INFLUENCE OF VIDEO FRAME MISS-SELECTION ON THE ACCURACY OF MOVING OBJECTS 3D MEASUREMENTS USING CLOSE-RANGE PHOTOGRAMMETRY

Mostafa A-B Ebrahim, Assistant Professor
Civil Engineering Department
Faculty of Engineering, Assiut University
Assiut, EGYPT
Mostafa.Ebrahim@btinternet.com

ABSTRACT

Digital close-range photogrammetry became one of the most important measurements tools for the moving objects. To take measurements of moving objects, at least two images must be taken from different positions at the same instance. To take images at the same instant, two cameras must be connected together using special equipment to give the order to the camera once a button has been pressed. To avoid complication and to save money, two video cameras can be used from different positions. Once the movies are transferred to the computer, two images (one frame from each movie) can be selected as right and left images. Miss-selection of any of the frames or both will affect the 3D measurements accuracy. Theoretical analysis and practical test have been done to find out the influence of this miss-selection on the accuracy of the close-range photogrammetric 3D measurements for the moving objects using two video cameras from different locations.

INTRODUCTION

Close range photogrammetry has been proved to be one of the precise and fast 3D measurements techniques in both, the classic applications such as the industrial, engineering, and architectural applications and also in modern applications, such as GIS and mobile mapping (Farrag F. A. and Ebrahim M. A-B, 2003).

Digital photogrammetric systems are becoming increasingly popular and are on the verge of gaining more importance than analytical photogrammetric systems. Digital close range photogrammetry has matured to the extent that it can now serve as a precise and reliable technique for non-contact three-dimensional measurements (Ebrahim M. A-B, 1998). The ease and speed of data acquisition, the inherent on-line and even real time capabilities, the high degree of automation and the adaptability to varying requests have made it a readily available measurement tool for a great number of different applications in science, art and industry (Ebrahim M. A-B, 2004).

The term digital photogrammetry depends mainly on digital images. One of the most important digital images source is digital cameras that have a wide use in the field of digital close range photogrammetry. Using digital cameras saves a lot of time, as they are reliable and easy to use. Long way to get digital form of the printed photos is not needed any more. Only take the digital photos and transfer them to the computer. Digital images can be acquired in several ways (Atkinson, 1996). Digital image acquisition can be done efficiently by means of CCD array sensor of different size. CCD cameras produce very fast frequency of digital images for automated or semi-automated measurements (Peipe J, and Schneider C. T., 1995). When selecting a digital camera for photography, it is important first to consider the requirements for photography. Digital cameras have proved for close range photogrammetry, yielding accuracies comparable to metric film camera (Warner W. S. and Slaattelid B. R., 1997). Also, they have gained wide acceptance for high precision optical three dimensional measurements (Shortis M. R., Robson S. , and Beyer H. A., 1998).

Digital close range photogrammetry has been proved to be the most practical technical 3D measurement tool for the moving objects. To take 3D measurements for the moving objects, at least two photographs of the moving object from different locations must be taken. Using still cameras is common for such applications, but with special connection between/among the cameras to assure that the photographs have been taken at the same instance. This could be a big problem for the unprofessional or those have limited budge for the application. To solve the problem, using video cameras is recommended in such cases especially with the huge improvement of the digital video cameras production.

In the past, photogrammetry technology has relied on still images for use in obtaining three-dimensional data. However, photogrammetry technology has grown to incorporate video images. Digital video's capacity to incorporate single images at 30 frames per second, combined with automatic tracking of features that change between each frame, has made video a powerful tool for obtaining three-dimensional data from a two-dimensional source (William T.C. et al 2004).

Still video cameras are easy to handle, portable, digital image acquisition devices for close range photogrammetry. They allow fast object recording without being connected to a computer (Peipe J. & Schneider C. T. 1995).

A high resolution still video camera is ideally suited for these tasks due to its independence on external power supply, frame grabbing and storage devices. While the CCD cameras usually used in digital close range photogrammetry or machine vision applications require a local host computer for image acquisition and storage, a still video camera provides a completely autonomous digital image acquisition system (Hans-Gerd Maas and Thomas P. Kersten 1994). The uses of video cameras are widely used in the photogrammetric applications.

Gruen A. 1992 has presented a fully digital photogrammetric close range systems allow for on line or even real time processing of data. It gives access to a great number of new applications, especially in those cases where a moving object has to be dynamically recorded or a moving sensor has to be positioned and oriented in three dimensional space, as is the case in robotics.

