Aerial Robotics

Versatile, Intelligent, Reliable

ideal for
Industry, Commerce, Teaching and Research

www.qopter.de
Emqopter is your partner to utilize resting potentials using latest aerial drone technology. Optimized workflows and reduced expenses by application of versatile solutions, customized for your individual industry, commerce, research and teaching. You will benefit of more intelligence, reliability and efficiency!

Reliability through intelligence –

efficiency through diversity.
The fully-autonomous Delivery Drone
The first licensed, fully-autonomous Delivery Drone equipped with automated landing spot detection and patented sensorics.

The Quanipulator – the flying grappler
As universal tool the Quanipulator is a high-tech-masterpiece for research, development and handicrafts.

Modular flight assistance systems
Our flight assistance systems come as modular Plug & Play units and give you the support to fly challenging objects with intelligent aerial drone technology.

Quadrotor Control System for teaching
A motivating and versatile system for teaching and development in your applied computer science courses.
First urban fully-autonomous Delivery Drone

Fully-autonomous aerial transport saves time and money! Due to intelligent sensors the whole flight, from take-off to landing, will happen automated. Instead of being caught in traffic jam, burning fuel and producing exhaust gases, this delivery-drone will autonomously take the shortest path to its destination by air. This will save money, will protect the environment and additionally will be a lot of fun!
YOUR COMPLETELY CAREFREE PACKAGE FOR MAXIMAL FLEXIBILITY, EFFICIENCY AND RELIABILITY

Logistics has to be faster, fully schedulable and cheaper. These are our demands for future logistics. To arrange your entry in tomorrow’s logistics as comfortable as possible, we will give you our carefree package:

License
We will take care of licensing and approval from the Federal Aviation Authorities.

Establishing
For implementing we will come to you and will put the delivery route into service.

Training
Your staff will be trained in theory and praxis according to legal guidelines.

Service
Our personal support will be available at any time.

Maintenance
According to legal requirements we will take care of maintenance and repair.
Our fully-autonomous Delivery Drone is the ideal solution for flexible and efficient transport of small components! As octocopter with redundant motors, the Delivery Drone is capable of autonomously carrying a payload of up to 2 kg, i.e. without any engagement of a pilot, to its destination. You will profit from the advantages of our high-tech-masterpiece:

- Cost saving
- Maximal flexibility
- Pioneering technology
- Emission-free transport
- Topmost planning reliability
- Ideal for small component transport
- 85 % energy savings over electric cars
- 5 % maintenance costs of a passenger car

**YOUR ADVANTAGES**

**System:**
- Tare weight: approx. 9 kg
- Max. take-off weight: approx. 12 kg
- Number of rotors: 8
- Span width: 140 cm
- Transport capacity: approx. 20 l
- Range: approx. 2 km
- Time of flight: approx. 15 minutes

Fully-redundant controls and electronics

Proven safety concept

Capable for any flights outlying the line of sight of the pilot.
PATENTED SENSORICS FOR MORE SAFETY AND RELIABILITY

With our patent pending sensorics the Delivery Drone will find its spot efficiently and automatically! This results in a new level of reliability so that even critical missions will be completed safely.

Simultaneously our sensorics provide collision-avoidance, which further increases our reliability! This enables the fully-autonomous flight from take-off to landing between your sites.

The first fully-autonomous Delivery Drone – developed by Emqopter – originated from a cooperation with the JOPP Holding GmbH to transport small components and groceries between two plants in Bad Neustadt. The air-line between those two urban sites is 600 meters. For Licensing and to provide top end reliability of our autonomous flight we have developed our patented pending sensorics for environment detection.
The Quanipulator – the flying grappler

A robot working in breezy heights, which elsewise could only be reached using expensive and bulky lifting ramps, is no science-fiction anymore! As a flying multicopter equipped with a gripper arm, the Quanipulator is THE universal tool of tomorrow!
The Quanipulator is a quadrocopter equipped with a swivelling gripper arm. Like an ordinary drone, it is freely manoeuvrable in 6 degrees of freedom via remote control. The gripper arm can be swivelled up and down, opened and closed using the same remote control. With the necessary flight experience, the precise transport and placement of objects is already possible today!

Like our teaching structure, called Quadrotor Control System (QCS for short, see page 22 ff), the Quanipulator is freely programmable via a software framework. In addition, it has numerous interfaces for the mounting and integration of sensors and function modules. Its range of functions is constantly being extended.

Thus you can adapt the Quanipulator perfectly according to your desires and conceptions.

