Small Format Aerial Photography – a Cost Effective Approach for Visible, Near Infrared and Thermal Digital Imaging

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Summary

Since February 2008, an advanced system to acquire digital images in the visible to near infra red and thermal wavelengths is being developed. Using two different instruments, it is possible to acquire data for a large variety of applications. The core of the system consists of the cameras; a Duncantech MS3100 CIR (Color-InfraRed) multi-spectral camera and a FLIR ThermaCAM P65 thermal camera. The main advantages of the system over commonly used equipment are its affordability and flexibility. Within an hour the system can be deployed against very competitive costs. In this paper, we will present two applications: one that uses the multi-spectral data in an environmental protection project and another that uses the thermal data to investigate local heat differences in urban areas.

1 Introduction

The acquisition of aerial photographs and conversion to a digital format has traditionally been a slow and costly process (WARNER et al. 1996). With the appearance of relatively inexpensive digital cameras and computer systems, along with GPS positional information, it becomes possible to reduce the cost and time involved in digital image acquisition. In 2008, an advanced digital image acquisition system based on a DuncanTech MS multi-spectral and a FLIR ThermaCam P65 camera was developed that can collect data for many different applications. Both cameras are commonly used for close range imaging (MURPHY et al. 2004; WU et al. 2008), but also for aerial remote sensing purposes (ABUZAR et al. 2009, HERWITZ et al. 2004). Earlier applications were also developed at our department using small format aerial photography and are showing the relevance of the presented acquisition system (MUCSI et al. 2000, 2005; SZATMÁRI 2008). The purpose of the system was to (1) minimize the time between the moment an acquisition project is started and the delivery of the data, and (2) to minimize the costs of the data acquisition and pre-processing. During several test flights, the system was operationalised and the first multi-spectral data were collected in March. The first thermal data was acquired in August 2008.

2 Description of the System

2.1 Duncantech MS3100 CIR Camera

The MS3100 camera (Fig. 1) is a 3CCD system with independent gain controls for each CCD. The standard acquisition software from the camera vendor is used to control the instrument. The camera operator has a real-time view of what the camera is capturing during the flight and can control the gains, integration time, and frame rate in flight. On-the-fly adaptation of these settings is needed due to changes in the brightness of the sensed area and the incoming solar radiation. The camera uses a 4.65 × 4.65 micron CCD to capture data at a resolution of 1392 × 1040 pixels per band, and has a 10-bit per band dynamic brightness range.

Fig. 1:
Duncantech MS3100 CIR

A National Instruments IMAQ 1428 frame grabber in a Windows based mini computer converts the continuous stream of data collected by the camera into digital images which are stored on a local hard disk. A GPS is used to mark the approximate centre point of each photo as it is taken. Obviously, the GPS only registers the position of the plane, which means that a large positional error of the image can occur if the plane shows a strong pitch or roll. This error mainly depends on the weather conditions during the flight, and is, at the typical flying height of 1500 meter about 26 meter per 1 degree roll or pitch. The centre coordinates are logged in a simple ASCII file that is later used to create a first coarse georeference for each image.

2.2 FLIR ThermaCAM P65 Camera

The forward looking infrared radiometer FLIR (Fig. 2) is a compact single band thermal camera with a temperature sensitivity of 0.08° C. The instrument can measure temperatures between -40°C and +500°C and has a resolution of 320 × 240 pixels. Since the camera is originally a handheld devise, a special case was created to attach the instrument to the plane. During the flight, the colour display can be detached from the camera and the operator can instantaneously inspect the recorded images and excess the menus to operate the camera, although while acquiring data, there is normally no need to adjust the basic settings. The camera is capable of saving data as AVI animations, but in our applications the thermal data is usually collected as JPG images accompanied with an ASCII grid file that stores the raw uncalibrated thermal measurements. The raw data is stored on a standard compact flash card. After the flight, the raw data needs to be calibrated to derive absolute temperature values.

Fig. 2:
FLIR ThermaCAM P65 Camera

The FLIR is owned by the Directorate for Environmental Protection and Water Management of Lower Tisza District (ATIKÖVIZIG), our partner in this project. The instrument has been used extensively in other applications as well (ATIKÖVIZIG 2009).

