

A DIGITAL EXTENSION OF THE AUTOMOBILE COLLISION INVESTIGATION PHOTOGRAMMETRIC SYSTEM

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ABSTRACT

A softcopy version of an economic photogrammetric system has been designed. This photogrammetric system was developed for automobile collision investigations. In the original film based system, the stereo-cameras constructed with two non-metric cameras are used to collect the photographic imagery. The photo coordinates are digitized with a slide-projector and tablet-digitizer combination. In the designed digital system, stereo-cameras are still used for image gathering. After the films are developed, the "soft" copy of the imageries are gathered with desktop scanners. With digital imagery, several schemes of different automation levels can be developed. This softcopy photogrammetric system eliminates the requirement of slide-projector and tablet digitizer. The stability and lighting condition for the working environment also become less critical.

INTRODUCTION

A photogrammetric system based on the non-metric stereo-camera approach (Faig & Shih, 1990) has been constructed for the car collision investigation. This system follows the analysis model described in Tumbas & Smith (1988). The only difference is that, instead of tape measurements, the deformations are measured by photogrammetric means. After the evaluation with data sets from real collision cases, this system has been found to be practical and useful (Faig, Wilson, & Shih, 1992). Currently, this system is used by several selected Multi-Disciplinary Accident Investigation teams (MDAI Teams) across Canada.

After the completion of this photogrammetric system, further research has been conducted to investigate its improvements and the extension. After discussion and idea exchange with transportation professionals, a digital extension is found to be of general interest. This paper describes the design and implementation of this extension. The analogue system

is described first, followed by the digital version. Then, the scanning process is discussed. Regarding to feature extraction, there are two directions of development as well. Both the manual approach and the semi-automated approach are discussed.

THE ANALOGUE SYSTEM

In the original photogrammetric system, a non-metric stereo-camera is used for data acquisition. This stereo-camera is composed of two fixed-focus compact cameras, a base-bar, a photographic tripod, and two camera mounts (Figure 1, 2). A slide projector and a tablet digitizer were utilized for the photogrammetric measurements. The digitizer is directly linked with a micro-computer, and all following computations are performed on this micro-computer as well.

Within the camera, a set of four reference marks was established by gluing a brass frame onto the lens cone. In the four corners of this brass frame, tiny circular holes are drilled. With these reference marks, interior orientation can be calibrated in the system

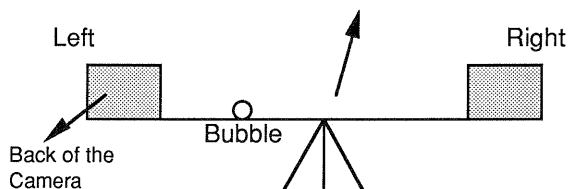


Figure 1: The Stereo-Camera

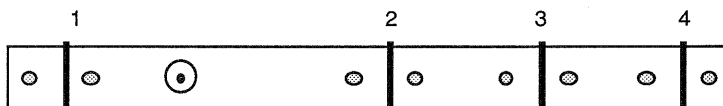


Figure 2: The Base Bar

calibration process, and re-constructed after the photo is taken during each operation.

A customized stand for the slide projector has been designed and manufactured in the Engineering faculty shop of the University of New Brunswick. This stand, on which an off-shelf 35 mm slide projector can be mounted, is used to facilitate the enlargement for the slide (Figure 3). After the enlargement, the image projected from the slide projector just about fills in all usable area of the digitizing tablet. The reason for this enlargement is to increase the resolution of the digitized photo coordinates in the original photo scale (Faig, et al., 1990).

Another solution would be using color films, rather than the color reversal films (slides), as the photographic material. For color films, the enlarged paper-prints can be used for digitization. In this case, the slide projector is not needed.

The operation flow of this photogrammetric system is illustrated in Figure 4. Crush analysis is performed with the program package Crash 3 (USDOT, 1986).

THE DIGITAL EXTENSION

The objective of this digital extension is to add the capability for accessing images in digital form. With digital images, the photo coordinates can be obtained from the display screen of the micro-computer. The advantages of having this extension are:

- the slide-projector and tablet digitizer are no longer required. This would eliminate special office requirements, such as stable platform, working space.
- various digital image processing and enhancement procedures can be applied. In case of the poor quality imagery, these functions may be useful for human visual interpretation.

- semi-automated or automated procedures, such as image matching, point extraction, even feature extraction can be implemented. This would ease the operator's work.
- an automated indexing system can be installed. Images can be transmitted via network conveniently and efficiently. This provides an option for different MDAI groups to exchange their data and facilitate mutual discussions in an efficient manner.

