A DIGITAL MULTI CCD CAMERA SYSTEM FOR NEAR REAL-TIME MAPPING

F. Savopol[(1)], M. Chapman[(2)] and M. Boulianne[(3)]
(1) Geomatics Canada, Ottawa, Canada
(2) Ryerson Polytechnic University, Toronto, Canada
(3) Université Laval, Québec, Canada
Fsavopol@NRCan.gc.ca
mchapman@acs.ryerson.ca
Michel.Boulianne@scg.ulaval.ca

Working Group C#/G#

KEY WORDS: Digital Camera, CCD Camera, Real Time Mapping, Multiple Sensors System, Sensors Integration.

ABSTRACT

Recently, Canada had to deal with three major natural disasters over a short period of time: flooding in the Saguenay area (province of Quebec) following heavy rain and the collapse of a water dam, flooding in Manitoba and an ice storm in Quebec and Ontario. In each of these situations, the emergency services faced two mapping problems:

a) the need for up-to-date existing topographical information on both digital and classical (paper) support showing the situation before the emergency situation (i.e., position of existing roads, bridges, community facilities, houses, etc.);

b) to acquire as quickly as possible, digital (eventually georeferenced) images from the disaster area in order to understand the situation, to evaluate the damage and the risk of injuries or additional damage and for the supervision of the rescue effort.

In the past, emergency services have used video recording from helicopters for reconnaissance purposes (disaster understanding and evaluation) but these images had a poor resolution and no metric quality. We propose the use of a new "Digital Multicamera System" able to provide imagery for both rapid reconnaissance and emergency mapping.

In order to demonstrate the feasibility of such a system, the present research work had two major goals:

1. To build a "Digital Multicamera System" for airborne image data collection by using 2 or more (preferably 4) digital frame cameras in order to maintain a higher image resolution over a wide area. Also, adapt software for the system calibration and for data extraction based on the results of a bundle adjustment.

2. To test this "Digital Multicamera System" in real flight conditions as an airborne image acquisition system and evaluate its potential for real-time emergency mapping by using a radio link for image data download.

1 INTRODUCTION

The compilation from classical, film based, aerial photographs was and is still the most popular method for topographic data acquisition for the production of new maps and for the revision of old and/or inaccurate maps and databases. For the image orientation and compilation steps, the introduction of digital photogrammetry software marked the transition to digital solutions, thus dramatically reducing any delays. The data acquisition step that previously relied upon photographs recorded on film represents a time consuming and expensive process. Now, the increased use of Geospatial Information Systems (GIS) for new thematic mapping applications is pushing the need for quality, up-to-date data ready for end-user consumption.

Some thematic mapping applications rely on real-time or near real-time data addressing the specialized needs of such disciplines as emergency response services, environmental impact assessment and response, utility corridor management and resource management.

In order to meet these requirements, we have to find solutions for to main problems:

- the image data capture in digital form with an acceptable resolution and

- the rapid, near real-time transmission of the image data to the user.

2 CONCEPT OF THE DIGITAL MULTI CAMERA SYSTEM

The existing classical, film-based, aerial photogrammetric cameras exhibit very high metric performances. The existing, commercially available frame CCD cameras can not compete with the resolution of a 9 by 9 inch photogrammetric camera. There is a trend in the industry for an increased resolution but it will take probably some time before it will be possible to directly replace the film with a large CCD sensor.

For the present situation, we propose to build a system using multiple CCD cameras as more economical solution.

2.1 General design

Some Multiple Cameras Systems were built in the past for remote sensing applications (King, D., 1995). In all of these systems, multiple cameras were used to produce multispectral images for the same object or area of the earth surface. Each camera was equipped with a different filter and all the cameras were pointing towards the same area - the optical axes of all cameras being parallel.

In the present project, each camera has a different orientation in order to obtain a maximum coverage of the terrain surface. There is only a minimum overlap between the individual images captured by each of the cameras. The optical axes of the cameras form a divergent bundle and the cameras are fixed using a rigid, sturdy metal mount.

If we consider a system using 4 identical cameras, the total ground surface covered by the 4 images (i.e., the total "footprint) is shown in **Figure 1 (C)**. For a better understanding, Figure 1 also shows the "footprint" of a single vertical camera (A) and the "footprint" of a single tilted camera (B).