2.3 Navigational Components

Ahead of the flight, a detailed flight plan is created and stored as a digital map in a navigational GPS (Mobile Mapper CE). In the air, a navigator directs the pilot to follow the flight plan as accurately as possible. It is important to accurately follow the plan since small deviations can result in a too large overlap between adjacent flight lines or even worse, it can result in missing data between flight lines. After the flight, the GPS track which was recorded during the flight and the original plan are compared to determine possible errors.

Fig. 3: The complete multi-spectral acquisition system and the Cessna 172 airplane

The complete system (Fig. 3) consists of the cameras, a mini computer for data storage and operation of the multi-spectral camera, a monitor, two handheld GPS systems, a laptop for the camera operator to follow the flight path and a 12 volt power supply. All equipment is build into a four seated, single engine Cessna 172 airplane owned by our joint venture company. It takes about one hour to install the instruments and set-up the GPS navigation and data acquisition system. The plane is stationed at the airport of Szeged, Hungary. The presented acquisition system has a limited spatial area that can be covered due to the limited capacity of the batteries and fuel tanks. The maximum flying time is about three hours including travel to and back from the area of interest.

3 Applications

3.1 Detection of Illegal Structures and Environmental Contaminations

The multi-spectral data from the MS3100 was used in a project to detect activities that may be harmful to the natural environment. Several objects were selected as potentially problematic, and were identified on the images (Tab. 1). A 30 hour flight campaign was executed between March and October 2008, and in total about 720 km^2 of multi-spectral data was collected (Fig. 4).

Table 1: Potentially harmful objects to be identified

1.	*Open water, where infiltration is prohibited by a plastic film, usually used for irrigation purposes. In general, these artificial ponds are found in areas with lots of large greenhouses.*
2.	*Greenhouses with a total area over 5000 m^2. Often these greenhouses are irrigated from reservoirs that are filled with illegally extracted water (from wells or ground water)*
3.	*Farms with intensive stock raising. For these farms, an environmental impact assessment might be obligatory, since they have a large influence on the surroundings.*
4.	*Illegal waste dumps*
5.	*Other objects of interest that changed and that are not reported*
6.	*Illegal sand or gravel extraction (pits or pit lakes)*

The objects of interest were often short lived events that occur in relatively small areas. Traditional air surveying campaigns are neither cost effective nor operative in these cases. Our flexible system, on the contrary, is especially developed for these circumstances. When flying at its typical flying height and speed of 1500m, the system acquires images with a footprint of 600m by 450m, a spatial resolution of 43cm and an overlap of 50 % between consecutive images in the flying direction. The raw data was stored as 24 bit TIF images resulting in false colour composites that could easily be interpreted by environmental specialists.

