Quad-Rotor Unmanned Helicopter Designs

Petar Getsov[1], Svetoslav Zabunov[2],Garo Mardirossian[3]

Space Research and Technology Institute, Bulgarian Academy of Sciences, BULGARIA.

[2] svetoslavzabunov@gmail.com

ABSTRACT

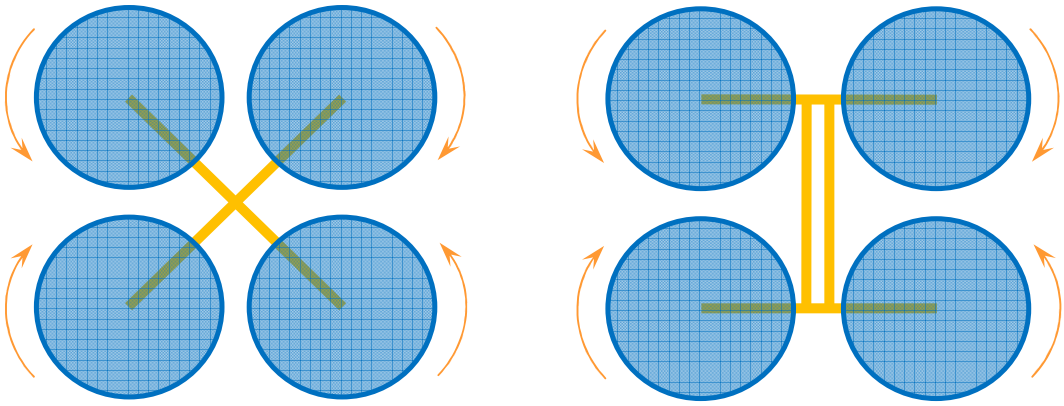
The quad-rotor unmanned helicopter design has superior capabilities in comparison to any other configuration because four rotors is the minimum number that assures attitude management without the need for control surfaces or tilt rotor mechanisms. Quad-rotors have drawbacks too, but the simplicity of their design and the low costs for obtaining and maintenance of such a helicopter make them most ubiquitous among multi-rotor aircraft.

Starting from the four rotor paradigm authors have developed innovative designs of quad-rotor unmanned helicopters that have further benefits from the current designs and although unable to offer the safety of helicopters with larger number of propellers they present novel features and give researches and users new flying platform for their projects and activities.

Keywords: Unmanned multi-rotor helicopter, quad-rotor helicopter airframe

INTRODUCTION

Several years ago unmanned multi-rotor helicopters became popular among hobbyists and researchers. The first models were tri-copters, i.e. helicopters with three rotors. In order to maintain attitude the third rotor was a tilt-rotor design using a servo-mechanism. This tilting feature was unreliable and soon users decided to go for a quad-rotor construction where no tilting mechanism was needed.



a) b)

Figure 1. (a) Classic quad-rotor helicopter in “star”-configuration; (b) XZ-1 H-airframe design

Theoretically, the minimum number of rotors for a multi-rotor helicopter without tilting mechanisms, control surfaces or cyclic and collective pitch control is four. Any larger number is also feasible, but the simplest machine is the quad-rotor. Thus tri-copters almost

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disappeared and were substituted with quad-rotors. Even the British Police department hired quad-rotors for their everyday work.

The benefits of the quad-rotor are their simplicity, low cost for buying and maintaining such a helicopter. The major drawback is that the quad-rotor is not very safe because the rotors are with larger diameter compared to a multi-rotor with greater number of propellers and the same payload capabilities and also if any of the rotors fails during flight the quad-rotor renders unusable and lands in most cases crashing over the objects beneath it. Nevertheless, quad-rotors have their applications where the lower safety margin is bearable.

The authors of the current paper have tried to invent novel quad-rotor designs each of them having its own benefits over the classic quad-rotor models. The designs presented in this article are part of the XXZ-series of multi-toot helicopters and VTOL aircraft.

