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THE ACCURACY OF A RIVER BED MOULDING/ CASTING SYSTEM AND THE EFFECTIVENESS OF A LOW-COST DIGITAL CAMERA FOR RECORDING RIVER BED FABRIC

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Abstract

Digital photogrammetry has been used to develop and test an artificial river bed moulding and casting system, which allows the pebbles within a coarse-grain river bed to be recreated for hydraulic research in a laboratory flow channel or flume. Imagery of both the original streambed and the cast facsimile was acquired using a non-metric Kodak DCS460 digital camera and digital elevation models and orthophotographs were derived and compared to assess the accuracy of the moulding and casting system. These comparative tests proved to be critical in modifying and developing the system.

Additional imagery was obtained in the field using a non-metric Olympus C3030 "compact" digital camera to assess whether far cheaper camera technology could deliver data appropriate for such comparative examinations. Internal calibration parameter sets and data that were generated were compared with data obtained by the non-metric Kodak DCS460. These tests demonstrate that digital sensors built around high-quality 35 mm professional camera bodies and lenses are required for comparative examinations and for similar system development.

KEYWORDS: camera calibration, DEM, low-cost digital camera, river bed studies, surface measurement

INTRODUCTION

GEOMORPHOLOGISTS and hydraulic engineers strive to understand the complex interactions between the flow of water and entrainment of sediment in natural river

channels. Experiments conducted within the controlled environment of a flume offer many advantages, but there are major difficulties reproducing river beds composed of coarse particles (pebbles, cobbles and boulders). Natural beds consist of complex arrangements of particles of wide-ranging size that have been deposited, reworked and oriented as a result of a large number of floods. The composite effect is a fluvial "fabric" that is extremely difficult to reproduce in a flume. In the past, scientists have relied upon creating artificial pebble clusters (Lawless and Robert, 2001) or on numbering surface pebbles in the field in order to reconstruct a bed in the laboratory (Young, 1992). Although these techniques have provided significant results, these are derived in environments that lack the true complexity of real gravel-bed surfaces. Research conducted at Loughborough University has developed a novel system of casting a natural river bed and reproducing a realistic moulded replicate (Buffin-Bélanger et al., in press). However, a key research question was just how accurate was the cast replicate when compared with the original river bed surface. The primary purpose of this paper is to describe how digital photogrammetry was used to assess the accuracy of the river bed moulding/casting system and show how the derived spatial data were critical to successful development of the technique. A secondary objective is to compare and assess the effectiveness of two contrasting types of non-metric digital camera for such a task—the Kodak DCS460 and the Olympus C3030. The Kodak DCS460 has been successfully used for photogrammetric measurement but its successors remain expensive. The Olympus C3030 is more recent and comparatively cheap (£500, March 2002). The Olympus has been successfully used for automatically extracting grain-size information from images of gravel river beds, but remains unproven for photogrammetric measurement.

PAST AND RELATED PHOTOGRAMMETRIC WORK

During the 1970s, the ability of analytical photogrammetry to correct for various systematic error sources led to the use of non-metric cameras for measurement (Schwidefsky, 1970; Murai et al., 1980). Abdel-Aziz and Karara (1971) developed the pioneering direct linear transformation (DLT), which was appropriate for 35 mm imagery without fiducial marks, but over-parameterisation of the solution introduced a lack of mathematical rigour. Rigorous approaches to model camera geometry were developed by Kenefick et al. (1972) and Faig (1975, 1976) and have subsequently been modified only slightly to compensate for affinity and differential scale associated with digital sensor systems (Fraser and Shortis, 1995; Patias and Streilein, 1996; Shortis et al., 1998). These methods have been used to measure particles and bed forms in a variety of studies. At extreme close range, Chiat (1977) used tilted images on a microscope stage to measure the size and shape of small particles typically less than 1 mm in size. Collins and Moon (1979) measured stream-bank erosion in the field environment, whilst Welch and Jordan (1983) used a 35 mm amateur camera and enlarged transparencies to derive a digital elevation model (DEM) of a river bed within a small channel. In a series of studies, Lane et al. (1994, 1995, 1996) applied analytical photogrammetry using oblique photographs in conjunction with field surveying methods to monitor change that was occurring within an active pro-glacial stream in the Alps. Lane et al. (2000) also provided a comprehensive review of photogrammetric methods employed by fluvial geomorphologists, particularly for measuring the complex topography within a streambed and to estimate stream channel change.

