Newest Technologies for Compact Digital Aerial Survey Cameras

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ABSTRACT

RolleiMetric GmbH was founded on 1st January 2007 as a subsidiary of Rollei GmbH. Rollei itself has been active in the field of photogrammetry for over twenty years: for more than five years the company has also specialized in digital cameras for aerial photography. These camera systems are in the medium-format category and now utilize sensors of up to 39 megapixels. Over the last two years RolleiMetric's products have dominated the market for digital cameras in this particular segment. The next stage of development has now been reached. Several individual cameras will be integrated into a multiple solution that is capable of producing images of a larger surface area. In this respect, one of the major problems is the computation of a virtual image, since, in order to produce an integrated image, the individual photos must also undergo photogrammetrical analysis. The article details the development of a compact digital camera for aerial photography which is extremely cost-effective as a result of the inclusion of innovative system components.

1. AN HISTORICAL OVERVIEW OF ROLLEI GMBH AND ROLLEIMETRIC GMBH

Image 1: Rollei 35

Rollei GmbH was founded in 1920 by Franke and Heidecke. Their passion for photography led them to develop precision-engineered cameras for the medium-format category. The two-lens GX Series was a milestone in the development of cameras, both in Germany and worldwide, since it was the first camera to adopt the principle of single-lens-reflex. During the next few decades Rollei continued to expand. The company was at the forefront in establishing new standards and categories for cameras. For example, the Rollei35, one of the greatest success stories in the field of photography, was the first compact 35 millimetre camera to appear on the market.

It was Prof. Dr. Wester-Ebbinghaus who initiated Rollei's interest in photogrammetry. He suggested that three medium-format cameras from the 6000 series should be upgraded with a Réseau plate in order to deploy the camera for photogrammetrical purposes. This involved using a Réseau grid which could correct for the deformation of the film and thereby establish a system of coordinates in the image. These three cameras were so successful that Rollei soon set up a separate department for photogrammetry. A short time later RolleiMetric was officially established. During the next few years the subsidiary developed a wide variety of camera systems: 6006metric, 3003metric, d7metric, as well as software solutions for 2D and 3D evaluation of images. From 1998 on RolleiMetric has produced digital metrical cameras for use on the ground: these were so successful that the company has now adapted them for aerial photography. Although analogue metrical cameras had been used for aerial shots before, the digital sensors incorporated in the cameras had caused considerable distortion. Previously, the cameras used for aerial photography had almost always been large-format, manufactured by Leica and Zeiss. With the introduction of digital sensors, the medium-format began to play a much more important role in aerial photography.

This is why the parent company decided to set up RolleiMetric in 2007. The subsidiary now has more independence and flexibility and can now concentrate fully on its core task, in particular the special applications connected with photogrammetry.

2. THE DEVELOPMENT AND APPLICATION OF DIGITAL SENSORS AT ROLLEI / ROLLEIMETRIC

Rollei has been working with digital sensors since their inception and has developed numerous different digital cameras. However, digital sensors are not only used for taking the actual photo; nowadays they also play a role in triggering the auto-focus mechanism. They can be found in almost all modern compact and medium-sized cameras. In the past Rollei has developed and produced its own digital cameras, beginning with the chip-packs, which operate with a black/white sensor. In order to generate the colour, three special colour filters for the RGB spectrum rotated in front of the sensor. A later development was the d-series, a totally digital SLR camera. Its construction was such that it could be very simply modified into a metrical version that was adopted by RolleiMetric. This camera was used worldwide for terrestrial photgrammetry and, in a 5 MP version, is still in use today.

