Fascination Quadcopter (Edition 2016/17)

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Faszination Quadrokopter

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Preamble

For quadcopters there are many names. They are also called quadrocopter, quadricopter, drone, multicopter or simply 'UFO'. This type of model construction is very young. It began early in the new millennium with commercial products for flying camera inspections. In 2005, the company Silverlit sold an inexpensive toy with four horizontally arranged propellers. So the hobbyists were able to have their first experience with the new model aircraft.
It was the current microprocessor technology which opened up this fascinating subject of model construction. It is able to evaluate sensors for attitude stabilization and change the speeds of the motors immediately. This book explains the working principle, the used motors, sensors and control systems.
One sees quadcopters in all sizes and price ranges on the market. They start with the toy quadcopters, which are small and, despite their low price, often surprisingly robust. In this model division, a similar trend can be observed as with helicopter and airplane models. The smaller and cheaper systems are often built as ‘ready to fly’, while larger systems are often available as kits.
Using kits, the model builder must execute the assembly and the putting into operation himself. Therefore this book also contains tips for the wiring and the making or purchase of the frame. This needs to be lightweight and stable. It also carries the components.
The chapters ‘Flight mechanics’, ‘Setting the controller’ and ‘Dimensioning of motors and propellers’ include a bit more theory. This is only meant as a link to the practice and will run only as far as is necessary to understand the basic functioning. The main findings are always shown in brief at the end of these chapters, based on the theory.
The setting of the regulator is of great importance. In many control systems, it is possible to download new software updates and individual parameters via a PC interface. Thus, in each quadcopter, a different behavior can be achieved according to taste. The aerobatic pilot wants an agile behavior. The novice flyer or photo flyer prefers more of a good-natured behavior.

The autonomous navigation using GPS and creation of photos and movies from the air today enjoys growing popularity as a hobby and also for commercial use. These quadcopters serving as camera platforms also find their place in this book.
It is important to take note that there are special rules for different countries on the use of quadcopters. Especially the use of GPS and the autonomous flight often requires special permits. Each quadcopter pilot should therefore check on the laws with the state government.

Contents

1. Functionality and Ready-to-fly quadcopters

1.1 Steering mechanism

Quadcopters are aircraft with four propellers. They have the same control capabilities as helicopters. Figure 1 illustrates this. The stick assignment of the remote control, as shown in Figure 2, is most commonly selected. However there are also model pilots who swap the left and right sides.

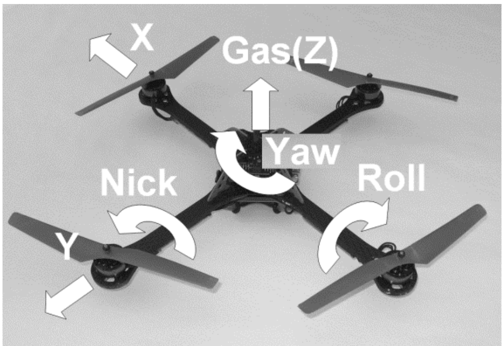

Figure 1: Control capabilities

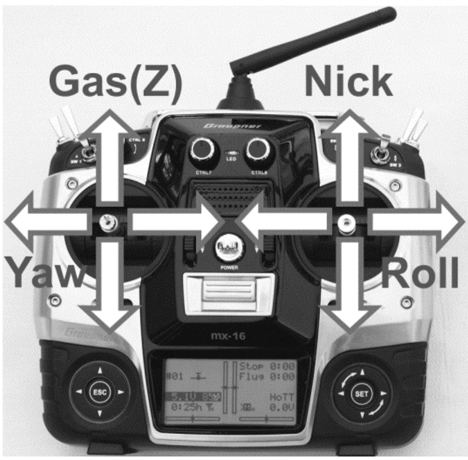

Figure 2: Stick assignment

‘Nick’ describes the tilting forward and backward. For that purpose, the stick of the remote control needs to be moved upwards (tilting forward) and downwards (tilting backward).
‘Roll’ describes the tilting to the left and right. The stick needs to be moved to the left and the right side.
‘Yaw’ describes the rotation around the vertical axis (z). The left stick needs to be moved to the left (counterclockwise yaw, view from top side) or the right (clockwise yaw, view from top side).
‘Gas’ describes the movement along the vertical axis (z). If the left stick is moved down, it means descent flight, and if the left stick is moved up into the full throttle position, it means climb flight.