Developments in digital photogrammetry have been significant, offering the opportunity to extract DEMs automatically, and Butler et al. (1998), Stojic et al. (1998), Westaway et al. (2000) and Chandler et al. (2001) have all used this facility to measure bed forms created in both real and simulated river channels. The massive increase in point density afforded by automated DEM extraction methods suggests that manual measurements using traditional methods offer few advantages (Hancock and Willgoose, 2001). Automated methods have even been attempted where the measurement of bed forms takes place through an air/water interface (Wolff and Förstner, 2000; Butler et al., 2002).

In most of the recent studies involving digital photogrammetry, use has been made of either a semi-metric camera (typically a modified Hasselblad) with digital scanning of the original negatives, or a digital camera such as the Kodak DCS460. Examination of the recent photogrammetric literature suggests that the Kodak DCS460 and its predecessors (DCS420/DCS200) are acceptable for many photogrammetric measurement tasks (Fraser and Shortis, 1995; Peipe and Schneider, 1995; Ganci and Shortis, 1996; Fraser, 1997). In two recent studies, Chandler demonstrated that this class of camera is certainly capable of measuring river bed forms accurately, using both vertical (Chandler et al., 2001) and oblique (Chandler et al., 2002) imagery. Although results are good, the disadvantage with this class of camera remains the cost, even the current equivalent model (DCS760) costs in excess of £7000 (March 2002). There is, therefore, a desire to utilise cheaper image acquisition tools, particularly amongst non-specialists keen to use photogrammetric methods.

THE RIVER BED MOULDING AND CASTING TECHNIQUE

The casting technique is fully described in Buffin-Bélanger et al. (in press), so it is only necessary to provide a brief description of the technique here. The method involves classical sculpting: a mould of the object, the bed surface, is made and the mould is used subsequently to replicate the object in the form of a cast. Although quite straightforward in principle, using such a technique to replicate complex river bed surfaces of a relatively large area (1 m × 2 m) constituted a real challenge.

A polyvinyl chloride, commercially known as Gelflex™, is used to create the mould. The Gelflex is melted and poured over a selected dry bed surface, around which a metal retaining frame is placed. The Gelflex penetrates into the interstices and covers the bed surface with a flexible skin that can be peeled off. It is necessary to create a more rigid structure on top of the flexible Gelflex to preserve the gross morphology of the bed, before removing the whole from the bed. Polyurethane foam resin was used because it cures quickly (within minutes) and has considerable strength on setting. As the foam expands and cures, surface irregularities ensure that it becomes mechanically locked to the underlying Gelflex. The entire mould can be then lifted onto its side, intact within the pre-positioned metal frame and embedded pebbles removed. This task is relatively easy because of the self-lubricating properties of the Gelflex. When cleaned and taken into the laboratory, the mould presents a negative impression of the gravel surface, with coral-like Gelflex prominences that reflect variably deep and complex interstices. Epoxy and polyurethane resins are then used to create the cast. When the casting is finished, the mould can be inverted in order to remove the polyurethane foam and the Gelflex

mould. The cast provides a highly realistic surface in which great detail in the original is preserved.

TESTING THE ACCURACY OF THE SIMULATED RIVER BED SURFACE

The moulding and casting system provided a river-bed replicate surface that looked realistic but quantitative data were required to assess the accuracy of the river bed moulding and casting system. Two separate photogrammetric surveys were carried out. Initially, the original river bed surface was measured in the field, prior to creation of the mould. Then, once the cast had been created in the laboratory, a second photogrammetric survey of the final cast surface was conducted. The same 3D rectangular Cartesian coordinate system was used in both photogrammetric surveys, to allow direct comparison and quantification of the accuracy of the system.

River Bed Survey

In the first survey, high-resolution digital images were acquired of the dry streambed using a Kodak DCS460. The camera was supported by a four-legged platform to ensure stability during exposure from a height of 1·6 m above the bed (Figs. 1(a), 1(b), 2). Fourteen premarked photo-control points were placed on prominent stones and coordinated to sub-millimetre precision using a digital theodolite, intersection methods, and a least squares "variation of coordinates" estimation program. Eight of these points were constructed from targets 5 mm in diameter, the other six were the tops of "No. 6" chipboard screws inserted directly into the streambed. Five vertical images of the test area were acquired using the Kodak DCS460, comprising two stereopairs for DEM extraction, each with a base-to-distance ratio of 1:6, and with a stereo overlap of 90% (Fig. 1(b)). An additional camera position (Fig. 1(b)) provided a single image over the whole area for colour orthophoto production. In addition, oblique and convergent images were obtained to provide appropriate geometry and redundancy to calibrate the DCS460 camera. Digital imagery was also acquired using an Olympus 3030 from a height of just 1·0 m. A simple stereopair configuration was adopted using a base-to-distance ratio of approximately 1:5, a typical configuration that a non-specialist might adopt for routine capture of field data. This was supplemented with four oblique images for calibration, the camera being set, in all cases, with a fixed focus distance. Table I provides a summary of the two camera specifications and configurations.