For aerial photography and high-resolution terrestrial metrical cameras, RolleiMetric utilizes the digital backs manufactured by Phase One, a Danish company that is the market leader in this field, offering a wide range of digital backs. Its flagship product is the P45 plus, a 39 MP digital back with a huge range of functions. Images can be stored on a CF card or a PC via FireWire. As with all the digital backs from Phase One, the first step is to take RAW images, which can then be transformed during post-processing into a TIF format with a colour depth of 8 or 16 bits. Employing the terminology of analogue photography, this process is called “developing”. One of the outstanding characteristics of these digital backs is their stability, a feature which plays a crucial role in aerial photography. For example, every 2.8 seconds, the P45 plus can take and store well over 1000 pictures, without interruption. And it has no need to resort to the internal buffer, which can produce a faster frame rate via a smaller sequence of images: instead, the pictures can be stored immediately on hard-disk or a CF card. During flights with fewer than 20 pictures on one strip, the frame rate time can be reduced even further if the internal buffer is used. Phase One is an excellent partner in other respects, too. The company lays great emphasis on research and development: this means that they tend to offer new technologies before anyone else and these products can be incorporated into RolleiMetric’s programme.

3. ADAPTING CAMERAS (FROM MEDIUM-FORMAT TO AIC)

At first RolleiMetric used the Rolleiflex 6008 Integral2 as a platform for aerial-cameras. However, it soon became clear that normal medium-format cameras were not particularly suited to the task. During flight, a camera is subjected to much greater mechanical stresses than on the ground. The vibrations and jolts that occur during landing and take-off have an immediate impact on the mechanical parts of the camera. The mirror drive of an SLR camera is a good example for this. It consists of many small components, like gears and axles, which will loosen and stop functioning if they are continually under stress. To prevent this happening, the cameras were reinforced in some areas and certain functions were simply disconnected. But even this proved to be only a stop-gap measure. Finally it was decided to develop a completely new camera for aerial photography, using electronics that had been tried and tested and reducing the mechanical parts to an absolute minimum. It was these considerations that led to the conception and development of the AIC

Image 2: RolleiMetric AIC

(Aerial Industrial Camera). As a first step, all the unnecessary mechanical components were removed, including the complete mirror drive, the film transporter and the auto-focus elements. The aperture-shutter assembly was the only mechanical part to survive. This is situated within the lens itself, which means that if there is failure, the lens can simply be replaced. The bayonet fixing of the lenses was also reinforced so that they could now be screwed in to increase rigidity. As a result, the AIC has highly stable calibration characteristics over a long period of time. Once the lens has been fixed in place, the AIC is more or less the same as a normal metrical camera. The next step was to adapt the electronics to the surroundings in an aircraft. The AIC can use the same power source as all the other instruments on board and also has connections to GPS/IMU and FMF systems. The firmware of the AIC was also modified. In normal medium-format cameras there is a firmware loop running internally. It checks the various interfaces to find out whether changes have been made by the user or to monitor the operating characteristics of various parts in the camera.

For example: “Has someone pressed the shutter button? What is the mirror position? Has the aperture been changed?”

If the camera is operated at a particular point in this loop, the loop moves on to the appropriate question and then reacts. The loop cycle can last up to 350 milliseconds, depending on the particular model. During this process delay-times can vary considerably and also influence the signals of a Flight Management System. In addition, there is the time-period for the digital back, which lies at around 250 milliseconds. This means that an exact exposure cannot be guaranteed, which can result in a great deal of variation in the overlap area of two pictures.

In the AIC the loop of the firmware has been reduced to a single question: “Has someone pressed the shutter button?”

This development also has an effect on measuring exposure times. The exposure meter fitted onto the camera analyses the light values during rather than before the exposure and adjusts the aperture as required. The AIC is controlled by means of a PC (RS232): it can also be pre-set and then works automatically with no need for an operator.

The overall concept behind the AIC is to produce a medium-format camera that meets all the requirements for aerial photography and incorporates a wide variety of interfaces for other systems. Modified medium-format cameras can, of course, play a role in this segment. However, it makes sense to adapt the camera totally to fulfil its task. The result is a more stable, robust camera that is easier to operate.

4. THE DEVELOPMENT FROM AIC TO AIC XN

After the AIC came onto the market, there was an increasing demand for greater resolution. In the beginning the medium-format cameras had been successful, particularly in the area of LIDAR systems. LIDAR flights also take pictures which can later be processed via the DTM of the LIDAR system. Colour components can then be added to the 3D point cloud. Since the aperture angle of a medium-format camera more or less corresponds to that of a LIDAR system, the two systems operate together well.

