Design and Development of High Performance Unmanned Autonomous Aerial Vehicle (UAAV) Using MATLAB/Simulink in Civil Applications

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Abstract

Micro-UAAVs are slight unmanned aircraft vehicles (UAVs) that are broadening the prowess of avionics. Moreover, there is a huge disparity in the shape, size, and abilities of these aircrafts, despite the tremendous demand for the advancement and development of these UAAVs. Many mini-UAAVs can only fly at low cruising velocities, and thermal systems and electronic parts are just yards away from rocket fuel combustion at tens hundreds of degrees Kelvin. Countless uses, such as mutual operations with human controlled aerial vehicles, intelligence gathering in vitriolic airfields, or offering as a target or decoy, necessitate faster take - off and landing velocities with aerial system that responds to the demand of high-performance micro-UAVs. This study aimed to model and simulate a low-cost and high altitude unmanned autonomous aerial vehicle (UAAV) based on MATLAB/Simulink. Linear and rotational dynamics were designed, while wind disturbances were created to test the performance. The propellers were developed for consistent engine power generations. A simulation and testing of aerodynamics and transonic steady states were modeled and simulated to provide guidance using MATLAB/ Flight Gear simulator. An autopilot control system was computed to launch and stabilize the UAAV during deployment. The results show that the torque of 32000N.m, 2050m of altitude, 300m/s of airspeed, 33000km/h of wind disturbances were observed. To conclude, the developed UAAV was tested, deployed, and performed at 99.98% of success rate with high peak endurance compared to the current civilian drones. Further study is recommended for undetectable UAAV using XFLR5 and DATCOM softwares.

Keywords: Unmanned Aerial Vehicles, MATLAB/Simulink, Aviation Systems, Aircraft System Design, Flight Gear simulator.

1. INTRODUCTION

A remotely controlled aircraft (RCA), an unsupervised air system (UAS), or a qua copter are all identities for an unmanned autonomous aerial vehicle (UAAV). An UAAV, in essence, is a pilotless aircraft. All aerofoil capabilities could be monitored by sensing devices, a sentient integrator on the surface, or by the enlistment of piece and electro-optical mechanisms [1]. Firefly was the name given to the integration of sophisticated systems in an observation UAAV system. This mini-UAAV is approximately the magnitude of a football and takes off from a crewed jet fighter. Firefly accomplishes a joint operation with the combatant during many minutes of autonomy, transonic flying after release. The use of a demonstration UAAV to build advanced technologies that imposes realistic and feasible mission and interoperability specifications. These framework implications are extremely important in the micro-tightly UAV's embedded, relatively dense design with the techniques developed in this study, kgs scale unmanned autonomous aircrafts (UAAs) will be capable of flying and be quickly deployed over tens of miles and take off and land joint missions along with operated jet fighters [2]. Creating high-speed, high-performance vehicles with long endurance UAAV is a difficult process because it requires meeting all design requirements or client expectations while maintaining the least potential take-off weight. Also, the maximum take-off mass of UAV attribute aircrafts must not exceed maximum weight for which it can necessitate the use of advanced light weight engineering components, making the design stage more exciting and difficult [3]. The analysis of battery powered propellant control systems for unmanned drones and correlating of optimizing airspeed and high performance techniques for supersonic aerial vehicles were developed. These techniques make use of natural gas and coal (Hydrocarbon fuels) like crude oil, petroleum that are frequently used in aircrafts. As a result, conventional construction methods are based on hydrocarbons [4]. Flying time is determined by the amount of electrons generated by the UAV. Crude oil, petroleum, lithium-ion and lead-acid batteries have specific energy densities of 46.4, 0.36-0.88, and 0.17 MJ/kg, respectively. Under the same flight conditions, high-energy-density fuels allow for lighter weights and enhanced efficiency and improve performance. As a result, incorporating low-energy-density fuels into aircraft design process is a challenging issue. Furthermore, the weight of the UAAV has a powerful influence on its energy usage, making it difficult to design and develop a battery powered that can meet the UAAV's relevant qualifications, range and endurance. A technique for sizing UAAV electrically powered aircraft subsystems was developed [5]. In all instances, an electric based UAAV is denser than a hydrocarbon UAV. If rechargeable batteries energy density improves in the long term, electric-powered UAVs with reduced battery weight and performance improvement may become a reality. Electric-powered UAVs have gained popularity as avionics devices such as batteries and motors have improved. Traub successfully created formulas for determining the scope and endurance of electrical powered UAVs [6]. This study proposes a novel methodology for high high-speed and high- performance electric-powered civilian UAAV, taking into account the specifications and limitations of electric-powered aircrafts.