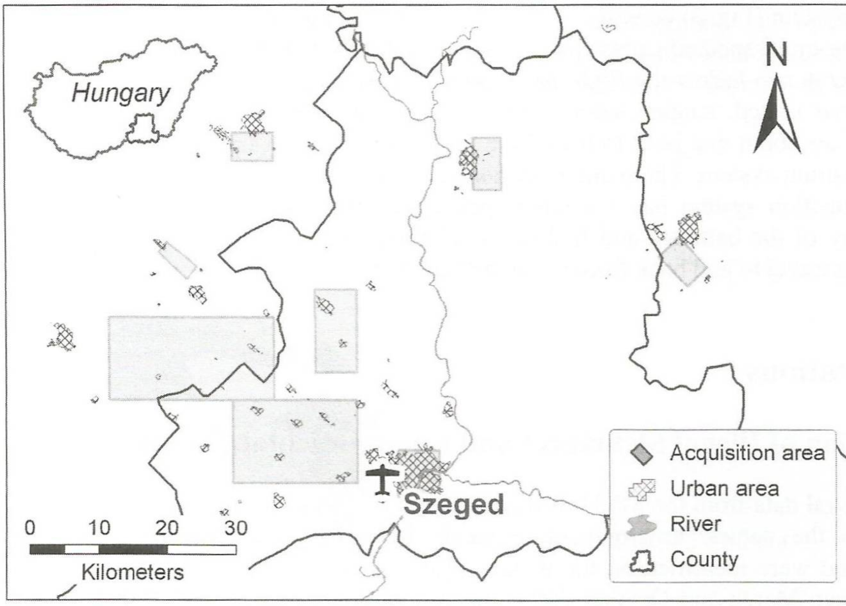


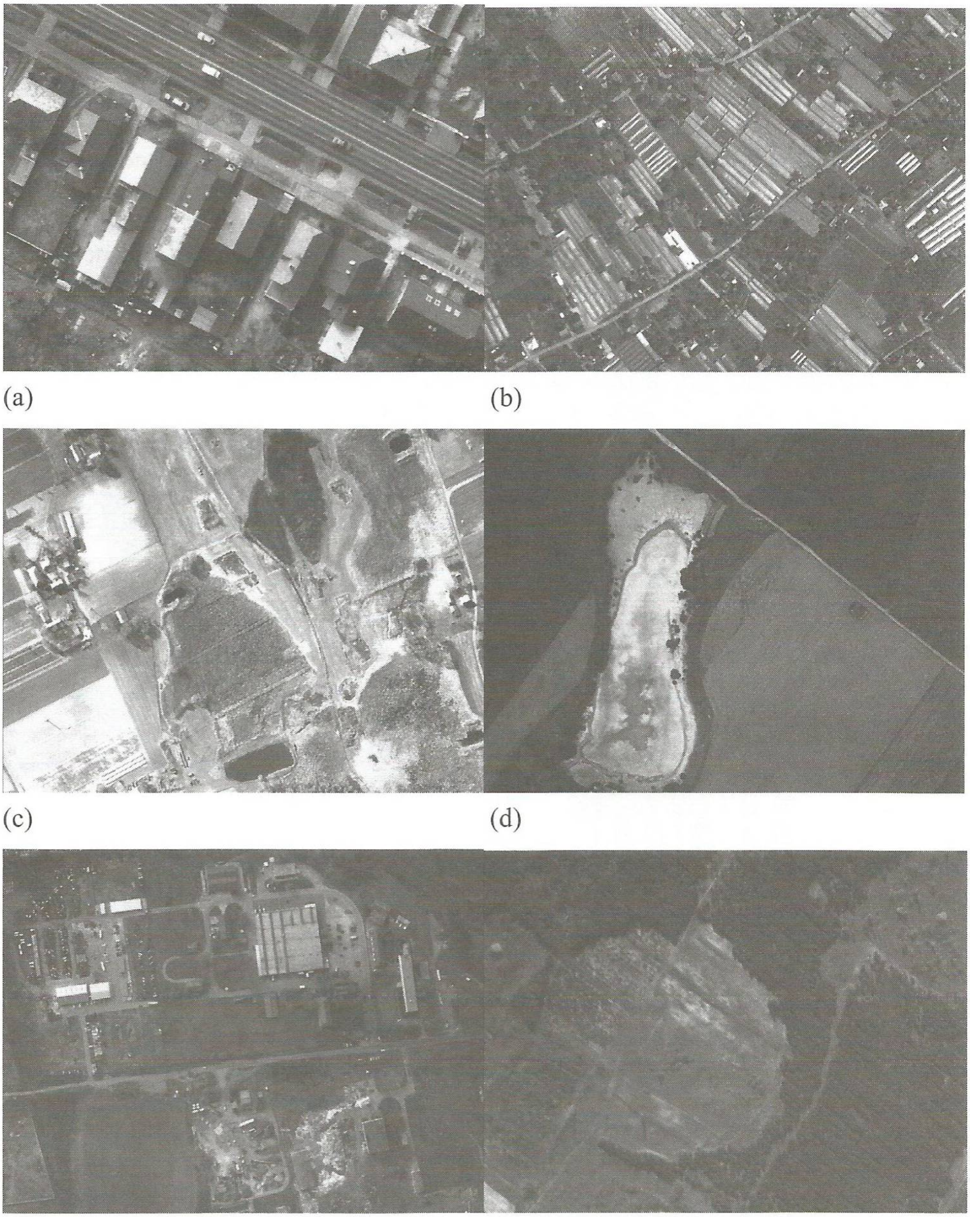
Fig. 4: Multi-spectral flight campaign (March-October 2008)

The raw data did not come with any georeference because no inertial data is acquired during the flight. To be able to use the data in combination with other georeferenced sources or to mosaic the images in a later stage, a first coarse georeference is required. For this purpose, a track was recorded with an accurate GPS during the flight. After the flight, the acquired images were time-synchronised with the track and tfw world files containing the georeferencing data were written to the TIF files using a custom developed ArcView Avenue script. The maximum error between the GPS centre point and the image centre that was encountered during the coarse georeferencing was 126 meter. Such a large error is due to a combined inaccurate GPS reading and a very large pitch or roll of the airplane.