**Technical characteristics:**
- Control: manual, semi-autonomous
- Power: approx. 1200W
- Dimensions: 83cm x 83cm x 42cm
- Tare weight\(^1\): approx. 1200g
- Pick-up weight: approx. 200g

\(^1\) without battery

**Included in delivery:**
- Quanipulator quadrocopter
- Integrated 2DOF gripper arm
- Powerful motors
- 3000 mAh 4S Lipo-accumulator
- Radio remote control
- Propeller protection
- 4 + 4 12” Propeller
- Programming interface
- Comm: SPI, I2C, USART
- Sample software
- Software library
- Documentation
- Instruction

We also provide you with all the necessary software tools and drivers for an easy start.
Intelligent flight assistance

Safety is the top priority when flying with drones. With our intelligent flight assistance systems you will reach a new level of reliability and simplicity!
SECURITY VIA INTELLIGENCE

Intelligent flight assistance systems detect obstacles in the vicinity of the multicopter, calculate control values to avoid collisions and automatically regulate the distance to detected objects.

The flexibility of multicopters makes them efficient tools for versatile applications such as inspection, maintenance, photogrammetry and observation. They serve as a platform for high-quality sensors and cameras. Despite the very good maneuverability, experienced pilots need to fly the copter to the position for the best shots. Dangers of falling in narrow or unclear places, however, deter even them from ideally placing the expensive system. Emqopter has set its goal to support the pilot in his task with intelligent sensor technology and autonomous functions in order to master even the most difficult flights.

Our result of intensive research and development in the field of autonomous drones is a wide range of sensor modules for use on multicopter systems that are optimally adapted to every application. With our many years of experience, we now are in a position to supply the perfect system for your individual requirements. We at Emqopter offer you intelligent flight assistance functions to perfect the work of flying demanding environment. Contact us and let us optimize your application tailor-made!
INTELLIGENT FLIGHT ASSISTANCE
SYSTEMS IN USE

Even for experienced pilots, many flights cannot be carried out without help for safety reasons. With intelligent flight assistance systems, however, you can also master challenging tasks reliably and easily!

Multicopter systems depend on continuous, reliable control of the flight attitude. This task is performed as standard by the copter’s flight control, which automatically detects the flight attitude via sensors and calculates positioning values in order to bring the system into the desired orientation. The flight attitude control also ensures that external disturbances such as wind are largely compensated or attenuated and that the copter is held in place. With increasing wind force, this attitude control reaches its limits, so the system quickly drifts a few meters from the target position due to gusts of wind, which can have fatal consequences for your system and the environment.

**During inspections based on close-ups, the risk of collision due to external influences such as wind is a highly critical problem!**

Emqopter’s collision avoidance systems continuously monitor the environment for obstacles in real time and actively intervene in the copter’s flight control to prevent collisions. This avoids collisions and damage.

A reliable collision avoidance system is essential to ensure a safe flight for inspection and maintenance purposes.

Just by analysing the flight environment for obstacles during the mission in real time it is possible to fly around objects in the flight path of the copter.

Only intelligent sensors enable autonomous and safe operation.
YOUR ADVANTAGES AT A GLANCE

Reliability
Intelligent flight assistance systems help you to master critical situations and complete your flight missions without a crash.

Time efficiency
With active collision avoidance you no longer lose time on safe maneuvering to get the best shots.

Cost reduction
Reduce your cost by minimizing repair and maintenance costs and increasing time efficiency.

Optimal results
Thanks to intelligent flight assistance systems, you can completely concentrate on your inspection and maintenance tasks.

Automation
Make use of the possibilities of autonomously working flying robot technology and optimize your processes in trade and industry.

Solving complex challenges
With intelligent sensor technology and assistance functions, you can master the missions that still seem too risky to you today.

The optimal sensor solution for every application!

To make the most of these benefits, it is critical to use the ideal sensor technology that reliably detects the typical obstacles in your application. Each sensor technology has intrinsic advantages and disadvantages, so that different solutions are optimal for different applications. In order to provide you with an overview of the various technologies we work with, we have compiled the portfolio of our sensor modules for multicopters on the following pages. We will be happy to advise you on your special case.
OBSTACLE DETECTION & COLLISION AVOIDANCE

The reliable detection of obstacles is essential for collision avoidance and the optimal support of the pilot during the flight.