QUAD-ROTOR UNMANNED HELICOPTER DESIGNS OF THE XZ-SERIES

The ubiquitous quad-rotor helicopter is the “star”-airframe helicopter or also called X-airframe machine (see Fig. 1). The second design most wide spread is the H-airframe designs. The first model of the XZ-series of multi-rotor helicopters developed at the Space Research and Technology Institute in Bulgaria is XZ-1 and it is an H-airframe helicopter (see Figure 1).

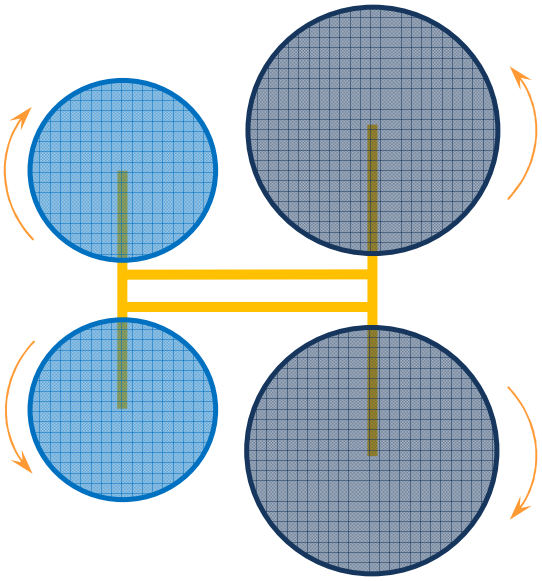

Figure 2. General view of an H-airframe quint-rotor helicopter (model XZ-1B). Above: top view, below: side view

The H-airframe quad-rotor has a number of benefits over the X-airframe, but it is not the matter of the present material. What authors want to disclose are models that haven’t been in use so far and these are described below in a systematic order.

Starting from XZ-1 several more unordinary quad-rotor models were developed. The first model that will be discussed is XZ-1B (see Figure 2).

XZ-1B is based in XZ-1 having asymmetry in its propellers. Two of the propellers mounted on one of the two rotor holding beams are larger in diameter. Their payload capability is increased and the centre of gravity is moved against this beam. The benefit from this design

is that the helicopter is more stable against the beam with the larger propellers this I the camera is mounted at the fuselage end with this beam the camera will be stabilized.

The next model is XZ-1C presented shown on Figure 3.

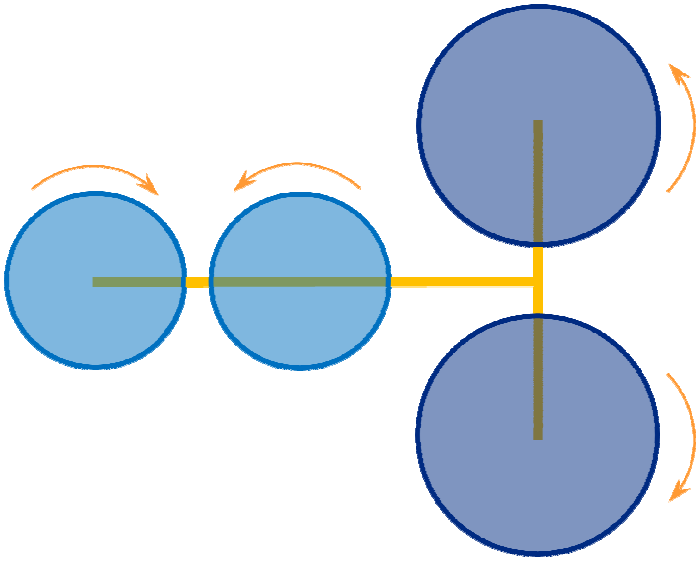

Figure 3. Quad-rotor helicopter model XZ-1C

It is developed around the tri-copter models and tends to resurrect the tri-copter idea. The tri-copter airframe has advantages over the classic quad-rotors - construction has a fuselage letting the user mount the camera far frontally evading the shading impact of the front propellers on the camera view. XZ-1C design employs four instead of three rotors by substituting the rear rotor of the tri-copter and its tilting mechanism with two smaller propellers mounted one behind the other on the fuselage (see Figure 3). The two smaller propellers are counter rotating thus cancelling out the yaw torque.