2. METHODOLOGY APPROACH

At the start of the design process, empirical values for the aircraft's zero-lift drag coefficient and induced drag factor from the first calculation were used. The matching plot is used to find the appropriate wing loading and power loading that can satisfy all given requirements. In the weight estimation approach, the maximum take-off weight is formulated and was estimated systematically. Then, the energy consumption and wing reference area of the aircraft are obtained. Aircraft aerodynamics and stability design starts with the given wing reference area were modeled and simulated. Then, the shape and configuration of the aircraft was determined. Software such as MATLAB/SIMULINK was used to model and simulate throttle, yaw, roll, and pitch of UAAV. The zero-lift drag coefficient and induced drag factor of the UAAV was also computed. The validation to ensure that the empirical value of the first calculation is appropriate were checked. If the variations are smaller than desired, the design is considered complete. If the variations are larger than desired, the new zero-lift drag coefficient and induced drag factor of the aircraft are substituted into the next design process as shown in fig.1

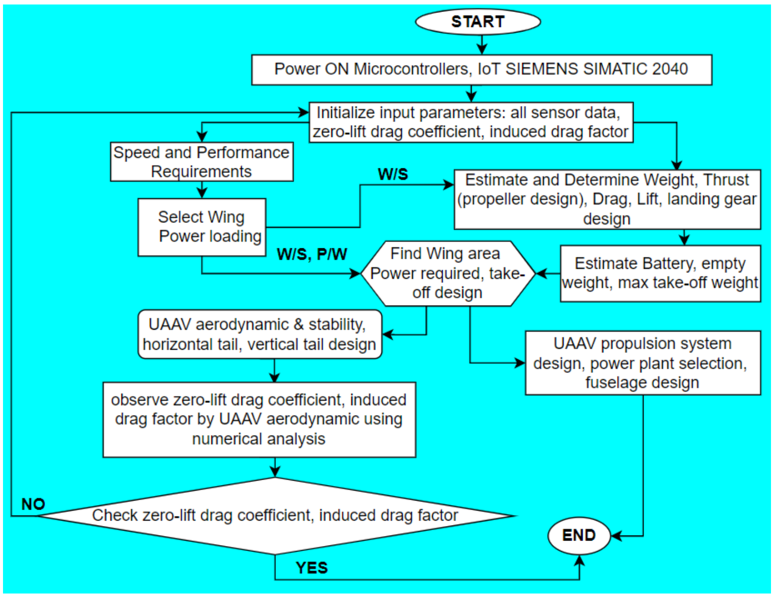

Fig. 1. Design Process of UAAV

3. RESULTS AND DISCUSSION

The aerodynamics of the high speed UAAV were computed in MATLAB/Simulink 2019a. These designs have high performances in terms of yaw, throttle, pitch, and roll characteristics and it has high airspeed when the wind gusts applied during flying as shown in fig. 2.