In order to provide the pilot with optimum support in critical situations, an intelligent flight assistance system must be given a picture of the environment as comprehensive as possible, from which corrective flight manoeuvres can be calculated and carried out. Each application is different. This means that the optimal sensor technology for environmental detection depends on the respective field of application of the copter. For this reason, we have developed a portfolio of sensor modules that are optimized for different applications. Due to the modularity of the sensors, the copters can be cost-effectively equipped for the respective application areas. The Plug & Play technology of the sensor modules enables existing copters to be quickly equipped with intelligent assistance functions such as obstacle detection, collision avoidance and active distance control. Each sensor module is equipped with its own processor to evaluate the acquired data and calculate correcting control values. The communication and the intervention in the flight control take place via standard interfaces such as USART or SBUS, so that a simple connection to all usual commercial autopilots is possible. In the development and production of all modules, we pay great attention to reliability, weight and energy efficiency right from the start in order to optimize flight performance.
CENTRAL CHARACTERISTICS OF OUR COLLISION AVOIDANCE MODULES

<table>
<thead>
<tr>
<th>Modular</th>
<th>Plug &amp; Play</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial Communication</td>
<td>Distance control</td>
</tr>
<tr>
<td>Energy efficient</td>
<td>Module-specific MCU</td>
</tr>
<tr>
<td>Weight-efficient</td>
<td>Reliable</td>
</tr>
</tbody>
</table>
ULTRASONIC

Distance measurement with ultrasonic is based on high-frequency sound waves. This technology is well suited to detecting large and smooth obstacles. Compared to infrared sensors, ultrasonic sensors have no problems detecting transparent obstacles operating in poor visibility and light conditions. They represent a cost-effective way of implementing simple obstacle detection and collision avoidance. The processing of the sensor data requires only low processor power.

Preferences:

• Simple processing
• Efficient for capturing large objects
• Cost-effective technology
• Independent of the optical properties of the obstacles
• No impairment due to poor lighting and visibility conditions

Ideal areas of application:

• Capturing of walls
• Distance measurement to walls
• Flying of glass facades

The CAA US-3 includes a CAA US+ and the central unit. One central unit is required per copter. The CAA US+ is the extension for another direction (front, rear, left, right).

### CAA US-3

<table>
<thead>
<tr>
<th>Hardware:</th>
<th>3 ultrasonic sensors, central unit with IMU and MCU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring range:</td>
<td>20cm - 500cm</td>
</tr>
<tr>
<td>Opening angle:</td>
<td>100° horizontal x 40° vertical</td>
</tr>
<tr>
<td>Frame rate:</td>
<td>11 Hz</td>
</tr>
<tr>
<td>Resolution:</td>
<td>1 cm</td>
</tr>
<tr>
<td>Weight:</td>
<td>approx. 70 - 100 g</td>
</tr>
<tr>
<td>Dimensions:</td>
<td>14 cm x 4 cm x 2 cm up to 14 cm x 11 cm x 5 cm</td>
</tr>
</tbody>
</table>

### CAA US+

<table>
<thead>
<tr>
<th>Hardware:</th>
<th>3 ultrasonic sensors, measuring range: 20cm - 500cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opening angle:</td>
<td>100° horizontal x 40° vertical</td>
</tr>
<tr>
<td>Frame rate:</td>
<td>11 Hz</td>
</tr>
<tr>
<td>Resolution:</td>
<td>1 cm</td>
</tr>
<tr>
<td>Weight:</td>
<td>approx. 50 - 80 g</td>
</tr>
<tr>
<td>Dimensions:</td>
<td>14 cm x 4 cm x 2 cm up to 14 cm x 11 cm x 5 cm</td>
</tr>
</tbody>
</table>

*Errors and omissions excepted. All specifications are non-binding.*
INFRARED

Infrared distance sensors use light pulses for distance measurement. The reflection of the light pulse is recorded and evaluated. The sensors are very suitable for medium-sized objects and also detect sound absorbing surfaces, where ultrasound fails. These sensors are optimally used inside buildings or complementary, i.e. together with other sensors, because with this technology disturbances can occur with very strong, direct sunlight. The measuring range of infrared sensors depends on the size, so that different sensors are used for different working ranges. The sensors are small, inexpensive and lightweight. Transparent obstacles, such as glass, are not reliably detected. Together with ultrasonic sensors, both technologies complement each other ideally and are an optimal solution for many applications.

Advantages:

- Simple processing
- Efficient detection of medium-sized barriers
- Cost-effective technology
- Detection of sound absorbing surfaces

CAA IRL

<table>
<thead>
<tr>
<th>Hardware:</th>
<th>8 infrared sensors in compact housing with IMU and MCU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring range:</td>
<td>80cm - 500cm</td>
</tr>
<tr>
<td>Opening angle:</td>
<td>8 sensors à approx. 5° in 360° arrangement</td>
</tr>
<tr>
<td>Frame rate:</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Resolution:</td>
<td>1 cm</td>
</tr>
<tr>
<td>Weight¹:</td>
<td>approx. 200 g</td>
</tr>
<tr>
<td>Dimensions¹:</td>
<td>13,5 cm x 13,5 cm x 6,6 cm</td>
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</table>

