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GPS 的微型系统及其制导

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摘要: 基于微型飞行器(MAV)尺寸小、载重及能量供给有限, 难于获取完整的飞行状态参数, 对机载的设备和导航控制系统要求很高等特点, 提出了一种应用于翼展 680 mm 的电动微型飞行器的基于航迹角度和偏航距误差的几何导航控制算法, 并利用 MEMS 传感器设计了飞行控制系统, 给出了 PID 控制率。Matlab 仿真试验表明, 该系统在 3 种 PID 控制率下均可很好地实现导航控制, 偏航控制误差低于 30 m; 空中飞行试验表明, 提出的算法有效地实现了电动微型飞行器的导航控制飞行, 在 2 级风情况下, 偏航误差低于 30 m。

关 键 词: 微型飞行器; 全球定位系统; 几何算法; 微机电系统

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Guidance and implement of micro system based on GPS

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Abstract: Micro Air Vehicles(MAV) are characterized by their small sizes, low powers and load ability, so it is difficult to obtain the full state measurements in real time and short of a full control degree. In order to solve the problems of autonomous flight control and stability, this paper presents a guidance algorithm for the relative miniature GPS-based navigation system of an electrically MAV. One standard geometric method for solving autonomous flight is adopted to derive a class of algorithm based on the heading angle error and yawing distance error and the MEMS sensors are used to design a flight control system. Simulation and practical experiments show that the guidance algorithm used in the MAVs is effective with different PID controlling parameters, which can obtain a yawing distance error less than 30 m. The TH680 equipped with the GPS-based autonomous flight control system loading the designed geometric algorithms has been successfully tested in a flight, and the yawing distance error is less than 30 m in a 2 level wind.

Key words: Micro Air Vehicle(MAV); General Position System(GPS); navigation; geometric algorithm; MEMS

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1 Introduction

Micro Aerial Vehicles (MAVs) are very practically aircraft in the field of surveillance and reconnaissance for military and civilian applications. Their instability, difficulty of guidance and relative control compared to an Unmanned Air Vehicle (UAV) and normal missiles due to their small scales, less flight speeds, less servos, less carrying weights, less power and so on renders them to be operated only by a strong pilot. AeroVironment Inc^[1] has developed and optimized a Black Widow MAV, which carries one color camera in MAVs and a RC remoter for the pilot on the ground to guide the operation of the vehicle. Lockheed Sanders Group^[2] developed a MAV named MicroSTAR with a 5g GPS-navigational system for control by ground station, developing the digital video transmitter within 2 km.

The decreasing vehicle size and increasing functional complexity of MAVs have generated a challenging variety. These challenging research topics in MAVs design fall into many categories^[3]. In this paper, the field of stability and autonomous flight control is presented especially. Guidance algorithm and relative control process are very different from UAVs and normal missiles because of less scales, less servos, less power and the lack of carrying weight. Many researches on stability and autonomous flight control have been developing^[4-6].

Many guidance algorithms for UAVs and missiles are derived from physical information, for example kinematics and their relative variants derived from mathematic techniques. Recent Trends in guidance design could be classified into two main approaches, optimization theories^[7] and geometric methods^[8]. Guidance algorithm takes the optimization theory to minimize some specific objectives, such as trace routes and trace time. Although theoretically appealing, the guidance algorithms in practice

are often difficult to implement in MAVs because of difficulty to obtain the full state measurements in real time and lack of full control degree.

In order to solve the problem of autonomous flight control and stability, design of guidance algorithm based on geometric theory is proposed with efforts and experiments, and the mini-GPS based autonomous flight control system^[5] is implemented and tested by TH680. In contrast to UAVs and normal missiles, the MAV guidance algorithm and relative control methods are obviously very different from the normal missile and UAVs because of the constraints of target MAV, such as no rudders, less weights, less scales, less carrying weight capacity and instability.