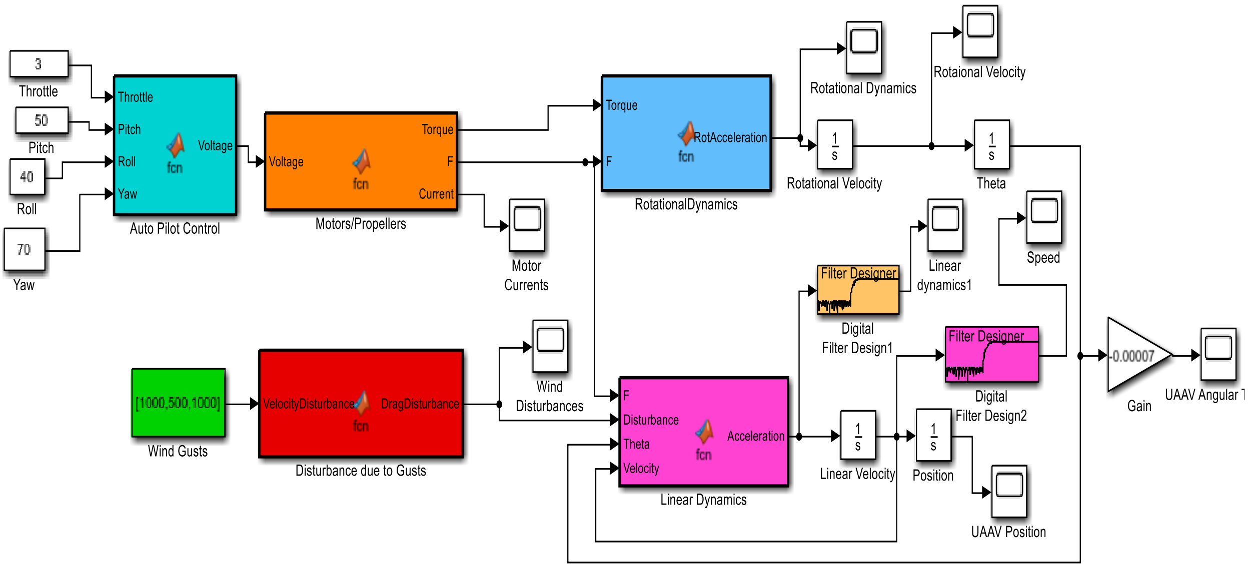

Fig. 2. UAAV Design

In order to confirm the function of this simulation system, the UAV flight control simulation tests were carried out by using Matlab/Simulink 2019a software. The simulation tests are carried out with the aerodynamic characteristics and parameters. Then, the auto pilot set values of the airspeed while it's flying steady with the control of the autopilot, the response of the throttle can be obtained as long as the wind gusts were applied as shown in fig. 3

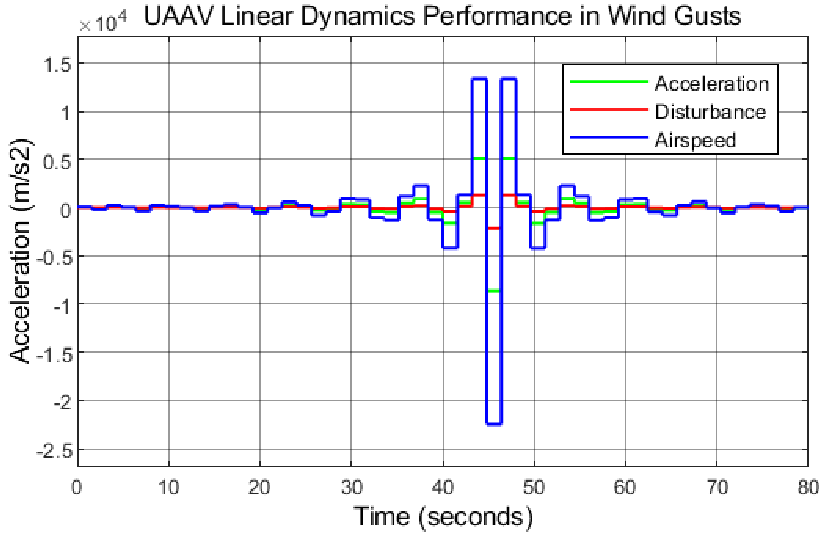

Figure 3. UAAV Linear Dynamics.