River Bed Photogrammetry

Processing of these data was carried out using the Erdas OrthoBASE Professional© system. The eight targets were used as control points with an assigned precision of ±1 mm, whilst the six screw heads were classified as "check points" and therefore not used in the restitution process directly. The software was used to manually measure the image coordinates of the control points and collect a series of tie points using an auto-tie facility. This latter operation was not entirely successful, primarily because part of the structure necessary to support the camera and indeed the author's footwear appeared within the photographs taken (Fig. 2). These features
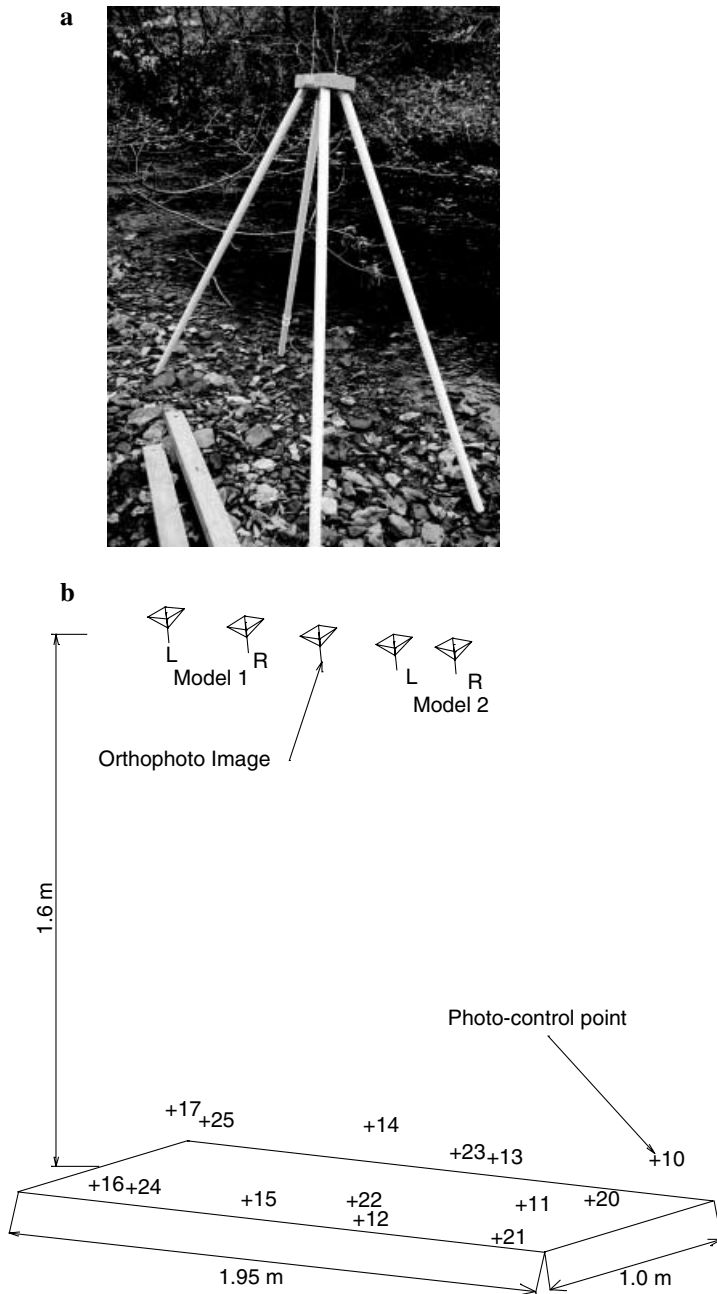
FIG. 1. (a) Field site showing camera support and nature of site/river bed.
(b) Photo and control configuration for river (laboratory) using Kodak DCS460.

TABLE I. Camera details and configurations.