2 Geometric guidance algorithm heuristics and relative control

The aircraft developed for use in this research has wingspans from 60.96 to 12.7 cm. For initial flight tests a 53.34 cm MAV, the latest research is shown in Fig. 1. Because of highest payload capacity, the 53 cm (21 in) plane is capable of carrying 120 g in addition to its primary flight systems including servos, a motor, receiver, and batteries. Using a standard configuration, the MAV equipped with a color and

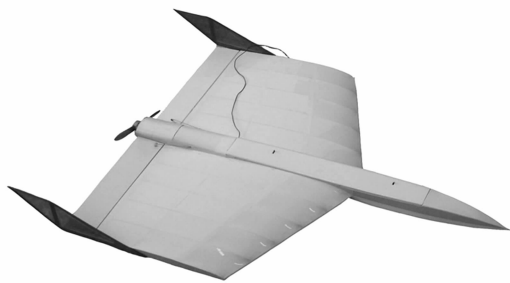


Fig. 1 Initial flight tests by using MAV with wingspan 53 cm (21 in)

transmitter is capable of sustained flight for up to 50 min. This flight time is essential for close-range surveillance missions. With the practical application, the ARC is used in MAV with wingspan 30.48 cm. Without rudders, the ARC utilized the geometric algorithm could navigate and guide MAV with flap and elevator steadily.

In finishing stability control of 30.48 cm and 53.34 cm, autonomous flight control is being focused on. The trace of mission for MAV consists of several trace points. As shown in Fig. 2, the predicted route is consists of several trace points. The main processor will store the geographic coordinate and decide which next trace point is according to the MAV position. What is more important, the predicted trace and points are generated by real mission and optimized route. ARC could control autonomously from trace point 1 to 5, which shown in Fig. 2.

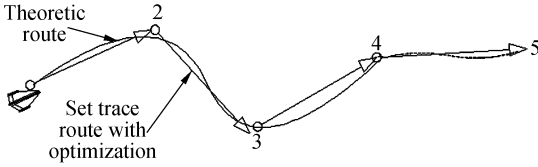


Fig. 2 Predicted Trace Curve and real flight route

In this paper, our main objective is to design the guidance algorithm valid for any initial trace, as shown in Fig. 2, the desired trace is composed of several trace point, No. 1, No. 2 and No. 5. Using a valid navigation reference frame, the kinematic equations for the aim are as follows with the proportion coefficient.

As the Fig. 3 shows, $\chi = \psi + \beta_w$ according to coordinate relationship, regulated value of azimuth angle is described as $\psi_c = \chi_c - \beta_w$, where χ_c is theoretic trace angle of route, ψ_c is the theoretic azimuth angle, β_w is the wind sliding angle with the affect of constant wind, d is the yawing distance.

From geometric theory to guarantee MAV flight along the theoretic and designed trace, the control target model in this paper with the geo-

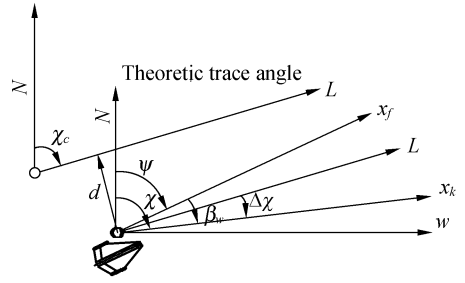


Fig. 3 Relationship of flight angles in trace navigation

metric theory has the form, which shown as follows:

$$\Delta\chi = 0 \quad (1)$$

Where could make the right flight direction:

$$d = 0 \quad (2)$$

Where could make the right desired trace for MAV flight.

Here Sign + is assumed that flies rightwards to designed trace, that means $d > 0$, and if MAV is turned left, than means $\Delta\chi > 0$, so the relationship of the warp which described as navigating deviation could be written as:

$$u_c = K_{\Delta\chi} \Delta\chi - K_d d \quad (3)$$

Where the absolute value of $K_{\Delta\chi} \Delta\chi$ and $K_d d$ would be limited. And the relationship between d and $\Delta\chi$ could be obtained:

$$\dot{d} = V_k \Delta\chi \quad (4)$$

The Inerratic Turn is the base of the horizontal navigation, where the aileron is the main controlling channel and elevator is the slave controlling channel. In this paper, the aileron is used to modify the trace through the navigating deviation.