Hans-Gerd Maas and Thomas P. Kersten 1994 reported practical experiences of the use of a high resolution still video camera in several projects. Bräger S. et al 1999 have developed a novel system combining stereo-photogrammetry and underwater-video to record dolphin group composition. The system consists of two downward-looking single-lens-reflex (SLR) cameras and a Hi8 video camera in an underwater housing mounted on a small boat. Page A. et al 2006 show the usefulness of video photogrammetry techniques in analyzing three-dimensional (3D) motions in the undergraduate physics laboratory. Using video data, recorded from a couple of synchronized cameras, and adequate data processing software, the main features of 3D movement such as spatial trajectory, velocity and acceleration may be accurately measured. Also, Page A. et al 2007 presented a technique based on 3D video photogrammetry for analyzing rigid body kinematics. Joshua S. Greenfield, 1993 mentioned that the Transportation Center at New Jersey Institute of Technology has developed a video-photogrammetry setup for collecting traffic data needed to analyze weaving under non-freeway conditions. Two video cameras were mounted on top of two vans, videotaping the traffic of a weaving section. The setup produces a stereo image of the traffic at any given time. William T.C. et al 2004 introduced video racking photogrammetry as a new tool in gathering accident scene and roadway data. The video tracking photogrammetry technique makes it possible to use accident scene video to record the accident scene geometry by incorporating photogrammetry principles.

Several software packages are available on the market that will create three-dimensional camera movement and calibration from video. These software packages make it easier to add computer-generated objects to live camera footage in 3D animation packages by creating a virtual camera that matches the physical one that took the shot. The process the software goes through to get this camera movement requires a three-dimensional point cloud to be generated of objects in the video scene (William T.C. et al 2004).

Tzivanaki, K. et al 2001 explore the application of modern digital video-photogrammetry to the measurement of surface waves. The method involves acquisition of simultaneous, overlapping images of the water surface. These images are acquired by two carefully aligned video cameras located at a fixed position over the water surface. Existing video camera technology routinely achieves temporal resolution as high as 1/30 of a second. Jordan P et al 2001 have developed a system for the measurement of three-dimensional deformations of horse hooves under different load conditions. They have concluded that off-the-shelf hardware components as standard video cameras and a low-cost software package for the photogrammetric evaluation of the image data offer a convenient tool to measure deformations of the horn hoof capsule under different load condition with a suitable accuracy.

Digital video cameras have been used as a component of a mobile mapping system for images acquisition system which consists also of two GPS receivers, a notebook computer, and a sound frame synchronisation system mounted on and put in a van (Ebrahim M. A-B and Khalil R., 2008).

Siggraph 2003 also presented several papers on the development of video photogrammetry and its ability to generate 3D data simply from video.

Video movies are kind of computer animation. Computer animation formats have been around for several years. The basic idea is that of the flip-books you played with as a kid. Rapidly display one image superimposed over another to make it appear as if the objects in the image are moving. Very primitive animation formats store entire images that are displayed in sequence, usually in a loop. Slightly more advanced formats store only a single image, but multiple color maps for the image. By loading in a new color map, the colors in the image change and the objects appear to move. Advanced animation formats store only the differences between two adjacent images (called frames) and update only the pixels that have actually changed as each frame is displayed. A display rate of 10-15 frames per second is typical for cartoon-like animation. Video animation usually require a display rate of 20 frames per second or better to produce a smoother motion (Ebahim M. A-B and Al-Sonbaty A.A., 2008).

The accuracy of the digital cameras is depending on some factors such as the camera mark and the used resolution. To obtain the best accuracy of digital camera, a calibration of the used camera must be done or a self calibration must be taken into consideration during the photogrammetric solution (Ebrahim M. A-B. 2004).

To obtain accurate 3D measurement for a moving object, a precise selection of the right and left images frames must be done. Miss-selection of any of the right or/and left image will certainly leads to inaccurate 3D measurements of the moving object.

This research has been carried out to find out how much the miss-selection of the images frames will affect the 3D measurements accuracy.

Accuracy is an important element in the world of measurements. It has been defined in several textbooks and articles as the degree of conformity or closeness of a measurement to the true value. Accuracy includes not only the effects of random errors, but also any bias due to incorrect systematic errors. If there is no bias, the standard deviation can be used as a measure of accuracy (Mikhail E and Gracie G., 1981). Also, it is defined as the degree of conformity with a standard ("The Truth").
Accuracy can be evaluated by using one of the following two methods (Hottier, 1976):

- Check measurements.
- The accuracy predictor.