In the next step, the TIF and tfw file were combined to a geocorrected IMG file using a Python script in ArcGIS. In ArcGIS, the IMG files were separately inspected to find the objects of interest (Tab. 1, Fig. 5).

If it is necessary to have a more accurate georeference and/or to create a mosaic of the total area, the data can be read into Leica Photogrammetry Suite (LPS). In LPS, the coarse georeference is accurate enough to semi-automatically create ortho-rectified images that can be mosaicked with an average accuracy of around 2 meter.

The data was visually inspected and when potentially interesting objects were encountered, the image was investigated further. This means that it was compared with official cadastral maps and a connected database that contains information about the economic/agricultural activity, the authorized water extraction and environmental permits that are given for the parcel under investigation.



(a) (b) (c) (d) (e) (f)

Fig. 5: Samples of the multi-spectral data collected between March and October 2008: (a) Buildings that require construction permits, (b) intensive agriculture (greenhouses) that need to be announced at the local environmental and economical offices, (c) reservoirs (dark areas at the bottom and the upper right corner) that are used for agricultural irrigation, (d) natural open water, used by migrating birds, (e) waste dumps (irregular light areas) possibly causing soil and ground water pollution, and (f) illegal lodging.

3.2 Investigations of Large Scale Temperature Differences in the Urban Environment

Many examples exist that show applications using a FLIR camera, but usually these are industrial application where the distance between the observed object and the camera is maximum a few dozen meters (FLIR SYSTEMS 2009). The application that is presented here is a remote sensing application where this distance is over 1000 meter. In this project, thermal data of urban areas was use to investigate large scale temperature differences. The temperatures are used in urban heat anomaly analyses. The data flow for the thermal data collection and processing is similar to that of the multi-spectral data, since the thermal images are also collected without accurate positional data. Thus the raw data needs to be georeferenced based on the GPS flight track data as well. A major difference in the processing chain is the need for calibration of the raw data to receive absolute temperatures. For this purpose, the camera needed to be set up with several parameters like atmospheric and lens temperature, camera-object distance and the general type of objects being observed. Since this project was executed in an urban area which is a very heterogeneous surface, the last parameter was specified as an average value.

In August 2008, a 3 day flight campaign using the thermal camera took place. The flights were executed between 8 and 10 o'clock in the evening, because then the measurements were not influenced by incoming solar radiation and the temperature differences are larger than during the day.

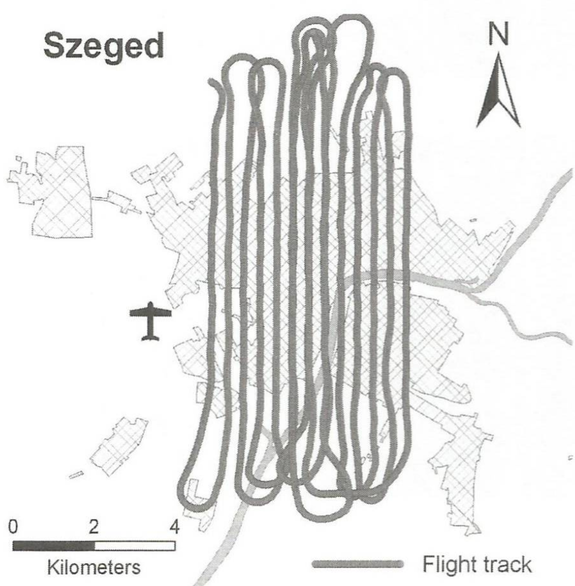


Fig. 6:
The GPS flight track of the thermal camera flight campaign of August 14, 2008

Figure 6 shows the GPS track log of the flight on August 14. At the same time, ground measurements were taken by a car and moving field crews. The field crews collected temperature data at ten different locations and at 3 different heights. These measurements were used to calibrate the thermal data after the flight using ThermoCam Researcher Pro software. Further input parameters for the software were the radiometric JPG images and the water temperature at the day of flying, which is measured daily and stored in a database maintained by the local water board (VÍZÜGYI ADATBANK 2009). Based on these input parameters, the software creates a temperature model and adjusts the temperatures measured with the thermal camera. The calibrated thermal data is stored as a CSV file which is geometrically corrected in the same way as the multi-spectral data.