CAA IRM

<table>
<thead>
<tr>
<th>Hardware:</th>
<th>8 infrared sensors in compact housing with IMU and MCU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measuring range:</td>
<td>20cm - 150cm</td>
</tr>
<tr>
<td>Opening angle:</td>
<td>8 sensors à approx. 5° in 360° arrangement</td>
</tr>
<tr>
<td>Frame rate:</td>
<td>10 Hz</td>
</tr>
<tr>
<td>Resolution:</td>
<td>1 cm</td>
</tr>
<tr>
<td>Weight¹:</td>
<td>approx. 200 g</td>
</tr>
<tr>
<td>Dimensions¹:</td>
<td>15,5 cm x 13 cm x 3 cm</td>
</tr>
</tbody>
</table>

¹Errors and omissions excepted.
All specifications are non-binding.
LIDAR

LIDAR distance sensors based on laser pulses are characterized by their high precision and processing speed. This enables a very accurate and stable flight even under difficult conditions such as turbulence. The LIDAR sensors used have no moving parts, are small and light. In addition, they show off with up to 40m measurable maximum distance and a precise measuring resolution of 1cm.

Advantages:
• High range
• Fast processing
• Clear environmental image

CAA L-8

Hardware: 8 point laser sensors in housing with IMU and MCU
Measuring range: 25cm - 4000cm
Opening angle: 8 sensors à approx. 1° in 360° arrangement
Frame rate: 500 Hz
Resolution: 1 cm
Weight¹: approx. 200 g
Dimensions¹: 20cm x 20cm x 4cm

CAA L+ and L-2

Hardware: 2 point laser sensors
Measuring range: 25cm – 4000cm
Opening angle: 2 sensors à approx. 1° in 45° arrangement
Frame rate: 500 Hz
Resolution: 1 cm
Weight²: approx. 80 g
Dimensions²: 13cm x 7cm x 4cm

¹Errors and omissions excepted.
²All specifications are non-binding.

The CAA L-2 includes a CAA L+ and the central unit. One central unit is required per copter. The CAA L+ is the extension for another direction (front, rear, left, right).
3D SENSORS

Imaging sensors are characterized by a high data density, which is important for flying complex interiors such as high bay warehouses and industrial facilities. This category includes the sensor technologies SV, PMD and RS. Due to the high data density, even relatively small or complex obstacles such as trees with leaves can be detected reliably.

**Advantages:**
- Clear environmental image
- Large amount of data
- Detects even complex obstacles
- Use of image data possible
- 3D Mapping / SLAM

### CAA SV

- **Hardware:** stereo camera with i7-CPU
- **Measuring range:** 1 - 20m
- **Opening angle:** 65°horizontal, 45°vertical
- **Frame rate:** 10 - 20Hz
- **Depth resolution:** 5 - 10cm
- **Image resolution:** 640 x 480 pixels
- **Weight:** approx. 250 g
- **Dimensions:** 16cm x 2,5cm x 1cm plus CPU: 10cm x 8cm x 2,5cm

### CAA RS

- **Hardware:** 3D time of flight camera Intel® RealSense™ with i7 CPU
- **Measuring range:** 20cm - 300cm
- **Opening angle:** 70°horizontal, 50°vertical
- **Frame rate:** 60Hz
- **Depth resolution:** 1cm
- **Image resolution:** 640 x 480 pixels
- **Weight:** approx. 300 g
- **Dimensions:** on request
- **CPU:** 10cm x 8cm x 2,5cm

### CAA PMD

- **Hardware:** 3D time of flight camera PMD with i7-CPU
- **Measuring range:** 10cm - 400cm
- **Opening angle:** 62°horizontal, 45°vertical
- **Frame rate:** 45Hz
- **Depth resolution:** 1mm
- **Image resolution:** 224 x 171 pixels
- **Weight:** approx. 250 g
- **Dimensions:** 7cm x 2cm x 1cm plus CPU: 10cm x 8cm x 2,5cm

*Errors and omissions excepted.*

*All specifications are non-binding.*
COMPLEMENTARY SENSORS

Complementary sensor technology combines the advantages of different sensor technologies and reduces the weaknesses of individual sensor types. Although ultrasonic sensors, for example, have difficulties in detecting sound-absorbing surfaces, they are not susceptible to interference when detecting transparent obstacles. Sensors, working with light waves, such as infrared and LIDAR, behave exactly vice versa, so these technologies complement each other perfectly.