Image 3: RolleiMetric AIC x2

This has resulted in the decision by both Optech, the leading manufacturer of LIDAR systems, and Toposys, to install the RolleiMetric AIC for aerial photos. Furthermore, the resolution of a 22 MP camera is a little higher than that of the LIDAR system, so again the two are compatible. The last few years have also seen an increase in the number of pure stereo flights, which has led to more medium-format cameras being used in this field. Financially, they are a good solution and extremely cost-effective. Nevertheless, the requirements are different. Compared with LIDAR deployments, stereo flights are more interested in the resolution and overlap. Additionally, on the ground the picture should be as large as possible and have a good base ratio. A single AIC is a good, initial solution to the problem but the real advantages of this camera are not utilized. Hence, RolleiMetric has begun work on the AIC xN, where individual cameras are linked into a cluster of two or more. The first development culminated in the AIC x2 with two AICs standing at a slant to each other. The angle depends on the focal length selected and the overlap required for the pictures. RolleiMetric has cooperated with a German engineering consultancy to develop software that can stitch the two pictures into one by making use of the internal orientation and the relative orientation of the two cameras to each other.

The cameras themselves have been equipped with a new electronics system called a Daisy Chain Connection. This links the two cameras and allows a PC to communicate directly with each one. The camera heads can then be adjusted, or board cast separately. This means that they can be individually synchronized, so that the apertures and exposure times of each camera are the same and the pictures can be taken simultaneously. The time for synchronization is less than 150 microseconds: even in very fast aircraft this results in a ground resolution that varies by less than one pixel. The present Daisy Chain Connection can control up to eight cameras in this way. Further development will lead to AIC x3, AIC x4 and, finally, AIC xN.

Image 4: Dresden, GSD 10 cm, Flown by Alpha Luftbild GmbH

5. STITCHING INDIVIDUAL PICTURES FROM THE AIC (VIRTUAL IMAGE)

Computing the virtual image from two or more AICs is the basis for the AIC xN. The years of experience gained by RolleiMetric in the field of metrical cameras, as well as the close cooperation with Phase One, mean that all the parameters affecting the stitching of the pictures can be influenced and adjusted.
Adjustments for the virtual image can be made when the camera is being installed, for example:
Optical parameters, such as

- Distortion, with wide-angle lenses
- Vignation
- Lens resolution

Technical aspects, such as

- Construction of the camera housing
- Lens construction
- Electronic control of the shutter and aperture
- Electronic handling of events

Image corrections, such as

- Calibration methods
- Handling of RAW-format
- Colour management corrections

6. PROSPECTS FOR FUTURE DEVELOPMENT

The development of digital aerial-cameras has undergone great changes over the last few years. In particular, medium-format cameras have established themselves as a definite force and their share of the market continues to grow. They are extremely cost-effective, which means that even smaller firms can move into the field of aerial photography and carry out their own flights. For small and medium-sized projects, the AIC, with its open-ended system for medium-format cameras, offers a real alternative, all the more so since the available FMS or IMU/GPS systems can be used. Even well-established companies can now consider implementing medium-format instead of large-format systems. The AIC xN versions now in the pipeline are, themselves, the equivalent of a large-format solution.

Image 5: Holland, GSD 50 cm, Flown by Geoinformatik Rostock

Further developments in this field have led to an increase in the surface area per picture, a greater level of ground resolution and a decrease in the time spent airborne. These three factors alone are a clear indication that the future lies with solutions using camera clusters that deliver larger pictures, increase the image size cross track and reduce flying times. This last aspect will also benefit from the increased frame rate made possible by a new generation of digital backs. Manufacturers like Phase One are already offering digital backs with frame rates of less than one second: in the future these will be even faster. The same holds true for sensors. Only two years ago we were talking about 11MP to 16MP. Today we already have 39MP, a figure that is set to increase shortly. It is this development, in particular, that will result in greater ground resolution and a wider track size. If all of these developments are combined in a cluster solution, for example the AIC x4, a figure of around 140MP can be achieved. This would enable large-area mapping flights to be undertaken.

So much has happened during the last two years. There can be no doubt that the next two years will produce just as many surprises and developments in the field of aerial cameras.