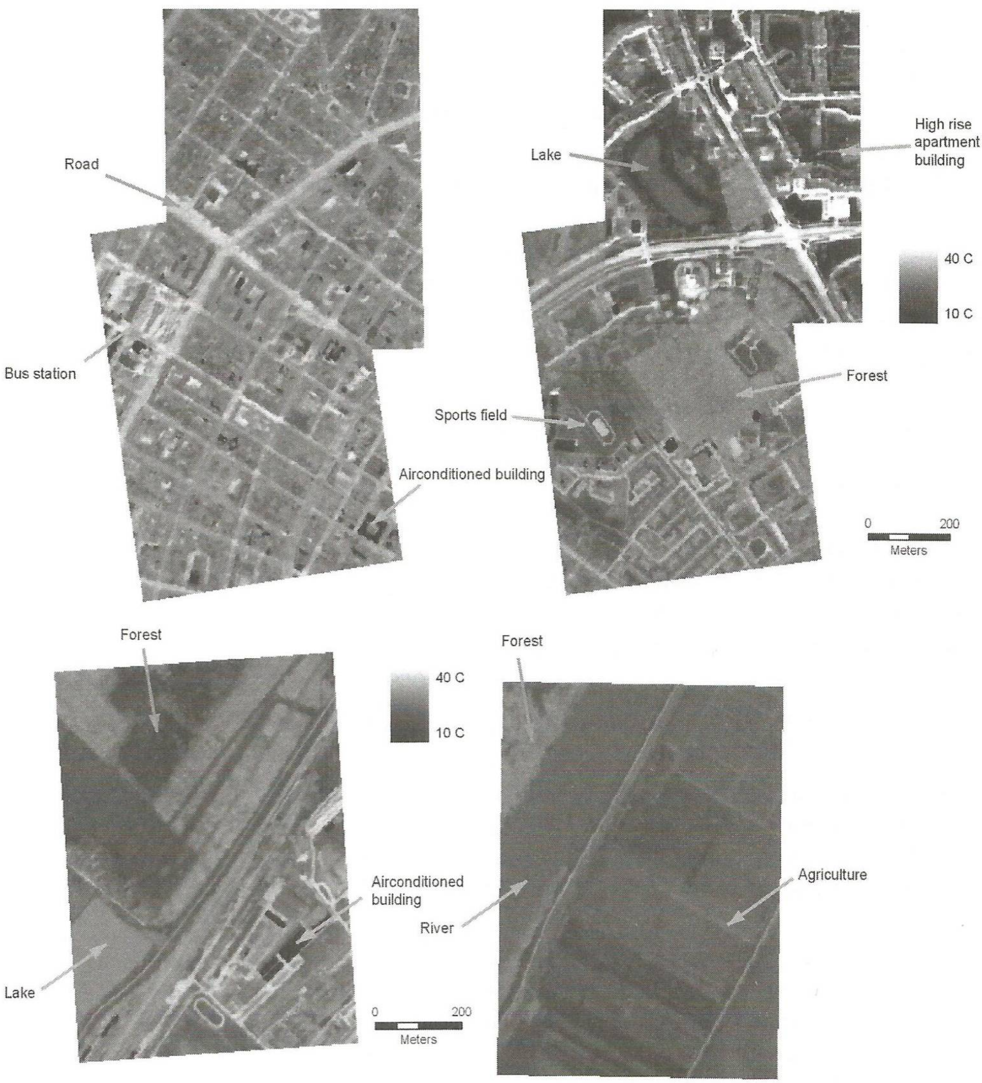


Fig. 7: Calibrated images of the centre (upper left and right), suburbs (lower left) and outskirts (lower right) of Szeged, Hungary, showing absolute temperatures (14 August 2008).

The images from the thermal camera were used to detect thermal anomalies in the urban environment. Clear temperature differences could be observed between similar buildings with and without air-conditioning. Also very high differences between concrete and vegetated surfaces could be detected. Some preliminary imagery is presented in Figure 7. Further research is going on to determine the relationship between the ground and airborne measurements and to quantify the accuracy of the airborne measurements.

4 Conclusions

The presented applications illustrate how the new system can help to build a sustainable environment using advanced spatial data acquisition techniques at an affordable price. Although fully operational, the system is still being developed further. To shorten the time required for referencing the data, it is foreseen that an inertial measuring unit will be integrated in the near future. This will also reduce the dependence on good weather circumstances which are now needed to minimize the positional error of the images. The usability of the system for further applications like vegetation research and the generation of digital elevation models for modelling flooding due to inland excess water is also being investigated.

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