**CAA UI**

<table>
<thead>
<tr>
<th>Hardware:</th>
<th>8 infrared sensors, 12 ultrasonic sensors, central unit with IMU and MCU</th>
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<tbody>
<tr>
<td>Measuring range:</td>
<td>60cm - 500cm</td>
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<td>Resolution:</td>
<td>1 cm</td>
</tr>
<tr>
<td>Weight:</td>
<td>approx. 400 g</td>
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<tr>
<td>Dimensions:</td>
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**CAA LU**

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<td>Measuring range:</td>
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<td>Weight:</td>
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**CAA UI mini**

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<td>Measuring range:</td>
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<tr>
<td>Weight:</td>
<td>approx. 400 g</td>
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<tr>
<td>Dimensions:</td>
<td>see single modules</td>
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1 Errors and omissions excepted.  
All specifications are non-binding.
## THE SENSOR SOLUTIONS AT A GLANCE

<table>
<thead>
<tr>
<th>CAA</th>
<th>Detects small objects</th>
<th>Cost effective</th>
<th>Small and light</th>
<th>Detects glass, measures through smoke</th>
<th>Detects sound-absorbing surfaces</th>
<th>Detects low-contrast surfaces</th>
<th>High range</th>
<th>Close measuring range</th>
<th>High repetition rate</th>
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<tbody>
<tr>
<td>US-3</td>
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Developed directly in the teaching environment, the Quadrotor Control System, or QCS for short, is a motivating, versatile and practical teaching and learning platform for use in schools and universities.
FUTURE-ORIENTED TEACHING AT UNIVERSITIES AND SCHOOLS

Technical progress, from computers and smartphones, to embedded systems such as automatic doors and programmable washing machines, to industrial robots and inspection drones, brings us more conveniences and benefits every day. It is hard to imagine today's world without this development. But we are only at the beginning. Research and development is currently underway on household robots, autonomous cars and parcel drones. The importance of the underlying technologies, the core of which is covered by the subjects of computer science, robotics, mechatronics and control engineering, is constantly increasing.

Not only the importance of technology is growing, but new, additional and more powerful systems are making technology increasingly complex. Inevitably there is a growing need to understand, master and use all this, but also to be able to teach and instruct.

The Quadrotor Control System (QCS), a teaching and learning system for universities and schools, contributes to this. The programming of quadrocopters or flying robots (drones) is just one excellent example of an application that motivates students and thus helps them to understand and master important basics in a fun and playful way. The QCS is an entry aid as well as a cornerstone for study, technical work and projects, with the aim of acquiring and deepening knowledge in the field of computer science and technology.

The QCS complete system:
- QCS quadrocopter
- DOF - hinges
- Safety ring
- EMQ 3000 development board
- 20A power supply unit
- 8 propeller
- Software framework
- Software Libraries
- Documentation
- Learning contents
- Task examples
- Sample implementations
- Sample solutions

Crash-proof development
With the DOF suspensions of the QCS, the system is held at the workplace without distorting the dynamics of the system.

Step by step to the solution
Optimal didactic approach through reconfigurability of the system for the next steps and tasks.

Start in research
Open interfaces for integration of own hardware and software modules according to own ideas and conceptions.
THE DOF PRINCIPLE

The programming and development of a quadcopter flight control system is a complex issue, due to the 6 degrees of freedom (DOF = Degree of Freedom) of free flight. But thanks to the DOF suspensions, you don’t have to worry about crashing the quadrocopter during development.

The DOF suspensions, specially developed for quadrocopter programming, serve to secure the system against unwanted lifting at the workplace and to mechanically switch individual degrees of freedom. This allows the user to independently edit the individual controllers for the different motion axes of the system. The hinges can be repositioned for the configuration of the degrees of freedom by means of a simple and fast plug-in system, so that no breaks for rebuilding hinder the development. In a few seconds the QCS is fixed at the workplace and operated in a controlled way or - if desired - as QCS-F is flown freely.

At the end of the development you have implemented your own flight control for the QCS quadcopter, which is ready to take off. Simply replace the DOF suspension with the battery holder included in the QCS-F extension, switch on the remote control and lift off!

Even beyond the initial development of flight control, the DOF principle allows you to put your self-developed software through its paces after critical changes before you go flying. This helps you avoid crashes, repairs and costs.
A quadrocopter can be rotated over all 3 axes of the three-dimensional space, so that altogether 3 controllers are needed for a stable position control of the copter in flight. For the entire programming of the QCS flight control system, only two DOF suspensions are required to program and configure all controllers independently of each other.

The 2-DOF suspension

With this suspension you get into the programming of the quadrocopter flight control. First, you start to take the quadrocopter to stabilize the roll axis. For this purpose, the suspension is locked in the yaw axis, so that rotations of the QCS are only possible around the roll axis. Through this fixation you can easily find the right controller parameters. If the control around the roll axis is stabilized, the control of the yaw axis can be started, for which the roll axis can be locked. Finally, the superimposed behaviour of the controller can be handled without locking the roll and yaw axes.