1.2 Physical movement

The immediate question is now how a quadcopter can be controlled physically with the above functions. A helicopter will again serve as a comparison.
‘Nick’ and ‘Roll’ is realized with a so-called swash plate. This provides at the end an angle-shift of the main rotor force axis to the fuselage. ‘Gas’ is provided by ‘pitching’, which is achieved by changing the pitch of the rotor blades. ‘Yaw’ is realized by a change in speed of the tail rotor. Some models also reach yaw by pitching the tail rotor blades.
Anyone who has ever built and flown helicopters knows that this requires quite a complex mechanism. A hard landing is rarely forgiven: bent rods, ragged ball heads and expensive repairs are the consequence. Many have thus abandoned the model helicopter hobby, the so-called pinnacle of model aircraft.
Quadrocopters, which – as mentioned above – have the same control options as helicopters, in contrast stand out by virtue of their much simpler and thereby massively less sensitive mechanics: There are four motors, which are rigidly connected with two right- and two left-rotating propellers – and that’s all.

Everything else is provided by a small electronic control board[1]. Figure 3 illustrates this.

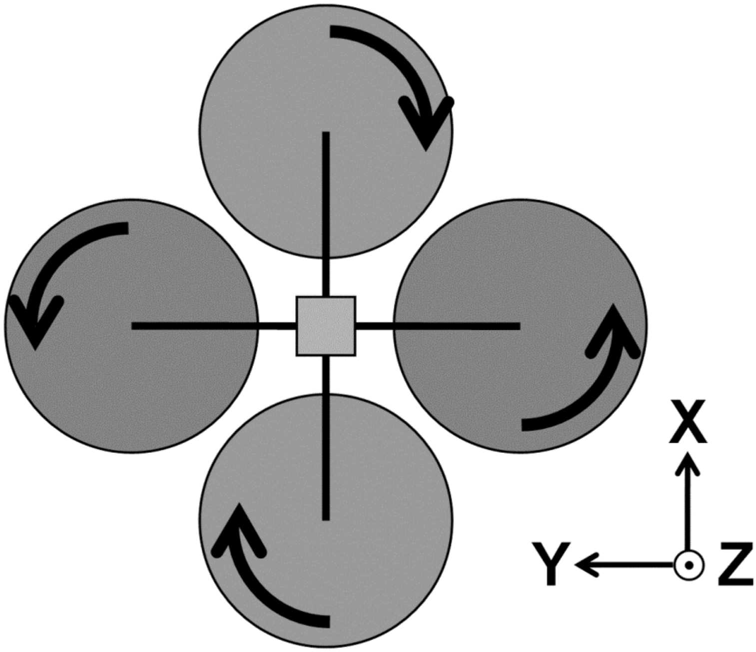

Figure 3: Two left- and right-rotating propellers, view from top side.

‘Nick’ is physically achieved by a change in speed of the upper and lower propeller (see Figure 3). To move the quadcopter in the X direction, the lower propeller is turning faster and the upper one slower. Thus, an inclination in the direction of the x-axis is achieved.

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[1] A fact which in the technology of the 21st century can be observed very often: A problem that was solved earlier purely mechanically with a sophisticated design is replaced by a combination of sensors, electronics and a much simpler mechanism. Examples as keywords are: mechatronics, fly by wire, direct-drive wheels... the Quadrocopter is therefore in good and modern company.