The rotational dynamics of the developed UAAV were obtained as shown in fig.4

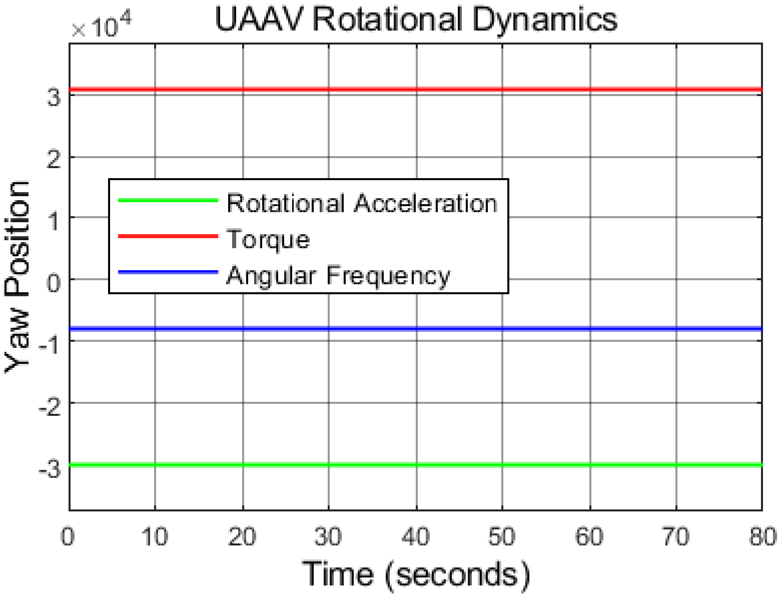

Fig. 4. UAAV rotational dynamics.

The linear velocity, the angular position, and aerial disturbances were computed and simulated. In addition, all of these characteristics were developed depending on throttle, yaw, roll, and pitch responses as shown in fig. 5, fig. 6, and fig. 7 respectively.