After the digital image is obtained. The hardware of this extension only requires a stereo-camera, and an IBM-PC compatible personal computer. In order to have quality image display, a VGA or Super-VGA graphic card and compatible display monitor should be used. Concerning the pointing device, although the arrow keys or other pre-defined keys on the key-board can be used to move the cursor on the screen, a mouse provides better human interface.

In the current situation, film based cameras are used. Therefore, after the photograph is taken and developed, a scanning process has to be performed to convert analogue photos into digital images. Two types of scanners exist. One type is specifically designed to scan 24mmx36mm color slides, the other is manufactured for general documentation scanning. During the development, an HP ScanJet desktop documentation scanner was used. More discussions on the scanning process are provided in the next section.

In the future, while the quality video camera and the digitization board become more affordable, the scanning process can be eliminated. For the video camera, no fiducial marks are required. The operations in Figure 4 can then be simplified into the operations in Figure 5. Details about the feature point digitization part will be described in the section of the semi-automated scheme.

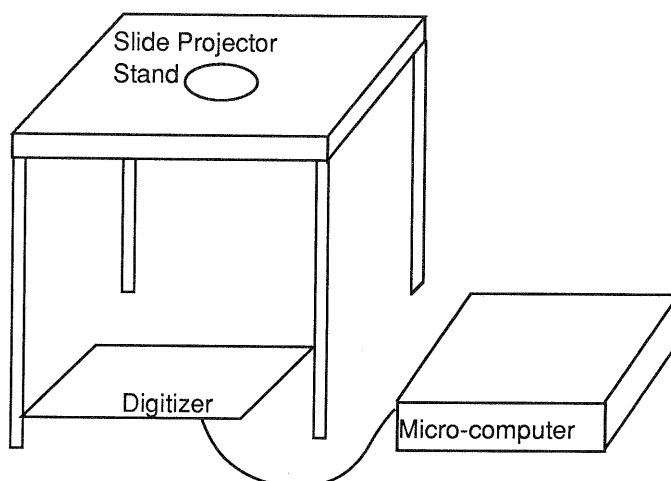


Figure 3. The Slide-Projector Stand

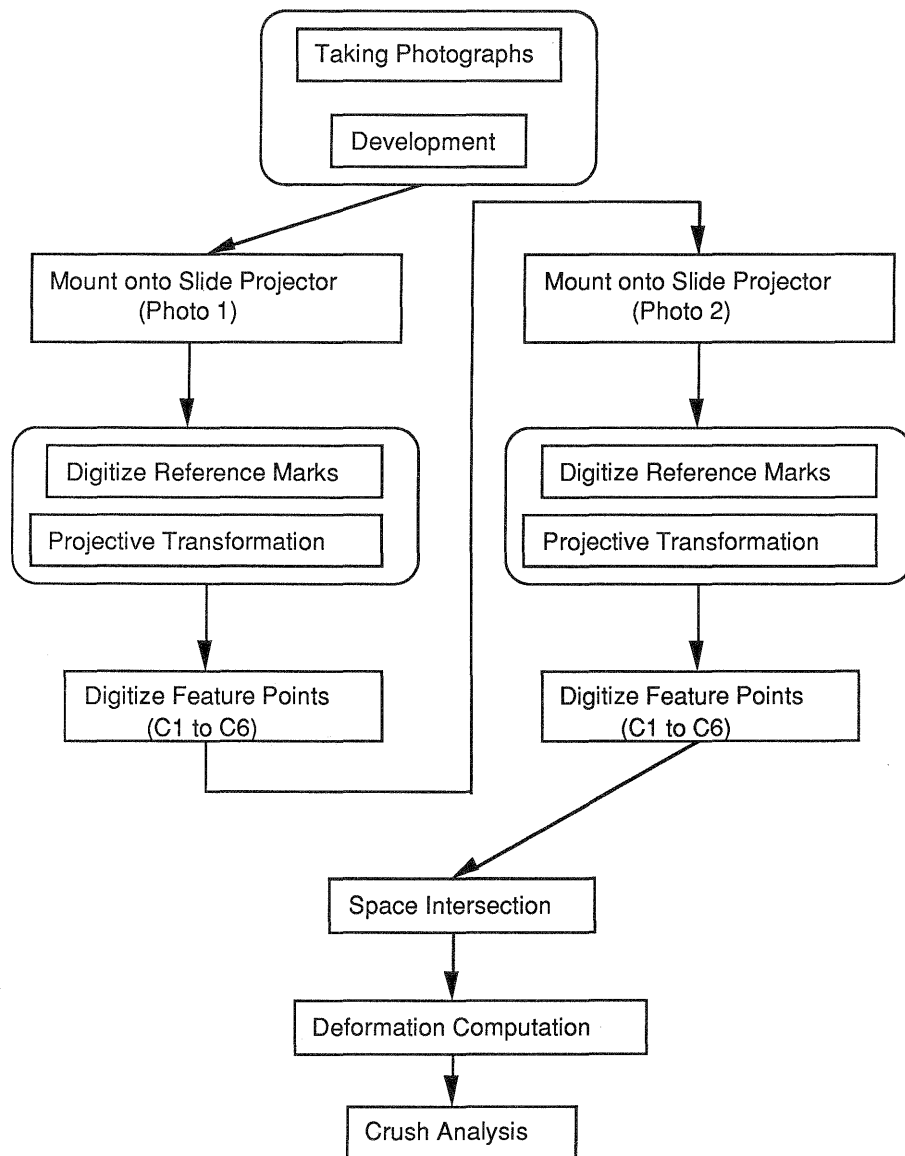


Figure 4. The Operations of the Photogrammetric system

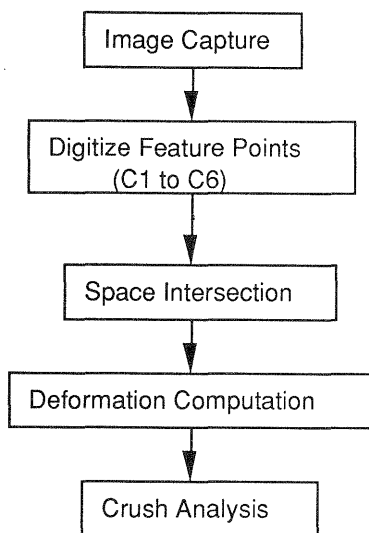


Figure 5. The Operations of the Video Based Photogrammetric System

THE SCANNING PROCESS

Using a scanner to convert graphic or image information of analogue form into digital form is a well established process. In mapping, scanners has been used to assist the conversion of paper map into digital map. In recent years, scanners have been widely applied for preparing multi-media presentation materials. This growing trend has induced massive progress in the manufacturing field of desk-top scanners, from both hardware and software aspects. These desk-top scanners are designed for documentary use such as desk-top-publication, electronic slide-show, etc. Compared with the high precision scanner conventionally used for mapping purposes, desk-top scanners have a significantly lower price tag.