Camera	Resolution (pixels)	Focal length (mm)	Flying height (m)	Ground dimension of pixel (mm)
DCS460	3060 × 2064	24	1·6	0·6
Olympus	2048 × 1536	14	1·0	1·0

FIG. 2. Kodak DCS460 image of real river bed (note: camera platform legs and the author's footwear).

shifted in location for successive images and these unstable interest points inevitably caused the software confusion. Once an initial adjustment had been achieved successfully, the measurements were processed using both the self-calibrating capabilities of OrthoBASE Professional and an independent self-calibrating bundle adjustment called GAP (Chandler and Clark, 1992). This duplication was carried out to provide confidence that the OrthoBASE software could derive appropriate estimates for the unspecified parameters used to model the inner geometry of the Kodak digital camera. The impact of including just one of the oblique images in conjunction with the five vertical images was also examined, to assess whether the stronger geometry would indeed assist in the self-calibration process.

TABLE II. Rms error values of Kodak DCS460 restitution.

Solution		Rms error control (mm) (8 points)			Rms error check (mm) (6 points)			Total image unit weight
Self-calibration method	Oblique (Y/N)	X	Y	Z	X	Y	Z	(μm)
GAP	Y	0·7	0·1	0·9	0·7	0·7	0·9	3·7
Obase Pro	Y	0·7	0·1	0·9	0·7	0·4	0·8	3·6
GAP	N	0·5	0·2	0·5	0·5	0·5	1·6	1·6
Obase Pro	N	0·5	0·2	0·4	0·5	0·5	1·1	1·1

Table II indicates the accuracy of the restitution process, providing rms error values for both the control and check points under two different photo-configurations and using two different camera calibration solutions. Solution "Obase Pro" utilised a "14 parameter Brown" solution, with the additional parameters being considered as weighted variables (Erdas, 2001). Unfortunately, the software manual provides little insight into these parameters and what they physically relate to, other than: "This model has fourteen additional parameters that are simplified from the suggestion of Dr. Brown" (Erdas, 2001). In contrast, the "GAP" solution incorporated three parameters to model the primary inner orientation (focal length, displacement of the principal point) and two parameters to model radial lens distortion (Kenefick et al., 1972; Chandler and Clark, 1992).

The results conveyed in Table II suggest that both calibration methods produced virtually identical results, providing confidence and confirming, perhaps, the applicability of the OrthoBASE self-calibrating bundle adjustment solution for this imagery. Inclusion of one oblique image degraded the image unit weight (1·1 to 3·6 μm), confirmed by a worsening of the accuracy of fit to the control (0·4 to 0·9 mm). However, accuracy with respect to the independent check points actually improved slightly (1·1 to 0·8 mm), demonstrating the value of oblique imagery for self-calibration and independent check points for assessing the quality of restitution.

Once a satisfactory restitution had been achieved, DEMs were generated from the two overlapping stereopairs and then merged to form a composite DEM. This was then used in conjunction with the single central image covering the whole test area (Fig. 1(b)), to generate an orthophotograph representing the original streambed as it appeared in the field.

River Bed Results

Fig. 3 represents an unedited DEM of the original streambed derived from the DCS460 imagery, captured at 5 mm resolution or post spacing. All major pebbles are represented and no gross errors are apparent. An acceptable quality of the DEM is
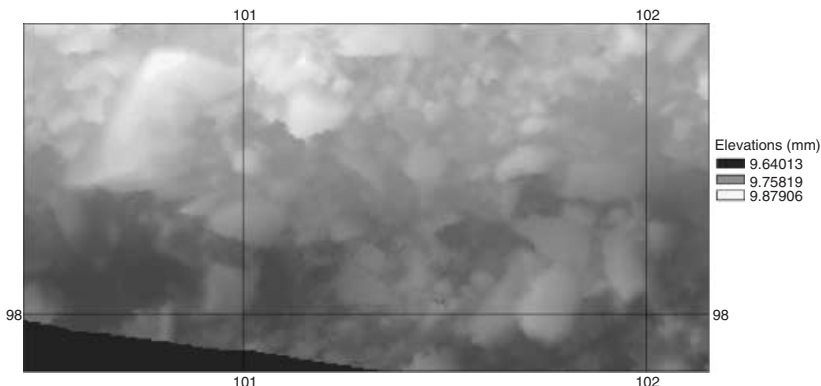

FIG. 3. DEM of river bed (derived using DCS460 imagery).

TABLE III. Rms error values of DCS460 DEM at six check points.

Self-calibration method	Oblique (Y/N)	Elevation rms error (mm)
GAP	Y	1·9
Obase Pro	Y	1·8
GAP	N	3·0
Obase Pro	N	2·2

confirmed by examining the rms errors of the DEM at the six check points (Table III), for the two different photo-configurations and self-calibration processing options.