The 3-DOF suspension

When the QCS is stable around the roll and yaw axes, the suspension can be exchanged in a few simple steps to view the control around all 3 axes simultaneously. The 3-DOF suspension is designed in such a way that its system characteristics correspond to those of free flight. Therefore a well regulating quadcopter on the 3-DOF suspension is ready for flight. The system can be equipped with the QCS battery holder and prepared for free flight in just a few easy steps. At this point your self-programmed quadrocopter is ready for take off!
The direct reference to practice and the work on a highly topical issue motivates the students of vocational schools and secondary schools to develop their own solutions. With fun and something tangible one learns faster and easier. The subject of computer science and quadcopter programming is covered comprehensively in 8 learning sections. Each learning section contains tasks, assistance, theory as well as software as a gap text and ready-made solutions. In a compact introductory course, you as a teacher will receive the background knowledge you need to immediately start your lessons with the QCS!

Requirements

The QCS teaching concept requires basic knowledge of programming. One year of computer science is recommended. In addition, a maximum six-month C basic rate is required.

Procedure and timeframe

Depending on the depth of the study, the duration can range from a few weeks to half a year. The tasks can be expanded or reduced independently of each other in order to focus on specific aspects. It is recommended to cover the basics of programming in C in the first half of the year and to start with the QCS teaching concept in the second half of the year.

Target audience

The QCS teaching concept is aimed at students in the upper classes of their secondary school or of the 2nd year of an apprenticeship at a vocational school. It is optimized for the following subjects:

- Computer science
- Mechatronics
- Robotics
- Control engineering
- Technology

Teaching materials

For each of the 8 sessions:

- Theory as booklet or slide set
- Tasks
- Software framework as gap text
- Ready-made programs as a solution
- Documentation on hardware and software

8 sessions:

- Introduction to Information Technology and Embedded Systems
- Information Processing (Part 1) and Presentation
- Communication: sending, receiving, processing information (data)
- Information acquisition and sensor technology
- Information processing (Part 2) and Filters
- Modelling using QCS as an example
- Control, regulation and parameterisation
- Automation

Additional information can be found in the two brochures for schools and universities.

Available online at

www.qopter.de
The QCS is a simple and versatile platform for the entry into embedded programming at universities and colleges. As a teaching setup, the QCS is optimized for use in courses and laboratory exercises. The software is available as an open source project, so that students can develop and integrate their own research projects beyond the contents of the QCS teaching concept. Modern and novel approaches can be implemented directly with the QCS for student research projects.

Exemplary module description of the course:

<table>
<thead>
<tr>
<th>Module name</th>
<th>Quadcopter programming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>12 weeks</td>
</tr>
<tr>
<td>Frequency of service</td>
<td>Once a year</td>
</tr>
<tr>
<td>Teaching language</td>
<td>German/English</td>
</tr>
<tr>
<td>Requirements</td>
<td>Basic knowledge of C programming</td>
</tr>
<tr>
<td>ECTS credits</td>
<td>5</td>
</tr>
<tr>
<td>Total workload &amp; composition</td>
<td>150 h (30 attendance, 120 self-study)</td>
</tr>
<tr>
<td>Form of teaching</td>
<td>Weekly 2h attendance exercises with independent preparation and follow-up.</td>
</tr>
<tr>
<td>Examination performances</td>
<td>Attestation</td>
</tr>
<tr>
<td>Learning outcomes</td>
<td>The participants are empowered to implement flight control for a quadcopter (sensor technology, data processing, filtering, control).</td>
</tr>
</tbody>
</table>

- Communication: USART, telemetry and tele commanding
- Sensor technology and signal processing
- (Kalman filter, complementary filter, quaternions)
- Quadcopter control (position, yaw, 3DOF)
- Automation of control commands

*Teaching & learning methods*

Teaching the theoretical and technical basics in frontal teaching and demonstrations, problem-oriented tasks for independent development on the Quadrotor Control System and PC.

*Literature*

- Fascination Quadrocopter, Büchi, 2010
- UAVs: since 1990, Laumanns, 2012
- Control engineering 1, Lunze, 2014
- An introduction to the Kalman Filter, Welch & Bishop, 2006
- Autonomous quadrocopter for interior exploration, Gageik, 2015
With the QCS you can teach and learn the complete programming and handling of information from the first readout of the sensors (information acquisition), data processing (information processing) up to control and automation (model building). For this purpose we have developed complete teaching materials, which we give you as slides and booklets.

12. The automation of processes, probably the most important application case of robotics, is dealt with in the last exercise.

11. Finally, the different controllers have to be super positioned in order to achieve a common and simultaneous control of all 3 axes of the room. In this section, the effects and boundary conditions of the superposition and multiple parameter controls are discussed.

9. - 10. Several controllers must be implemented for the position control of a quadrocopter. Two sections explain the functionality of a PID controller and cover the independent control of the roll, pitch and yaw axes of a quadrocopter.