Based on the material which is designed for scanning, there are two main categories of scanners. One is for documents, such as paper prints, the other is designed for digitizing slides.

The scanners work similar to the photo-copying machine. However, rather than reproduce another hard-copy, the light intensity of the original document is converted and stored in a digital form, i.e., the raster imagery.

- There are three major indices for a scanner,
- the geometric resolution, traditionally this is measured in dpi (dots per inch) or lpm (line per mm);
- the radiometric resolution, this is normally represented by the depth of each pixel, such as 4 bits imagery gives 16 gray-scales, and 8 bits imagery gives 256 gray-scales;
- the physical dimension, that is, how large the original document can be.

The common value for the desk-top document scanners are 300 dpi maximum geometric resolution, 16 or 256 gray-scales, 8.5 x 14 inches (legal size) physical dimension. The specifications of three commercially available models are listed in Table 1. Converting to pixel size, 300 dpi provides 0.0849 mm resolution; while 600 dpi provides 0.0425 mm.

The slide scanners have relatively higher spatial resolution. Typically, the physical format is designed as 35 mm by 35 mm. The related data of a commercial model is listed in Table 2.

Converting to pixel size, the resolution is 0.0137 mm. Because the standard format of a 35 mm camera is 36 mm x 24 mm, the slides can be digitized in either horizontal (landscape) or vertical (portrait) orientations.

The resulting digital image, to the maximum spatial resolution, would have about 4.46 M pixels. For 8-bits pixel depth, the file size would be 4.46 Mbytes.

THE MANUAL OPERATION

An operation module is designed to mimic the original analogue system. The flow is the same as illustrated in Figure 4. The only difference is that instead of mounting photos onto slide projector, the image is loaded and displayed on the screen. Several functions are provided:

- image display,
- image enhancement,
- coordinate digitization.