This reveals that an accuracy of 1·8 mm was achieved using OrthoBASE calibration routines, combined with the full configuration of images. A similar result (1·9 mm) was achieved using the same image set and an external camera calibration solution. Interestingly, the removal of just one oblique photograph degraded the accuracy of the DEM slightly to 2·2 mm, implying again, the prudence of acquiring oblique imagery to assist in the camera calibration process. Overall, these results suggest that the quality of the extracted DEM is appropriate, as perhaps would be expected with this type of non-metric camera with proven capabilities (see also Fraser and Shortis, 1995; Peipe and Schneider, 1995; Ganci and Shortis, 1996; Fraser, 1997; Chandler et al., 2001, 2002).

Laboratory Survey and Photogrammetry

The second phase of the photogrammetry involved extracting similar data, but using imagery acquired of the replicated river bed cast, in the laboratory. The same image configuration and camera platform was used (Fig. 1(b)) but only DCS460 imagery was acquired. Three of the original screw heads and three of the original targets appeared in the cast, to which five new photo-control points were added. As before, the positions of these targets were determined in a 3D Cartesian coordinate system, using theodolite intersection methods. To achieve meaningful spatial comparisons between the two photogrammetric surveys, it was necessary to adopt the same object coordinate system in both the field and laboratory environments. Photo-control points common to both the field and laboratory surveys were used to compute the seven parameters of a 3D similarity transformation. Once these parameters were established, all laboratory photo-control points were transformed to the coordinate system used originally in the field. Data extracted and representing the cast could be then be directly compared with the original field data-set.

ACCURACY EVALUATIONS

Accuracy of the Moulding and Casting System

Fig. 4 represents an orthophotograph of the replicated cast derived from the DSC460 imagery. A simple comparison with the original image (Fig. 2) demonstrates how much detail the casting system is able to record and represent, to the extent that they appear virtually identical. However, the key research question is just how accurate is the surface morphology of the cast when compared with the original river bed? Fig. 5(a) is a colour map of elevation difference, derived by subtracting the river bed
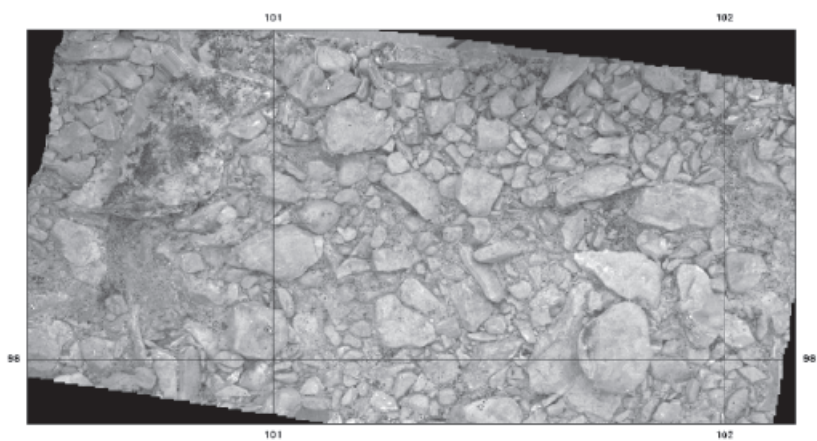
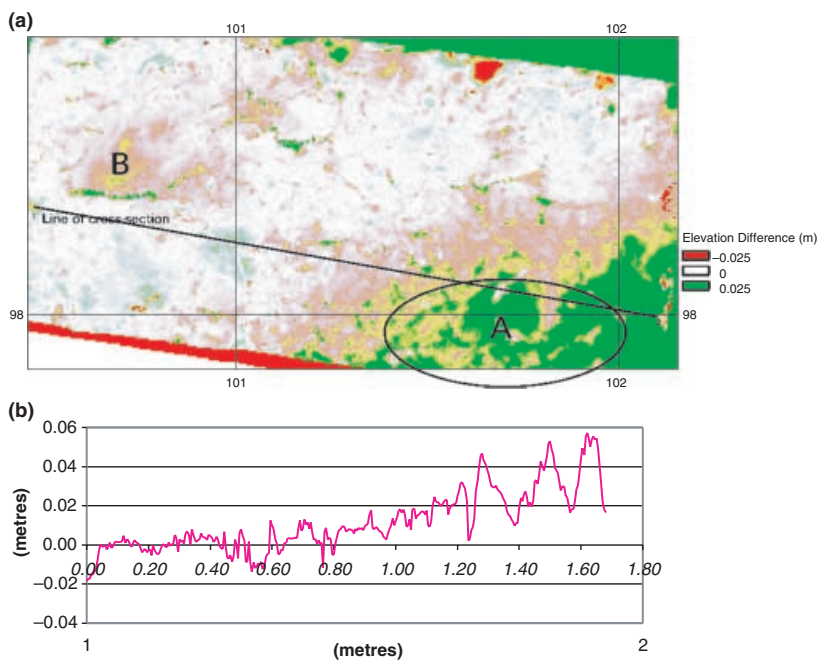FIG. 4. Orthophotograph of cast (derived using DCS460 imagery).