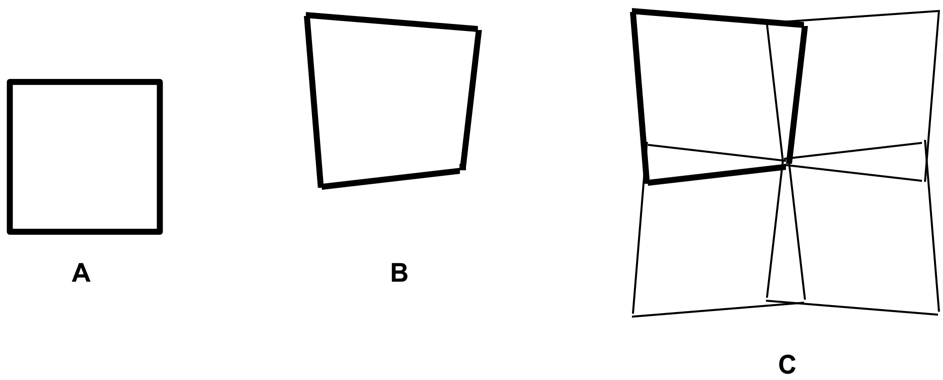

Figure 1: The "Footprint" of a single vertical camera (A), of a tilted camera (B) and of a 4 camera system (C).

In a multiple camera airborne system, the cameras must be synchronized with high precision in order to take advantage of the "multiple camera" configuration. A poor synchronization will not only generate some gaps in the terrain coverage but also will increase the need for ground control points (GCP) because each image will have to been oriented, as in a more classical photogrammetry survey. **Figure 2** illustrates the generic configuration for such a 4-cameras system. The number of cameras was chosen as 4 because there are some frame grabber cards on the market offering up to 4 input connectors and enabling the simultaneous capture of up to 4 synchronized video signals.

2.2 Calibration and first experimentation

We tested a first configuration of our system with 4 CCD video cameras using the RSS-170 standard (the North American video standard). The analog video output signal was digitized using a Genesis-LC frame grabber card, build by Matrox Inc., Montreal. This card accepts 4 analog inputs and has the capacity to capture 4 black and white RSS-170 standard signals. The mount used for this configuration is shown in **Figure 3.**

Any camera used for a photogrammetric work needs to be calibrated. All of the cameras used for the present research work were calibrated using the facilities of the Department for Geomatics at Laval University. This "Calibration and Test Site" has 133 spherical targets distributed in 3D over a space cube of about 4 by 3 by 4 meters. The method used is the self-calibration technique (Kenefick and al., 1972). The calibration of a digital imaging system should always be seen as a "System calibration" including the frame grabber and not as a camera only calibration since the change of the frame grabber could result in a change of the interior orientation parameters.

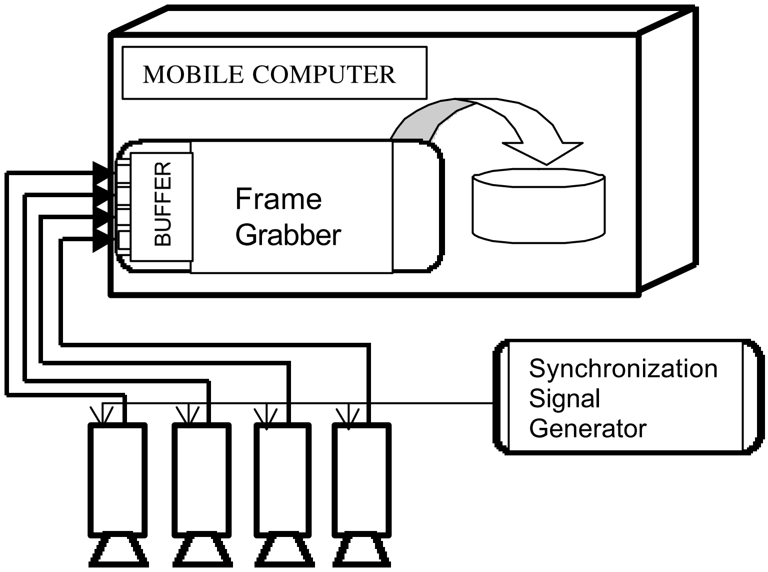

Figure 2: The generic configuration for a 4-cameras system.