‘Roll’ is achieved by a change in speed of the left and right propeller. A movement in the Y direction requires a higher speed of the right and a lower speed of the left propeller.
The main rotor of a helicopter produces a torque about the vertical axis (z) because of its twisting. The tail rotor serves to compensate for that torque. The two right- and left-rotating propellers of the quadcopter do this job instead. Thus a tail rotor is not needed. ‘Yaw’ is achieved by ensuring that both left and right propellers have a different speed than both upper and lower ones. A counter-clockwise yaw (viewed from above) requires a higher speed of the upper and lower propeller and a lower speed of the left and right one.
A change in ‘Gas’ requires a change in the speed of all propellers together. During the climb flight, all propellers have a higher speed. As mentioned above, quadcopters and helicopters are controlled by the same functions and also have the same possibilities of movement – almost. Because of the control over the speed of the propellers it is not possible to fly stably overhead and to ‘mow the lawn’, as some pilots demonstrate with their pitch-controlled helicopters[2]. However, loops are possible with quadcopters. They are flown as with a model airplane, where the gas is taken away close to the apex and strongly accelerated for the subsequent stabilization in the suspense position.

1.3 Flight in ‘+’ or ‘x’ configuration

Since a quadcopter is constructed so perfectly symmetrically, the question of where is the front is justified. Most model pilots think it is as shown in Figure 3 and they mark the front boom with a piece of tape or similar. This flight configuration is called the ‘+’ configuration.

[2] However, there are already prototypes of pitch-controlled Quadrotors. These are special designs, but then the advantages of simple mechanics disappear.

The complete symmetry has its problems though. Thus quadcopter pilots seldom fly their flight models further than 50m from themselves, because they will not be able to correctly identify where the front is. The word ‘flight model’ is also worthy of discussion. ‘A model of what?’ could be the question of an inveterate model aircraft builder.

Many quadcopter pilots have therefore gone over to another attitude of flight, the so-called ‘x’ configuration. There, the front end is not one of the booms, but the central point between two of them. There are control circuit boards which support this in the configuration and carry out internally a so-called transformation of coordinates.

Figure 4: In reality a roll bar would probably make sense

However, an ‘x’ configuration can always be achieved without problems also on the part of the remote control by using the V tail mode, which couples horizontal and vertical tail (here nick and roll).

So the advantage arises that the model can be provided with a body, for example one made of plastic or depron. So, the orientation is always clear, and it is therefore possible to fly larger distances. On the other hand, this brings the quadcopter closer to the ‘right’ model aircraft. Also the creativity in building fuselages is taken into account. Figure 4 shows an example of a model in the ‘x’ configuration (an example of the future?). More examples and pictures can be found later in the book.

1.4 Ready-to-fly quadcopters

Figure 5: RTF quadcopters can be quite small – here compared to a credit-card-sized card

At the beginning of the development of quadcopters in the early 2000s one had to buy all the components separately. At that time there were only a few complete systems. So you had to assemble the systems by yourself – control electronics, brushless controllers, motors, propellers and frame. Then you had to download the appropriate software for the system. In those days, this kind of

construction required a good level of technical knowledge about the function of each component.
But the ongoing development of the electronics in recent years means that quadcopters are today mainly purchased by users as complete systems and RTF (‘ready to fly’). So today, for the pure fun of flying it is no longer absolutely necessary to understand the technology of these fascinating systems to the finest detail. And that’s good because in this way quadcopter systems can be made accessible to many model pilots.
Often there are model pilots from other sectors, e.g. aircraft, helicopter, car or ship model builders, who simply buy and fly such aircraft out of curiosity. Or there are complete newbies who have never previously come into contact with flight models.
The ‘ready to fly’ market goes hand in hand with a substantial price reduction. In the early years of development it was still necessary to pay about the same price for a quadcopter as for a large model helicopter, making many people think twice about whether they really want to start this hobby. Today, however, one sees quadcopters in all sizes and price ranges on the market. They start with the toy quadcopters, which are small and, despite their low price, often surprisingly robust, and finish with big quadcopters with several kilograms of weight and a payload to transport cameras for photo flight.
In this model division, a similar trend can be observed as with helicopter and airplane models. The smaller and cheaper systems are often built as ‘ready to fly’, while larger systems are often available as kits, with the possibility of software downloading and the installation of extensions, e.g. photo flight or GPS systems.