FIG. 5. DEM of difference (a) and transect (b) (River – Lab).

DEM from the cast DEM measured in the laboratory. Fig. 5(b) is just one cross section through this accuracy surface at the location marked in Fig. 5(a). Differences are comparatively small over larger areas, typically less than 3 to 5 mm, as depicted in the

left-hand side of the cross section. This suggests general conformity between the two surfaces and implies that the moulding and casting system has been both effective and broadly accurate. There are three type-regions where differences are more significant and these discrepancies need to be discussed and explained.

The largest area of difference is centred on the ellipse "A" (Fig. 5(a)) and identifiable towards the right-hand side of the cross section (Fig. 5(b)), where a systematic pattern exhibiting large differences up to 30 mm is apparent. These discrepancies had actually been identified during the establishment of the seven parameters of the 3D similarity transformation. The residual for one of the control points in the area, a target, had been 32 mm. It was assumed originally that this point had been perhaps knocked or displaced and was therefore excluded from the initial solution. However, the DEM of difference demonstrates that the discrepancies cover a much larger area than a localised target. Certainly some form of systematic error is present, either in the photogrammetry or the casting procedure. It was not possible to attribute this to the photogrammetry because the error was apparent in the control point residual prior to conducting any photogrammetric processing. The original casting in the field had been carried out in quite cold conditions (4°C) and the polyurethane foam had not expanded as much as was hoped. The foam performs a critical role because it provides the rigidity required by the flexibility of the moulding agent. It is believed that this lack of rigidity allowed a slight twisting in the mould during transportation from the field to the laboratory, which was then reflected in the constructed cast. The differences in elevation detected are consistent with this theory and steps have now been taken to reduce this effect in future applications. Without the quantification provided by the photogrammetric assessment it is unlikely that this weakness in the casting and moulding method would have been identified.

The second example where large differences are apparent is for a few individual points around the periphery of large particles (the stone located between 1·28 and 1·50 m, Fig. 5(b)). These small inaccuracies are due to the slightly differing camera positions, and are particularly apparent when recording high relief objects relative to flying height. This effect has been noted before (Butler et al., 1998, 2002) in a similar application. It is perhaps most familiar to photogramm-etrists in the context of generating DEMs and orthophotos in urban areas (Skarlatos, 1999) where area-based cross correlation techniques are particularly ineffective in providing accurate height estimates where there are sharp disconti-nuities in the surface created by buildings. The third type of discrepancy is apparent within the areas occupied by very large particles ("B", Fig. 5(a)), where there is a small systematic difference within the area defined by an individual particle. It is believed that these differences result from small distortions of the mould during the curing process of the epoxy resin, in the large holes in the mould that correspond to large clasts. The area covered by these imperfections is small and is only associated with the largest particles.

Despite these small and localised discrepancies, conformance is generally very high and certainly demonstrates the accuracy of the casting system and its appropriateness for hydraulic flume work. A useful method that can be adopted to rapidly identify differences in orthophotographs graphically, is to generate an animation. An animated sequence was derived from the orthophotographs of both the original river bed (derived from Fig. 2) and the laboratory cast (Fig. 4). This

animation is impossible to represent within a paper manuscript, but readers may access it at the following website: http://snap.lut.ac.uk/Jim/Images/ManifoldMovie.gif. The animation provides a graphical and powerful way of demonstrating the degree of conformance of the moulding and casting procedure.

Accuracy Comparison of the DCS460 and Olympus C3030

Additional imagery had been obtained in the field using a non-metric Olympus C3030 "compact" digital camera to assess whether far cheaper camera technology could deliver appropriate imagery for such photogrammetric comparisons. The restitution of the Olympus imagery adopted very similar processing steps to the DCS460 data-set. Initial results suggested poor accuracy, despite attempting a number of photo-configurations and calibration options provided by the OrthoBASE Professional software. The calibration options attempted included use of the three primary parameters of inner orientation and the 14 "Brown" parameters selected as weighted variables. Photo-configuration options utilised either two vertical images plus three oblique images or just the two vertical frames. Table IV summarises the accuracies of restitution, under these differing processing scenarios.