8. Telecommands are used to transmit instructions. This exercise deals with the opposite side of telemetry or control of the QCS.
1. The QCS is controlled by an AVR 32bit microcontroller, which is programmed in C. In an introductory section, the AVR development framework and the actuation of a display are covered.

2. Communication and debugging are important tools for programming embedded systems. All transfers of data between the QCS and the ground station can be designed according to your requirements, which this section provides an introduction for.

3. To control the QCS, an IMU, a so-called inertial measuring unit, is required, which can be used to determine the current orientation in 3D. This section deals with the basics, the control and the reading of the IMU.

4. The correct processing of the inertial sensor data for orientation determination is crucial for later use in position control. Quaternions are the means of choice today. This exercise gives a valuable introduction to the numeric system of quaternions and their practical uses.

5. An accelerometer and a gyroscope are required to ensure drift-free orientation. Both sensors have their intrinsic weaknesses, but complementary data fusion can overcome them. The complementary filter discussed in this exercise is a simple but effective filter to achieve this.

6. The Kalman filter is the most common process for data fusion. It is used in robots, cars, airplanes and spaceships. In this exercise, a Kalman filter for the QCS is explained, discussed and implemented using a simple example.

7. Telemetry is the transmission of system information to the ground station. A graphical ground station software as well as a communication protocol will be discussed.
THE BASIC MODULES

The QCS in its basic configuration contains everything you need for a safe and easy start in programming quadrocopters! Thanks to extensive hardware and software, you are fully equipped with the complete package to get started right away!

The QCS is mounted on the supplied stand and can be used as a mobile unit. For your safety, the QCS is equipped as standard with a 360° protective ring.

In addition, the scope of delivery includes a universal 32bit development board, a high-performance power supply, the learning content consisting of tasks and solutions as well as replacement propellers, documentation and the complete software you need.

The flight module extends the QCS to the QCS-F. It contains everything you need to make the QCS fly. This includes battery, remote control and receiver, as well as an independent onboard microcontroller. The battery holder is attached to the quadrocopter with just as little effort as the DOF hinges.

The onboard microcontroller is identical to the one on the development board for developing the flight control of the QCS at the workplace. This allows the same software developed on the ground to be used for the flight.

If you order our training system as QCS-F, we already integrate the flight module during production.

### QCS complete package

Contains everything you need to get started in the programming!

- QCS Quadrocopter with safety ring made of EPP (62 cm x 62 cm)
- DOF hinges and tripod
- Development board (32bit AVR, 60MHz, 512 KB Flash)
- Software framework and libraries: programming language C
- Teaching content with tasks and solutions
- 20A power supply unit
- Documentation
- Spare propellers (10")

### QCS-F flight module

With the flight module the QCS is ready for departure! Included are:

- On-Board 32bit MCU
- Remote Control + receiver unit
- 3S 3000mAh LiPo battery
- Battery mount
- Landing gear
## ADD-ONS

A variety of add-ons are available for QCS and QCS-F, which provide even more versatility while working with the system. Getting an optimal start, you will receive driver software for each module for integration into the QCS as well as sample implementations.

### UPGRADES

<table>
<thead>
<tr>
<th>Add-On</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Upgrade</td>
<td>More power for larger payloads</td>
</tr>
<tr>
<td>Case with logo</td>
<td>Your personalized case</td>
</tr>
<tr>
<td>Frame Pro</td>
<td>For even more safety and stability</td>
</tr>
<tr>
<td>i7 Board</td>
<td>Powerful computing power and storage capacities</td>
</tr>
</tbody>
</table>

### SHOWCASE

<table>
<thead>
<tr>
<th>Add-On</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>QCS Showcase</td>
<td>Maximum safety during development</td>
</tr>
<tr>
<td>Case labelling</td>
<td>Personalised showcase lettering with logo</td>
</tr>
</tbody>
</table>

### COMMUNIKATION

<table>
<thead>
<tr>
<th>Add-On</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM/TC Modul</td>
<td>Real-time communication via Bluetooth</td>
</tr>
<tr>
<td>Additional RC</td>
<td>Second remote control for simultaneous control</td>
</tr>
</tbody>
</table>

### POSITION CHECK

<table>
<thead>
<tr>
<th>Add-On</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS module</td>
<td>Position determination for outdoor missions</td>
</tr>
<tr>
<td>Optical flow Basic</td>
<td>Simple 2D recording of the movement of the QCS-F</td>
</tr>
<tr>
<td>Optical flow Pro</td>
<td>Robust 4D motion detection of the QCS-F(^1)</td>
</tr>
</tbody>
</table>