Indoors – outdoors

Figures 5 and 6 show RTF quadcopters which you can buy for a relatively small amount of money and which promise good fun flight already after a few minutes. You just need to take the quadcopter out of the box and charge the battery, and you’re ready. The size comparison with a credit card shows that even quite small miniature quadcopters can be built. The question of whether such systems can be operated both indoors and outdoors then arises. The situation is similar with model helicopters. In both cases, the smaller systems are more suitable for indoors, because of their small size. They often have too small a thrust to be used outdoors. This causes problems with the wind influences. They will sometimes be completely blown away. As soon as the systems are slightly larger than the smallest format, you can go outside on windless days and risk some test flights. From a propeller size of about 4 inches (= 10 cm) the produced thrust is quite suitable for use outdoors and the quadcopter is also able to withstand light wind influence. Then it is also really interesting for outdoor flights undertaken with built-in cameras.

Figure 6: An RTF- quadcopter

Package

Such RTF models can include different features. Mostly, however, it is so that in addition to the completely assembled quadcopter, the radio control and maybe even a small battery charger are also

included. Often in very small systems, the battery of the radio control is tapped as a charger to recharge the battery. Some quadcopters can also be charged via a USB cable directly from a PC.
But the packages of RTF models today in many cases also include other accessories. Figure 7 shows a quadcopter which is housed in a flight case. It is one of those systems which in the basic equipment can be purchased as RTF along with the radio control. But here a lot more is included than with small systems. For example, even a GPS is built in. Thus the quadcopter can hold its current position when you press a button with the radio control, or it can fly along programmed waypoints. In addition, this quadcopter can also be expanded with a camera holder. It is then ready for photo and film flights. There is even the possibility to put a smartphone on the radio control and watch what is being filmed. Of course, such complete systems are more expensive than those which were shown above. When purchasing one, you should always first consider what extension components you would like to use later and find out whether they are also available for these systems.

Figure 7: Quadcopter in a flight case, ready for takeoff

A good example of an RTF quadcopter system with integrated video system is illustrated in Figures 8 and 9. A camera is already installed in this quadcopter. The radio control even includes a display. This shows the transmitted images from the camera already during the flight. So the model pilot can see the transmitted image data while also keeping visual contact with the quadcopter. He may just feel as if he were sitting directly in the cockpit himself.

Figure 8: Quadcopter with integrated camera

Figure 9: Radio control with display

In many quadcopters additional functions are included which can produce great effects in the air. There are some which can fly autonomous figures at your fingertips on the radio control. This may for example be a flip, so a fast rotation around the pitch or roll axis or a rotation around the vertical axis, or the trajectory of a figure of eight.
The trend is clearly that in the future there will be even more RTF quadcopters on the market. Extension components can then be mounted or just plugged in. A lot of features such as cameras or GPS will increasingly be offered already out of the box or as a complete set. In the future, the user will be confronted even less with the software and configuration. He will be able to activate the components just by switching a lever on the radio control. And many systems will detect by themselves which component is currently active.

2. Components

The issues addressed in this chapter are at first basic components which are mandatorily necessary for the flight. They are built by almost all manufacturers in this or similar form.
The extension components, which are described later, allow additional functions. They can be added as desired or are even already built- in. Before the purchase decision you should first consider the application field of your quadcopter. Not all systems can be provided with all the enhancements. This should be checked on the Internet. Figure 10 shows the basic components of a modern quadcopter. These are described in the following sections.

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