The total image unit weight suggests that the optimum restitution was achieved by using the second processing option. However, closer examination reveals that the rms error fit to the control in height was 4·8 mm, much larger than the first solution (2·8 mm). This option was derived using the full photo-configuration, combined with the 14 Brown and three primary inner orientation parameters. This is confirmed when the rms errors for the six independent check points are examined; here, the first solution achieved 2·9 mm in height compared with 13·0 mm with the alternative processing options. It would therefore appear that the first processing option is perhaps the "best", although such a decision depends on whether the total image unit weight or the rms error derived from the check points is perceived to be important.

If these results are compared with the accuracy of the DCS460 restitution (Table II), it is clear that the rms error fit to control, check point and total image unit weight are very much worse for the Olympus camera. The average accuracy achieved with the DCS460 for all ordinates is better than 1 mm (0·7 mm), whereas, for the Olympus, the average value is approximately 3 mm. If DEMs extracted using these various calibration options are analysed, then the same view is confirmed. Table V tabulates the rms error of the extracted DEM for the same check points using the differing processing options. This suggests that the initial configuration provides the optimal solution for this particular camera, but, when compared with the DCS460 (Table II, 1·9 mm), we can see that this is an order of magnitude worse.

TABLE IV. Rms error values of Olympus C3030 restitution.

Solution		Rms error control (mm) (8 points)			Rms error check (mm) (6 points)			Total image unit weight
Self-calibration method	Oblique (Y/N)	X	Y	Z	X	Y	Z	(μm)
Inner + Brown	Y	4·8	4·6	2·8	3·1	4·5	2·9	17·6
Inner + Brown	N	5·0	5·1	4·8	2·2	3·4	13·0	11·1
Brown	N	4·6	4·4	6·0	4·0	3·1	16·1	11·3

TABLE V. Rms error values of Olympus C3030 DEM at six check points.

Self-calibration method	Oblique (Y/N)	Elevation rms error (mm)
Inner + Brown	Y	12·6
Inner + Brown	N	12·9
Brown	N	17·4

Fig. 6 represents a colour surface of difference derived by subtracting the DEM created by the Olympus camera from the same surface obtained by the DCS460. This demonstrates the spatial variation of difference and confirms the poor rms error achieved using the limited number of check points. Two comments are appropriate. There appears to be a domed structure within the differences, which is consistent with poor modelling of the inner geometry of the Olympus camera. This type of "domed structure" has been seen before (Stojic et al., 1998) and although it is easy to surmise that such a surface arises from inadequacies in lens modelling, the author believes that other uncertainties in inner camera geometry can be responsible (Stojic et al., 1998). Superimposed upon this pattern are clear influences of individual large stones. It is suggested that the relative variation of relief at these locations is large, which emphasises the differences arising from the poor modelling of the camera.

The resolution of the Olympus camera is only marginally lower than the DCS460 (Table I) and it may be slightly surprising that accuracies achieved using the Olympus C3030 are so much worse than those achieved using the Kodak DCS460. However, the two cameras are of very different design and cost. The
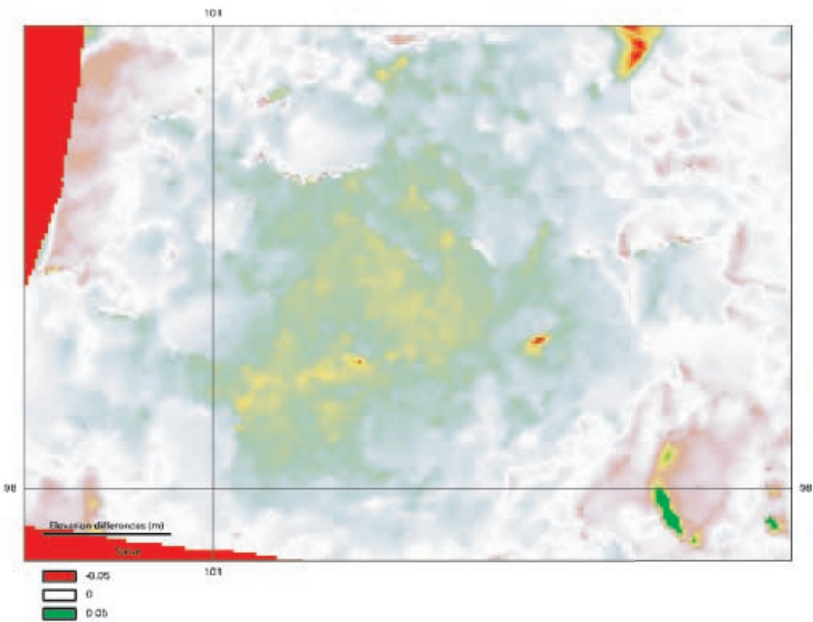

FIG. 6. DEM of difference (Kodak – Olympus).

