \quad (2)$$

of which, S_{bb} is the straight flying range; V_{tk} is the interceptor's speed.

The take-off route shown in Figure 5a is calculated by the formula:

$$S_{cc} = V_{mt} * T_{cc} = V_{mt} * T_{tk} \quad (3)$$

The Level 1 route shown in Figure 5a is calculated by the formula:

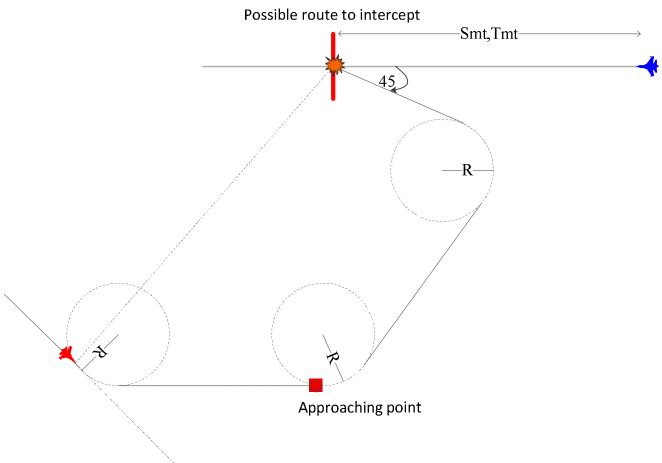
$$S_{c1} = V_{mt} * T_{c1} = V_{mt} * (T_{tk} + T_{chuyencap}) \quad (4)$$

2.2. Calculating interception option

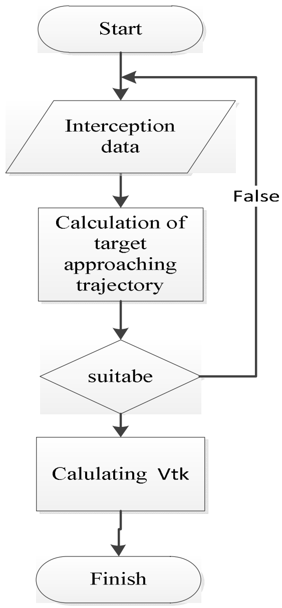
Depending on changing positions of the interceptor, the target, and the associated flight data, an interception option must be calculated as quickly as possible in order to determine a trajectory and flying speed for the interceptor to approach the target at a desired position. The interception option is calculated at the same altitude and is performed every time the target or interceptor maneuvers.

There are two important metrics in calculating the interception option: trajectory to approach the target (arcs, straight and direct flying segments) and speed of the interceptor (V_{tk}).

Direction on each flying segment can be easily determined on the map according to the PN coordinate system after the trajectory has identified.



a) Approaching Option



b) Algorithm flowchart

Figure 7. Calculation of interception option

V_{tk} is calculated to ensure that the interceptor approaches its target on the designated route (Figure 7a) and is done by the formula:

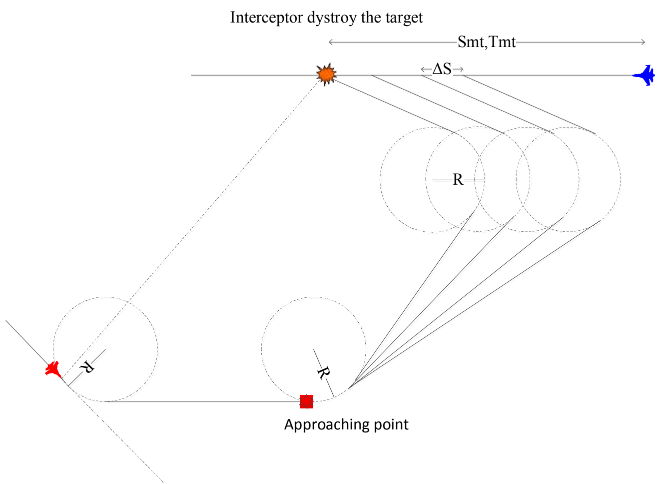
$$V_{tk} = S/T_{mt} \quad (5)$$

of which S is the length of the interceptor's trajectory; T_{mt} is the time it takes the target to reach the interception route.

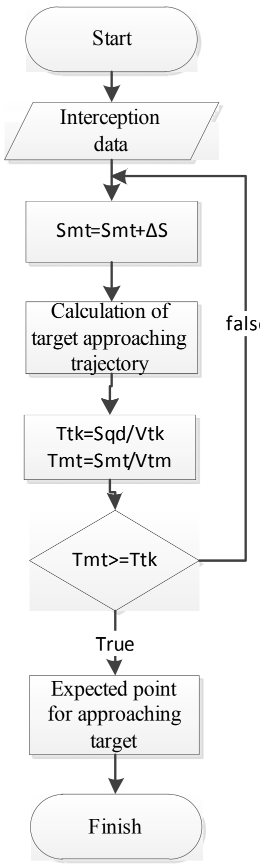
These data can be used to control the interceptor via air-to-air systems or integrated into the automatic flight program.