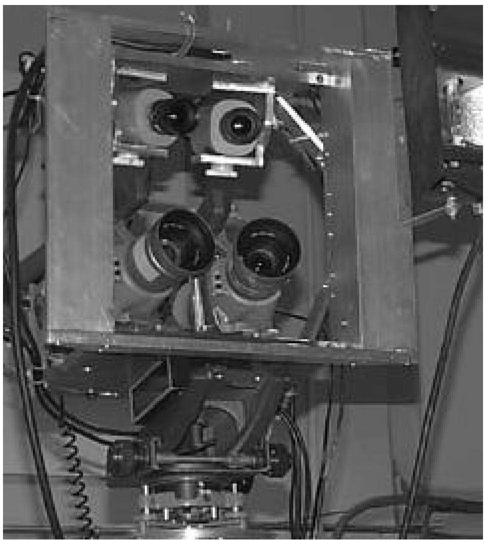

Figure 3: The mount holding the multiple cameras system in its first configuration (4 cameras).

2.3 Tests using high resolution cameras

In an effort to improve the image resolution of our system and its mapping capabilities, it was decided to replace the old standard video cameras (RS-170) with digital high-resolution cameras. For economical reasons, it was decided to purchase only two high-resolution cameras. The selected model was the Hitachi KP-F100, 1300 by 1024 pixels. It has analog and digital outputs (10 bits). The goal of our project was to demonstrate the feasibility the concept….if it works with two cameras, it will also work with 4 cameras.
A new mount was built in order to accommodate the 2 cameras for calibration and experimentation in the laboratory but also with the idea for it to fit directly into a Leica (Wild) aerial camera mount.

The most difficult problem was the synchronization. A synchronization signal generator was build following the technical specifications from the Camera manufacturer. Initially, a significant “jitter” of up to 5 to 10 pixels was present when using the analog mode and, in the digital mode, the image from the second camera was unusable. The experiment was repeated using different configurations for the synchronization signals. In digital mode it was still impossible to capture useful images from the second camera. The results were improved in analog mode using two HP signal generators for the vertical and horizontal synchronization. The images from the first cameras were distortion free and those from the second one had generally a jitter of about 2 to 4 pixels. **The Figure 4** shows an image of the Calibration and Test Site captured by the second camera; it is distorted by a jitter of about 2 to 4 pixels. The vertical lines are plumb lines and should be straight lines on the image.

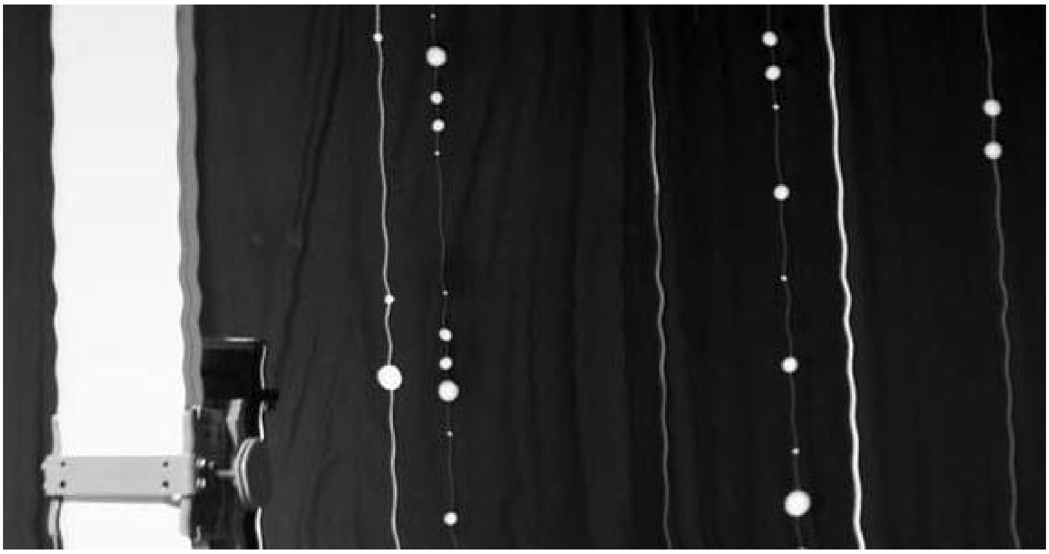

Figure 4: An example of an image distorted by a jitter of about 3 to 4 pixels

Considering that a image distortion in the form of a jitter larger than one ore two pixels will make this images unusable for a high quality cartographic work, it was decided to test a new configuration using two frame grabbers. It was a wise decision since this time we acquired distortion free images in analogue mode. However, the system was not totally stable, some times an unexpected, mild jitter was present (maximum 1 pixel). The system was now working also in digital mode. The digital images were good (better than in the analogue mode) but sometimes distortions were present and some “drop out” occurred.