DCS460 is built upon the rigid and expensive Nikon N90 camera body and utilises high-quality optical lenses designed for professional photography. In contrast, the Olympus C3030 is aimed at a non-professional market purely concerned with obtaining digital imagery for multi-purpose use, in which spatial measurement is not considered. There has been some concern expressed in the photogrammetric literature regarding the instability of the CCD array in the DCS460 (Shortis et al., 1998) but for extracting DEMs from a vertical perspective at the levels of accuracy of 1 to 2 mm, such systematic error sources are insignificant; a fact which has been confirmed before (Chandler et al., 2001). While the accuracies achieved using the Olympus C3030 may be certainly appropriate for some applications, such as extracting grain size distributions (Butler et al., 2001), the recommendation must surely be to use the DCS460, or cameras of similar design, if photogrammetric measurement is intended.

CONCLUSION

Data derived by digital photogrammetry to represent both an original river bed and a cast facsimile have demonstrated and quantified the accuracy of a river bed moulding and casting system. More significantly, analyses of these data-sets have helped to improve the method involved in the production of the original mould. Further tests using imagery derived using both a Kodak DCS460 and the Olympus C3030 have confirmed the higher accuracies achievable with mature, non-metric professional camera technology. It is suggested that "compact" digital cameras should only be used for photogrammetric measurement if proven cameras are unavailable and only in situations where lower accuracy can be tolerated.

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Résumé

On a utilisé la photogrammétrie numérique pour réaliser et essayer un systéme de formage et de moulage artificiel du lit d'un fleuve, qui permet aux cailloux à grains grossiers de ce lit d'être reproduits à des fins de recherche hydraulique en laboratoire, dans un canal d'amenée. Avec une caméra numérique non-métrique Kodak DCS 460 on a saisi à la fois l'imagerie du lit réel et celle de sa copie par le systéme; on a pu en dériver des modéles numériques des élévations et des orthophotographies que l'on a comparées ensemble pour évaluer la précision du systéme de formage et de moulage. L'analyse de ces essais comparatifs a permis de modifier et de développer ce systéme. On a saisi une imagerie supplémentaire sur le terrain, avec une caméra numérique non-metrique «compacte» Olympus C 3030, pour savoir si une caméra bien meilleur marché pourrait fournir les données recherchées dans de tels essais comparatifs. Les jeux de paramétres d'étalonnage interne et les données obtenues ont été comparées à ceux de la caméra Kodak DCS 460. On en a déduit qu 'il fallait placer les capteurs numériques sur le corps de caméras professionnelles de haute qualité, sur film 35 mm, pour pouvoir faire ces examens comparatifs et développer de tels systemes.

Zusammenfassung

Mit Hilfe der Digitalen Photogrammetrie wurde ein künstliches Modellierungssystem für ein Flussbett entwickelt und getestet. Dieses System erlaubt es, kleine Steine innerhalb eines grobkörnigen Flussbetts für hydraulische Forschungen in einem Lobor mit Strömungskanal oder Schwemmrinne wiederherzustellen. Mit einer nichtmetrischen Kodak DC460 Digitalkamera wurden Biulddaten von dem originalen Flussbett und der generierten naturgetreuen Abbildung erfasst, und digitale Höhenmodelle und Orthophotos abgeleitet und verglichen, um die Genauigkeit des Modellierungssystems zu beurteilen. Diese vergleichenden Untersuchungen waren für nderungen und Entwicklung des Systems entscheidend. Mit einer nichtmetrischen Olympus C3030 Kompaktdigitalkamera wurden zusätzliche Bilder im Feld erfasst, um festzustellen, ob deutlich preiswertere Kameratechnologie ebenfalls Daten für die vergleichenden Untersuchungen liefern kann. Innere Kalibrierdatensätze und Daten wurden mit Daten der nichtmetrischen Kodak DC460 verglichen. Die Tests machten deutlich, dass digitale Sensoren in Verbindung mit hochqualitativen professionellen 35mm Kamerakörpern erforderlich sind, um vergleichende Untersuchungen dieser Art durchzuführen und entsprechende Systeme zu entwickeln.