The control equation of the aileron described as δ_c can be defined as follow that based on the PID control method^[6]:

$$\delta_c = K_p u_c(k) + K_d (u_c(k) - u_c(k-1)) + K_I \sum_{i=0}^k u_c(i) \quad (5)$$

Where the coefficients expressed by K_p, K_d, K_I are the gain of proportion, difference and integral process, respectively.

3 Simulation and experimental results

In terms of several yaw rate, simulation test has been implemented based on the geometric algorithm, which makes a theoretical trace from initial point coordinate (0,0,50) to (100,1 000, 50). Wind level is below 2-Class, and flight velocity is 10 m/s. the initial flight trace angle and azimuth angle is respective 0 and 180 degree, and control frequency is 25 Hz. (Fig. 4)

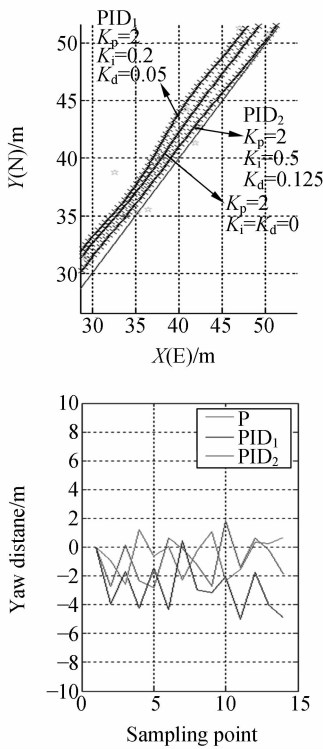


Fig. 4 Several flight traces and yaw distances in different control rates

shows the several flight trace and the yaw distance in different control rate. Fig. 5 illustrates that geometric method for solving autonomous flight adapted to derive a class of algorithms based on the heading angle error and yawing distance error is proved suit for MAV.

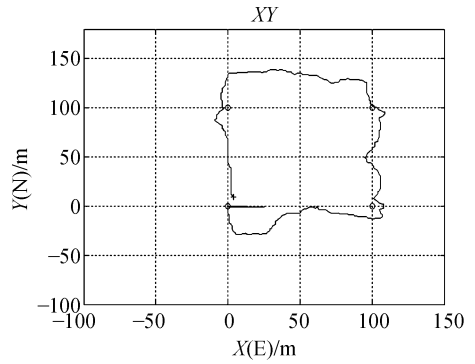


Fig. 5 Flight tests along a square with 100 m

4 Conclusions

By simulations and experiments, a autonomous flight control system utilizing geometric guidance algorithm is constructed with a Mini-GPS and a film antenna, in which MEMS components is very effective for MAVs. It is shown that the algorithm and relative control is suitable for MAVs to fully control the flight by a non-skilled person. Difficulty to obtain the full state measurements in real time and lack of full control degree has been coped by the algorithm. TH680 equipped with the GPS-based autonomous flight control system loading the designed algorithms has been successfully tested in the flight, and the yawing distance error is less than 30 m in a 2 level wind.

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●下期预告

加权最小二乘算法在机器视觉系统中的应用

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为了进一步提高机器视觉的重建精度,对相机站位和重建精度之间的关系进行了分析,并在此基础上估计权值,将加权的最小二乘算法应用于机器视觉系统的三维重建算法中。首先,利用参数方程描述了机器视觉系统,推导了空间点三维重建的参数方程解法;接着,利用误差传递原理,分析了从相机像平面上协方差到物空间协方差的传递过程,给出了误差传递和相机布局的直接关系;然后,利用得到的物空间协方差估计加权最小二乘算法的权值;最后进行解算。仿真和实验结果表明:加权最小二乘算法总体上优于普通的最小二乘法,当噪声方差比较小时,两种算法的区别不大,但是当噪声方差 >0.5 时,拍摄像片数量少于30幅的情况下有更优的精度,对距离为37.031 0 cm, 24.970 4 cm, 26.015 3 cm的测量中,和普通最小二乘算法比较,加权最小二乘算法提高精度平均为0.4 cm。