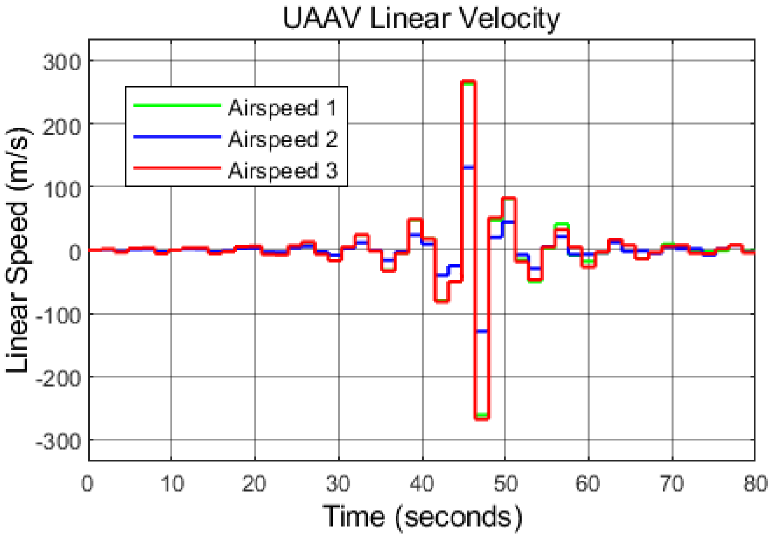

Fig. 5. UAAV Linear Velocity Characteristics

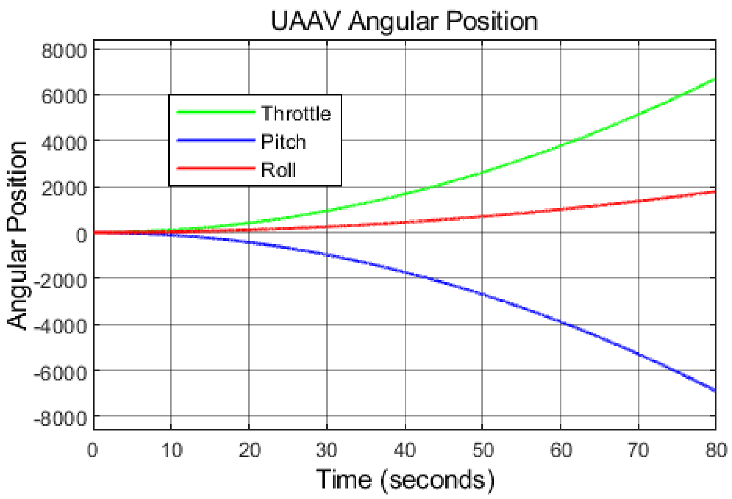

Fig. 6. UAAV angular position

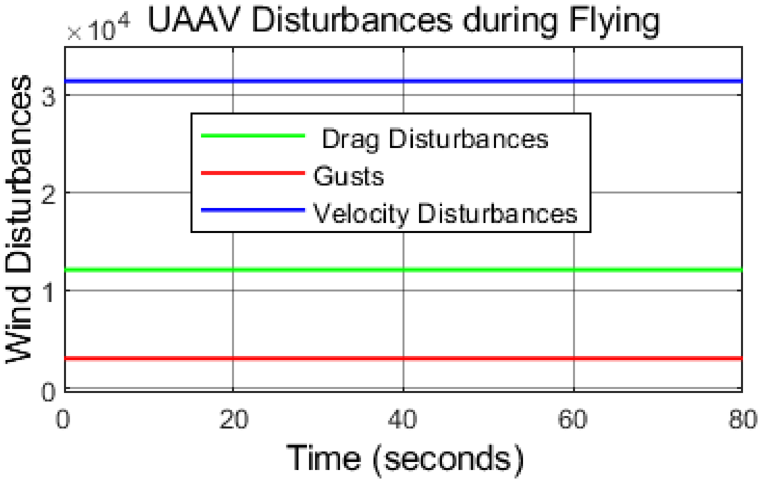

Fig. 7. Disturbances characteristics

The UAAV airspeed with elevator was tested and observed during computational and simulations of this developed pilotless drone. The drag and velocity disturbances were created to test and observe the UAAV flight performance during landing and flying. It demonstrated the capability of safe flight at high speed when the disturbances were detected by autopilot control system (see fig. 3 and fig.7) which shown the 99.89% of flight success rate compared to the current aircraft.

The UAAV was also tested using flight Gear simulator (see fig. 8) and provide confident computational performance with high-rate elevator of the designed UAAV and provide a good controlled altitude of 2050m as shown in fig. 9

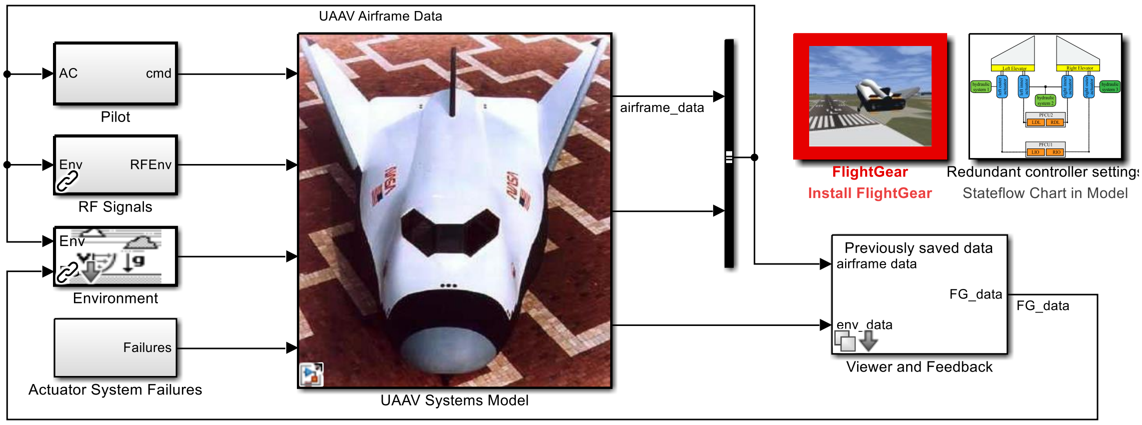

Fig. 8. UAAV Flight Gear Modeling simulator.