With the help of the Electrical Engineering Department, a new set up was installed whereby the synchronization signals (vertical and horizontal) are now generated by the first Matrox frame grabber card. This first card works as the “master” card, controlling the synchronization of both cameras. The digital images delivered now by the system, using the described configuration, are distortion free, high quality images.

3 EXPERIMENTATION IN REAL FLIGHT CONDITIONS

Before the test in real flight condition, a simulation was organized inside the laboratory. The camera mount and the mobile computer containing the frame grabbers were installed on a mobile platform. The camera mount was oriented horizontally, perpendicular to the wall where about 50 targets were installed and measured using micro geodesy techniques. The power supply was provided by batteries, thus simulating real-time conditions.

The test area for the real flight test was chosen over the campus of the Laval University in Quebec City. A number of control points were selected, most of them being natural details of the terrain. With the help of our colleagues from the Department of Geomatic Sciences, about 24 points were measured using the differential GPS technique. These points should have a precision of better then 10 cm while the image captured during the test flight should have a pixel size of about 40 by 40 cm. A flight plan was prepared for a small block of 3 lines with an along track overlap of about 75 % to 80 %.

The first test flight took place in October 1999 following the prepared flight plan. The hardware and software components for the direct, near real time image data download from the airplane were not operational at the moment of the flight. This capability of the system will be tested later. However, the image inspection and the selection of the more useful images were tested during the flight.

4 DATA TRANSMISSION FOR (NEAR) REAL-TIME MAPPING

In the case of an emergency situation such as an airplane accident, an ecological accident or a natural disaster (earth quake, flooding), the availability of a real-time or near real-time "Mapping Tool" could dramatically improve the result of the rescue operations and save human lives.

Each emergency situation will generate its specific needs in term of spatial information and emergency mapping. We can identify three typical scenarios:

A. The existing topographical information in the form of digital data or/and as paper maps is old and probably out of date. The emergency mapping team should provide, in the shortest possible time, (and probably in the form of a disturbed environment) a more or less classical mapping service, the updating of the topographic information.

B. An emergency situation such as a natural disaster (earth quake, flooding, major forest fire) has modified the environment and the emergency mapping team is in charge of the mapping of these changes (limits of the flooded areas, of the forest fires or the areas with destroyed buildings and bridges). The main difference with the preceding situation (A) is the dynamic nature of the phenomena to map.

C. The emergency mapping team is in charge of mapping the results of an accident such as the debris of a major airplane crash or the spread of oil in the case of a tanker spill. The major difficulty of this scenario and the main difference from the preceding situations is the need to identify and position objects very different from the typical topographic objects mapped on the standard maps and GIS. And, in the case of an airplane crash, there is no minimum size for the area of the debris to be mapped.

In all this three scenarios, the delay between the inspection flight and the image data delivery is critical.