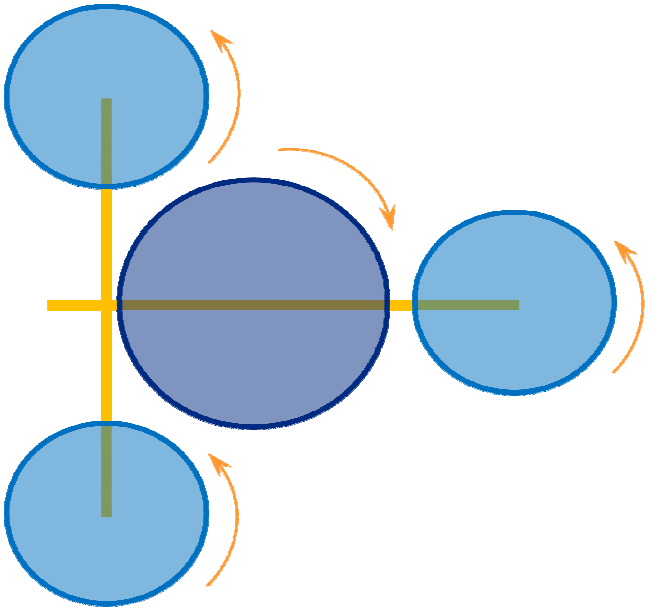

Figure 4. Quad-rotor model XZ-1D

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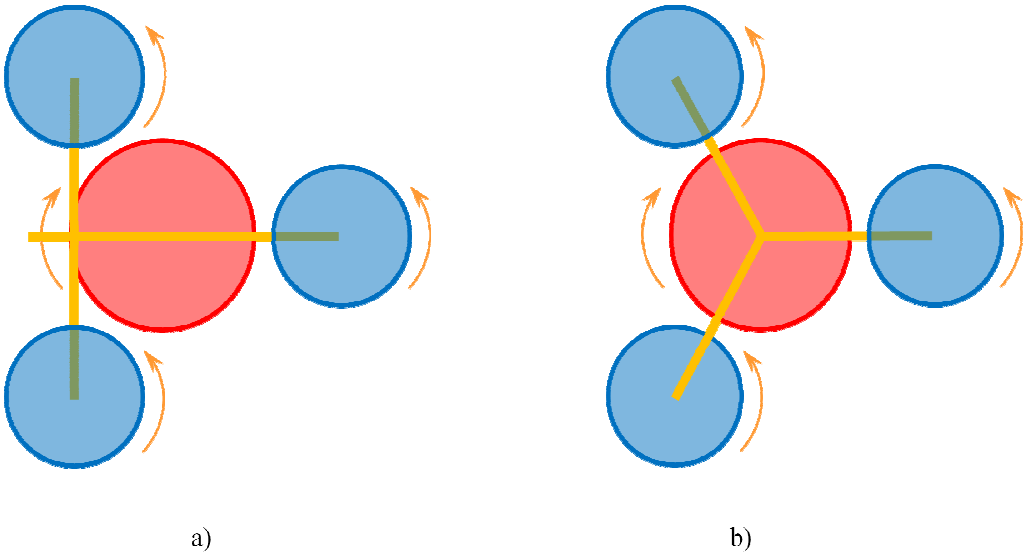
A similar design is shown on Figure 4. XZ-1D model is a quad-rotor with three small propellers and one large rotor. Again, the tri-copter benefits are obtained in a quad-rotor design. Another advantage of this design is that when the helicopter is not performing yaw manoeuvre the centre propeller is rotating at constant speed thus increasing efficiency and lowering the sound signature of the helicopter.

XZ-1D can be modified by mounting the centre propeller beneath the fuselage instead of above it (see Figure 5). The benefit from this change is that the centre propeller will increase its efficiency.



a) b)

Figure 5. Quad-rotor models: a) XZ-1E; b) XZ-1F

The resulting model is marked XZ-1E. The "propeller-below" paradigm also reveals the top of the fuselage for mounting equipment that needs upward free view such as scientific measurement instruments, sensors, etc.

Yet another design of a quad-rotor helicopter is a recreation of the famous tri-copter. This is model XZ-1G (see Figure 6).