\(^1\) Requires i7 Board
<table>
<thead>
<tr>
<th><strong>OBJECT DETECTION</strong></th>
<th><strong>ALTITUDE SENSORS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Object Detection" /></td>
<td><img src="image2.png" alt="Altitude Sensor" /></td>
</tr>
<tr>
<td><strong>Object Detection</strong></td>
<td><strong>Altitude Sensor</strong></td>
</tr>
<tr>
<td>Frontal camera for Object detection</td>
<td>Baro, IR und US Sensors for height determination</td>
</tr>
<tr>
<td><img src="image3.png" alt="Object detection Pro" /></td>
<td><img src="image4.png" alt="Altitude sensor Plus" /></td>
</tr>
<tr>
<td><strong>Object detection Pro</strong></td>
<td><strong>Altitude sensor Plus</strong></td>
</tr>
<tr>
<td>Pivoting camera for object detection</td>
<td>Laser, baro und US sensorics for height determination</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>VIDEO TRANSMISSION</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.png" alt="Video link Basic" /></td>
</tr>
<tr>
<td><strong>Video link Basic</strong></td>
</tr>
<tr>
<td>Frontal camera with analogue video transmission</td>
</tr>
</tbody>
</table>

With the QCS Add-Ons you get everything you need to develop completely autonomous drones that independently regulate their flight altitude and avoid collisions.

2 Requires i7 board
## UPGRADES

### INFRARED AND ULTRASOUND

<table>
<thead>
<tr>
<th>Sensor Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstacle detection US</td>
<td>Sensor module with 3 ultrasonic sensors</td>
</tr>
<tr>
<td>Obstacle detection IRL</td>
<td>Sensor module with 8 infrared sensors up to 5m</td>
</tr>
<tr>
<td>Obstacle detection IRM</td>
<td>Sensor module with 8 infrared sensors up to 1.5m</td>
</tr>
<tr>
<td>Obstacle detection US12</td>
<td>4 sensor modules, each with 3 ultrasonic sensors</td>
</tr>
</tbody>
</table>

### LIDAR TECHNOLOGY

<table>
<thead>
<tr>
<th>Sensor Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstacle detection LA8</td>
<td>Sensor module with 8 laser sensors</td>
</tr>
<tr>
<td>Obstacle detection LA2</td>
<td>Sensor module with 2 laser sensors</td>
</tr>
</tbody>
</table>

### COMPLEMENTARY SENSORS

<table>
<thead>
<tr>
<th>Sensor Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstacle detection US-IRM</td>
<td>8 Infrared- (5m) and 12 ultrasonic sensors</td>
</tr>
<tr>
<td>Obstacle detection US-IRL</td>
<td>8 Infrared – (1,5m) and 12 ultrasonic sensors</td>
</tr>
<tr>
<td>Obstacle detection US-LA</td>
<td>8 point lasers – and 12 ultrasonic sensors</td>
</tr>
</tbody>
</table>

### 3D SENSORS

<table>
<thead>
<tr>
<th>Sensor Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obstacle detection RS</td>
<td>3D ToF Intel® RealSense™</td>
</tr>
<tr>
<td>Obstacle detection PMD</td>
<td>3D ToF PMD</td>
</tr>
<tr>
<td>Obstacle detection SV</td>
<td>Stereo optical obstacle detection¹</td>
</tr>
</tbody>
</table>

¹ Requires i7 board
EXPERIENCES WITH THE QCS

The Quadrotor Control System has been in use at universities and schools for 7 years. The teaching system has proved to be very popular among students and teachers from the beginning and continues to be so.

Prof. Dr. Fischer explains the Quadrotor Control System to the Brandenburg Prime Minister Dietmar Woidke on the occasion of the Prime Minister’s visit to CeBIT 2016 in Hanover:

„I have never experienced so long and highly motivated working on solutions in the workplace“

Prof. Dr. Arndt Balzer from the University of Applied Sciences Würzburg-Schweinfurt is convinced of the QCS:

„We have been using the QCS for several years in teaching (computer science) and are always pleased with how motivated the students are with the varied topics and consistently practice-relevant tasks.“

Prof. Dr. Sergio Montenegro and his students at the Chair of Aerospace Computer Science at the University of Wuerzburg, where the Quadrotor Control has been successfully used in teaching for over 6 years, are enthusiastic:

„Just great!“
Participant of the Summer School "Aerospace Information Technology" 2015 in Wuerzburg:

„I am in my 1st year master studies and this was the best exercise I ever had!“

“Quadrotor exercises – VERY COOL!”

“I really liked the Quadrotor Lab and enjoyed to work with the system!“

The effect of using the QCS teaching concept on students was measured in comparison to other courses. Here are some results (published on the SPIE - Conference in San Francisco 2015):

For design reasons, the masculine form was occasionally used to address persons of both sexes. All illustrations of products in this brochure are exemplary and may differ from the actual appearance.