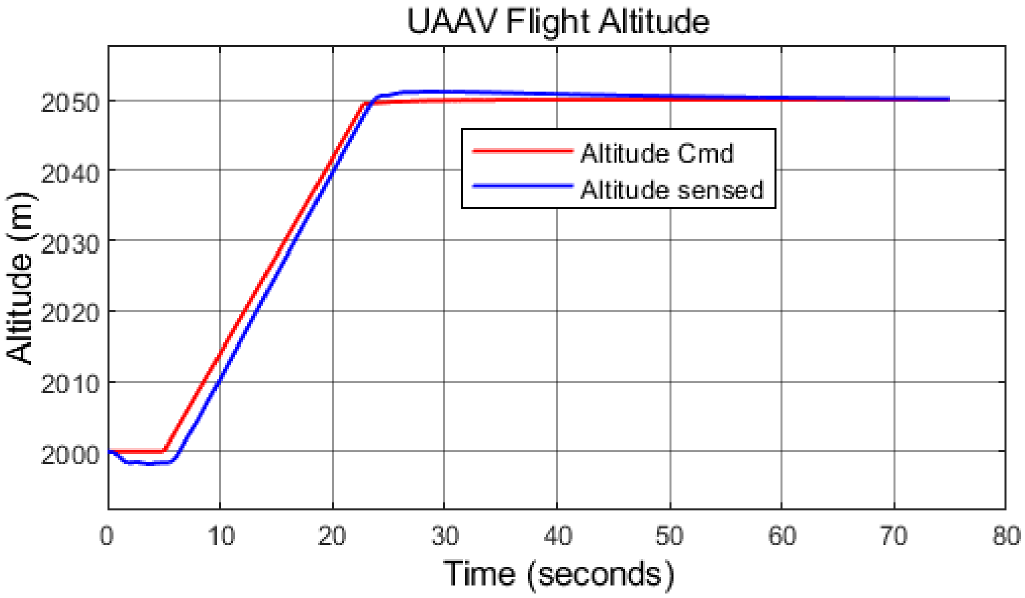

Fig. 9. UAAV cmd and sensed altitude.

In the deployment performance, the UAAV has shown better performance in throttle, yaw, pitch, roll characteristics in terms of angular position. The high speed and endurance during flight performance were successful achieved.

The autopilot system was able to land and fly at any disturbances and provide a higher success rate of 99.998% (see fig. 10) compared to the existing civilian drones which fly only at 1500m of altitude.

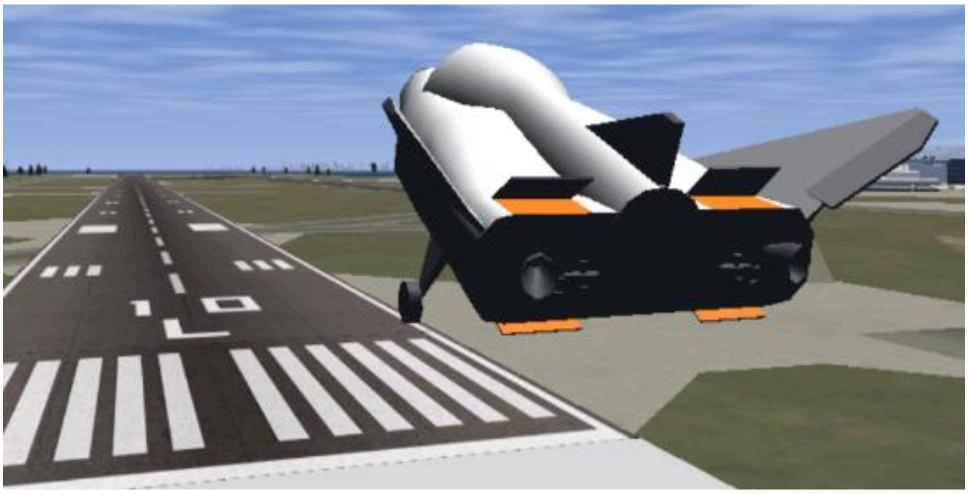

Fig. 10. UAAV in flight gear simulator test performance and deployment.

The torque of 32000N.m, altitude of 2050m, airspeed of 300m/s were observed and obtained. The wind disturbances of 33000km/h due to gusts were simulated to test the performance rate. The throttle, pitch, roll, and yaw characteristics were computed and simulated. The simulation launching and deployment tests were performed using MATLAB/Simulink/flight gear simulator. The developed UAAV was tested, deployed, and performed at 99.98% of success rate with high peak endurance compared to the current civilian drones.

4. CONCLUSION AND FUTURE WORK

An UAAV rapid prototyping simulation method based on Matlab/Simulink 2019a was designed and developed. First, establish the mathematical UAAV model under the Matlab/Simulink environment according to the characteristic of the pilotless drone. Then take use of the Matlab/Simulink 2019a to translate the UAV simulation model into simulation code and combine the target computer with the autopilot hardware to form a Hard-In-Loop simulation environment. With the work done above, the UAAV simulation test was accomplished to check the correction of the control law. Finally, the result of the UAAV simulation test shows that the developed UAAV could simulate precisely aiming at different simulation background and requirement, and provided a good system to the flight performance verification work and at high speed and high endurance performances. Future work is recommended to take on different simulation software like XFLR5 and DATCOM to prevent modeling errors and improve simulation test performances.

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Bibliography

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