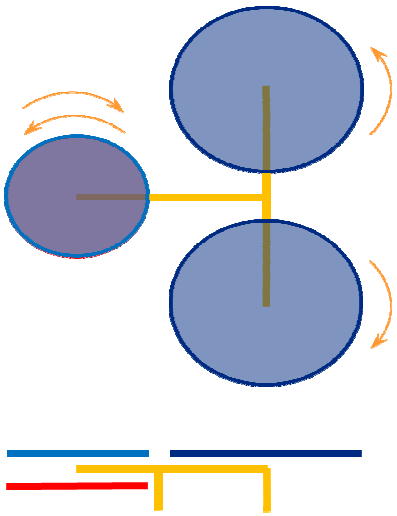
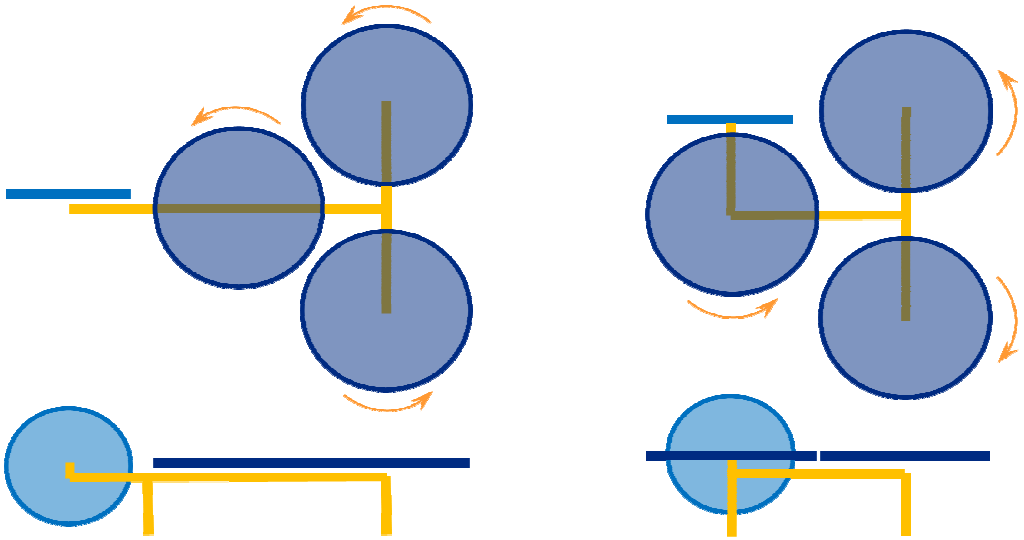


Figure 6. Quad-rotor model XZ-1G

This design is compact. The rear propeller tandem is contra-rotating. The contra-rotation is compensating to some extend for the lowered efficiency of the rear tandem. Placing two propellers one over the other decreases their efficiency because air moved by the upper propeller enters the area of the lower propeller at high speed and in turbulence. The benefit of this configuration is the concise design offering small overall dimensions of the aircraft.

A different approach for constructing a tri-copter using four rotors is shown on Fig. 7a (model XZ-1H) and Fig. 7b (model XZ-1J). Both designs implement a vertical stabilizer propeller just like in classic single rotor helicopters. This propeller is smaller in diameter and neutralizes the yaw torque created by the lifting propellers. The difference between XZ-1H and XZ-1J is the position of the stabilizing propeller. While in XZ-1H it is placed on the tail of the fuselage using a classical paradigm, the XZ-1J helicopter employs the stabilizer propeller to one side of the real rotor thus saving space and making the model more compact.



a) b)

Figure 7. Quad-rotor models: a) XZ-1H b) XZ-1J

CONCLUSION

Quad-rotor unmanned helicopters are the most popular multi-rotor helicopters due to their simplicity and low cost. Building on that basis authors have proposed designs of quad-rotors encompsing further benefits and feature and offering to the user a number of models applicable in different scenarios and showing superiority over the classical quad-rotor designs,.

Authors are continuing their work in multi-rotor helicopter development aiming at novel designs disclosing unattained advantages of this rather thrilling and useful technology.

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