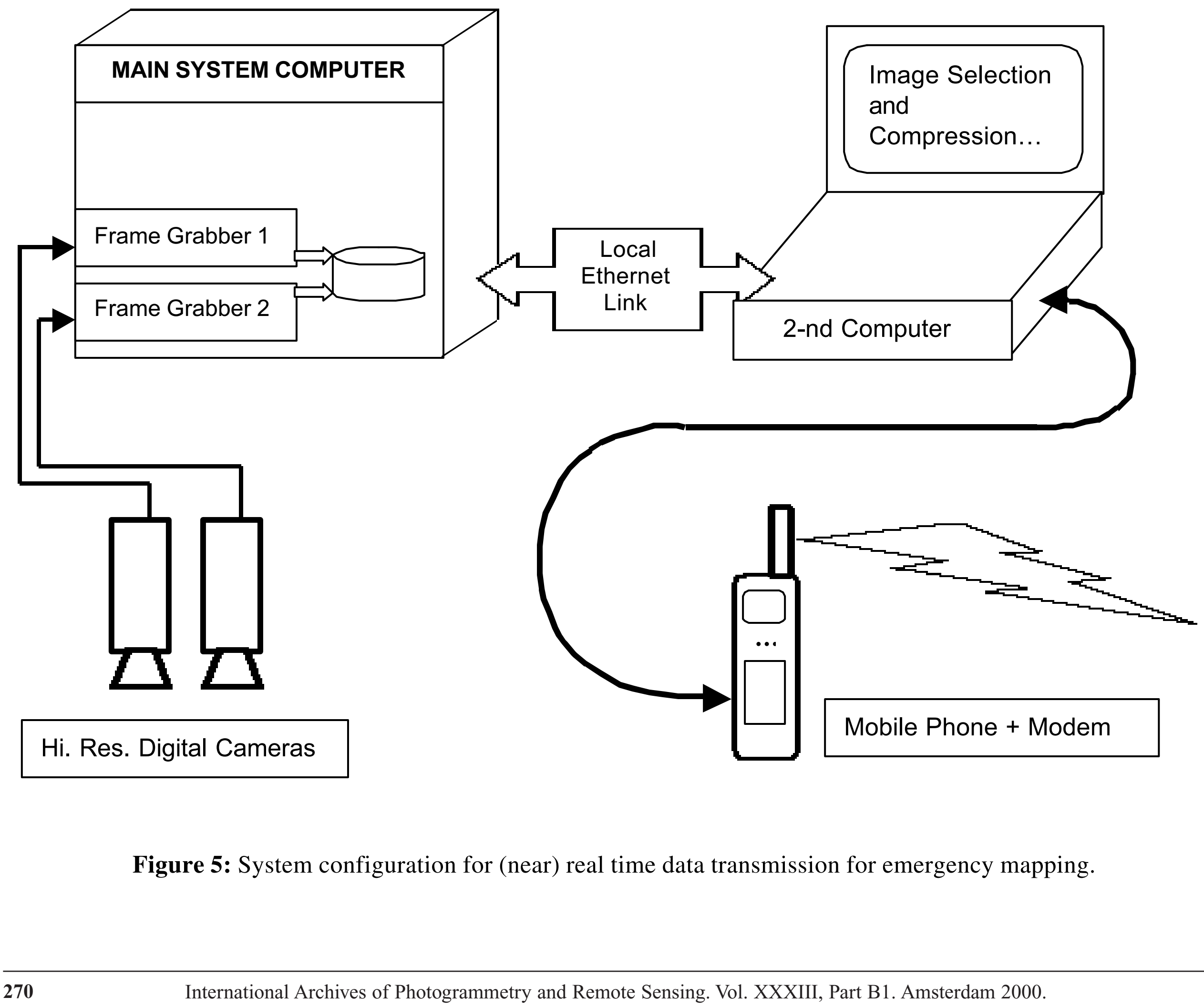

Figure 5: System configuration for (near) real time data transmission for emergency mapping.

The **Figure 5:** shows the proposed system configuration for near real-time image data downloading in a case of emergency mapping. This configuration was successfully tested in a simulated situation. All the hardware components were installed on the top of a 17 floor building situated in the test area used for the flight test on the campus of Laval University in Quebec City. In order to simulate real flight conditions, the power supply was provided by the same batteries as used during the test flight.

5 CONCLUSIONS

The possibility of using a multiple-camera system for emergency mapping in near real-time conditions has been successfully tested.

There are two main solutions for image orientation and exploitation in the case of such a multiple cameras system mounted on a rigid, stable mount:

A. In a first step, the creation of a synthesized image equivalent to a single high resolution image which would cover the same area as the total of all the individual single images captured at the same moment. This approach was presented in (Savopol et al., 1996). In a second step, the synthesised images could be used in a traditional manner for stereo compilation using standard soft-copy photogrammetric software.

B. To handle all of the individual images of a block in the same manner, using a modified bundle adjustment where additional condition equations were added in order to take advantage of the known relative orientation parameters between the camera mounted on their rigid mount.

The evaluation of the image geometry and the precision of the extracted topographic information are still in progress. Details of the results are expected in the near future.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Clement Nolette and Mr. Sylvain Lacompte from Laval University for their invaluable assistance in solving the multiple hardware and software problems during the system integration work.

The authors wish also to thank Hauts Monts Inc., Quebec City for their collaboration by providing the test flight.

REFERENCES

Kenefick, J.F., Gyer, M.S. et Harp, B.F. (1972) : Analytical Self-Calibration. Phot. Eng., Vol. 38, No. 11, 1972.

King, D. (1995): Airborne Multispectral Digital Camera and Video Sensors: a Critical Review of System Designs and Applications. Canadian Journal of Remote Sensing, Volume 21, No. 3, August 1995.

Savopol, F., Boulianne, M. and Nolette, C.(1996): Production d'images synthétiques de haute résolution pour la stéréorestitution photogrammétrique. The International Archives of Photogrammetry and Remote Sensing, Volume XXXI, Part B2. Vienna 1996

Schiewe, J. (1998): Effect of lossy data compression techniques on geometry and information content of satellite imagery. The International Archives of Photogrammetry and Remote Sensing, Volume XXXII, Part 4, The ISPRS Commission IV Symposium "GIS – Between Visions and Applications".