For VGA mode 18, the spatial resolution is 640x480 with 16 colors. That means, on the screen, 640x480 pixels can be addressed and displayed as one of 16 colors. Apparently, this is quite limited. Higher resolution devices are increasingly becoming available. For example, AcerPower Ultra-VGA from Acer provides 1024x768 pixels with 256 colors (for 1MB video memory). Although there is massive progress in the graphic display devices, the designed system uses VGA as the base platform due to its generality. The program automatically determines the type of the video display and activates the proper procedure. The design principle is to display the full image in a one-to-one ratio on the screen at the same time.

THE SEMI-AUTOMATED SCHEME

A semi-automated (computer-aided) module is also designed. This module is based on the mono-plotter concept (Shih & Derenyi, 1992). With image matching technique, the operator only has to digitize the feature

Table 1: The Specifications of Three Document Scanners

	AppleScan	HP ScanJet	Microtek ScanMaker
maximum geometric resolution	300 dpi	300 dpi	600 dpi
maximum gray scale range	16	256	256
maximum physical dimension	8.5" x 14"	8.5" x 14"	8.5" x 13.5"

Converting to pixel size, 300 dpi provides 0.0849 mm resolution; while 600 dpi provides 0.0425 mm.

Table 2. The Specifications of a Slide Scanner

	Microtek ScanMaker 1850
maximum geometric resolution	1850 dpi
depth of pixel	1 or 8 or 24 bits
maximum physical dimension	35 mm x 35 mm

points in one of the images. The corresponding image point in the second image is located automatically by the program. The operation flows are illustrated in Figure 6.

CONCLUDING REMARKS

"Digitization" is the most important photogrammetric development at the present time (Leberl, et al., 1992). The utilization of a "softcopy" photogrammetric process is a growing trend. This article reports on a digital extension of a photogrammetric system, which is dedicatedly designed for a close-range application, the car collision investigation. Further developments in the direction of automated algorithms and schemes are also undertaken. A graph-based matching and automated feature extraction scheme is described in Hellwich and Faig (1992). In their scheme, zero-crossing is used to extract feature points, then the points are screened and linked into line segments. Matching is performed with both descriptive and relational parameters of the features. Besides, attempts in applying Hough Transformation have been made (Adamos and Faig, 1992). It is expected that in the foreseeable future, a more friendly and efficient photogrammetric system will be available.

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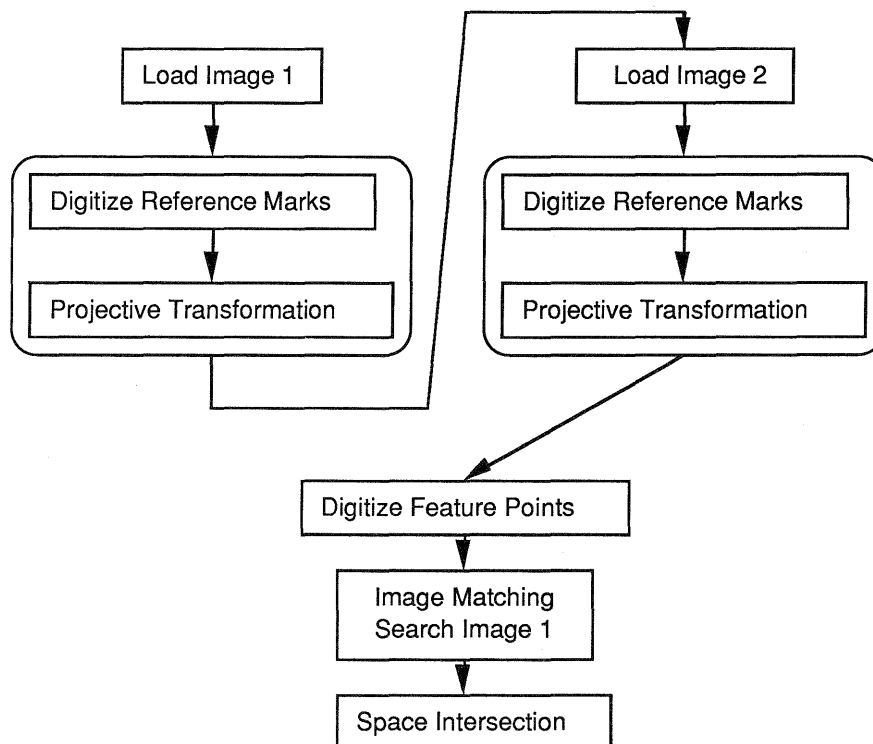


Figure 6. The Operation Flow for the Semi-Automated Scheme