2.3. Calculating the interception probability

Basing on current positions of the fighter, the target and the navigation data, a fundamental requirement in calculating the probability of interception is to determine the furthest position so that the interceptor can attack the target. The interception probability also helps the commander come up with an appropriate option.



a) Approaching trajectory



b) Algorithm flowchart

Figure 8. Calculation of interception probability

Calculating method:

Constantly moving the possible interception point from the target to the possible interception route with the distance ΔS, then determine the approaching trajectory for the interceptor.

Calculate the time when the interceptor and the target could reach the possible interception route. The furthest point is the first one satisfying the condition $T_{mt} \geq T_{tk}$. Its accuracy depends on the selected distance ΔS.

3. RECEIVED RESULTS

3.1. Data for calculation

- Airport to take off: Bien Hoa Airport;
- Navigation radar station: T16;
- Type of aircraft: SU-30MK2;
- Mode: combat, engine rotation; fully increased force;
- Loading oil: 6000kg;
- Armament: 3200kg; drag force: 4;
- The target flying from the South China Sea (assumed fying path as shown in the figure) with a speed of V = 600km/h, altitude H = 7000m;
- The ointerceptor's speed: V_{tk} = 800, interception altitude 7000m, target information relayed every 30 seconds.

3.2. Calculation results

Figure 9. Result of possible interception route

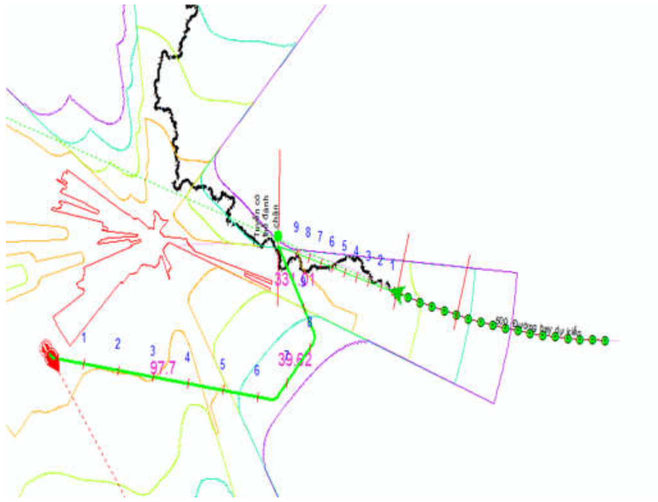


Figure 10. Result of interception option

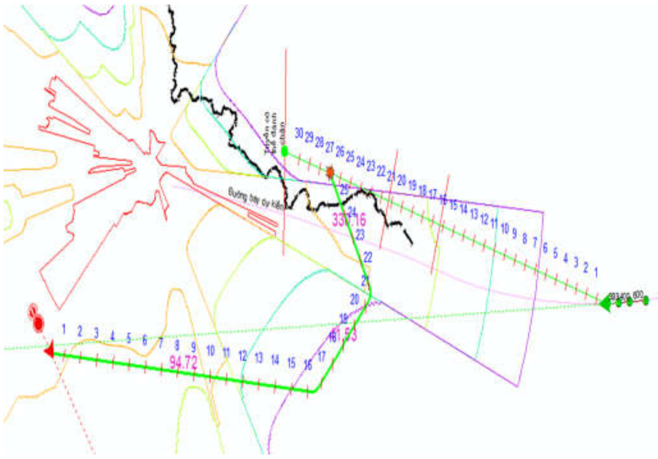


Figure 11. Result of probability for interception

Table 1. Result comparison

Order	Contents	Time calculated by tranditional method	Time calculated by the authors's new method
1	Calculation of Level 1 Route, Take-off Route	Approximately 1 minute (approximate calculation)	300ms (detailed calculation)

2	Calculation of interception option	Approximately 2 minute (approximate calculation)	700ms (detailed calculation)
3	Calculation of interception probability	Approximately 2 minute (approximate calculation)	1500ms (detailed calculation)

From the obtained results, the proposed solution has a faster and more accurate calculation speed than the traditional method, modeling the interception problem is correct and feasible. With a reading time of 20 seconds, the proposed solution is highly reliable and meets the actual requirements.

4. CONCLUSION

In theory of navigating calculation for intercepting airborne targets [2, 4], the method of using such tools as specialty rulers, pencils, paper maps produces low levels of accuracy and response, mainly depending on personal experience. To address these issues, the paper authors have developed an alternative solution to automatically calculate the navigation with assistance of computer systems and digital maps, which significantly contributes to assist the navigation at the headquarters for intercepting airborne targets. Calculating results could be applied to develop a automatic flight program and contribute to building an automated air combat system. Upon completion, the solution could be intergrated into software programs designed to calculate flight routes for regiments and divisions of the Air Force.

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