In the first method, the photogrammetric results are compared with the results obtained from a more accurate measuring procedure. The accuracy predictor is a theoretical way to evaluate a system using its main parameters. If check points are available in the object space, the root-mean-square (RMS) error of photogrammetrically determined target point co-ordinates can be used as an accuracy measure (Fraser, 1990 and Hottier, 1976).

The procedures of evaluating accuracy in digital close range photogrammetry are common and well known. To evaluate the accuracy in digital close range photogrammetry field measurements that can be compared with those measurements obtained from the photogrammetric application must be given. The field measurements usually are accurate (up to a certain limit). This accuracy depends on the used instruments and on the mathematical models used to calculate the 2D or 3D co-ordinates. Brief definitions of the accuracy and how it can be achieved in the photogrammetric works have been mentioned by Ebrahim M. A-B, 2000. There are a lot of studies that have been carried out about photogrammetric measurements' accuracy by the author, for example; Hanke K and Ebrahim M. A-B 1997, Ebrahim M. A-B, 1999, Ebrahim M. A-B, 2000, and Ebrahim M. A-B, 2005.

THEORITICAL ANALYSIS

A theoretical analysis has been done to illustrate the effect of miss-selection of image frame(s) on the 3D measurements of a moving object from different camera locations. Figure (1) shows four camera locations, three object positions and the intersection points of the sight rays from each case.

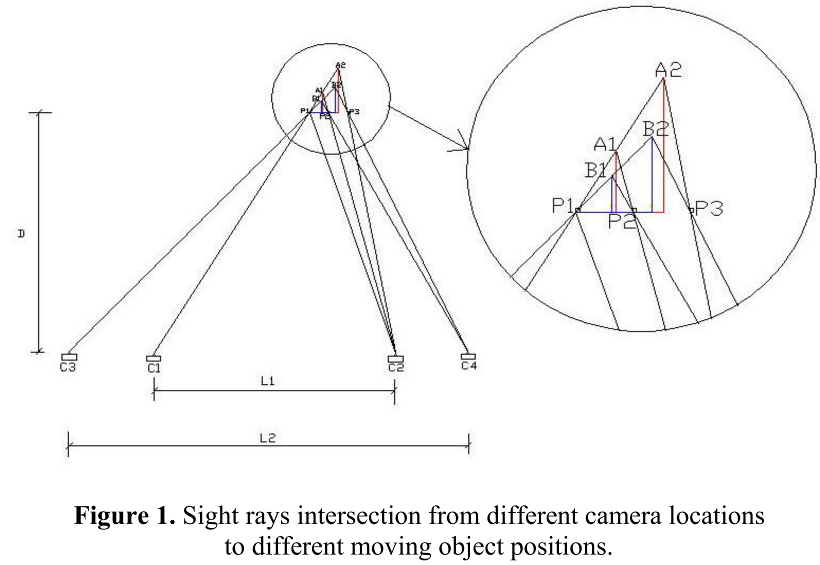


Figure 1. Sight rays intersection from different camera locations to different moving object positions.

It is clearly seen from figure (1) the following cases:

1. Camera locations at C1 & C2 (Base distance L1); moving the object from P1 to P2 has caused miss-location of the sight rays intersection from point P1 to point A1. While if the object moved to P3, the sight rays intersection will be at point A2. It is clear that the errors are increasing with moving the object away of its original position.

2. Camera locations at C3 & C4 (Base distance L2); moving the object from P1 to P2 has caused miss-location of the sight rays intersection from point P1 to point B1. While if the object moved to P3, the sight rays intersection will be at point B2. It is clear also that the errors are increasing with moving the object away of its original position.

It can be noted that as the object moves the sight ray intersections is moved away of its original position. That means miss-selection of image(s) frame(s) will lead to inaccurate 3D measurements. Also, the errors in case 2 are less that that of case 1 in both directions X & Y. This because the base line in case 2 (L2) is bigger than the base line in case 2 (L1). The relationship between the base line/object distance and the measurements accuracy has been studied in intensively by Ebrahim M. A-B 1992.

To find out the theoretical effect of miss-selection of the image(s) frame(s) on the accuracy of the moving object 3D measurements, the following exercise has been done.

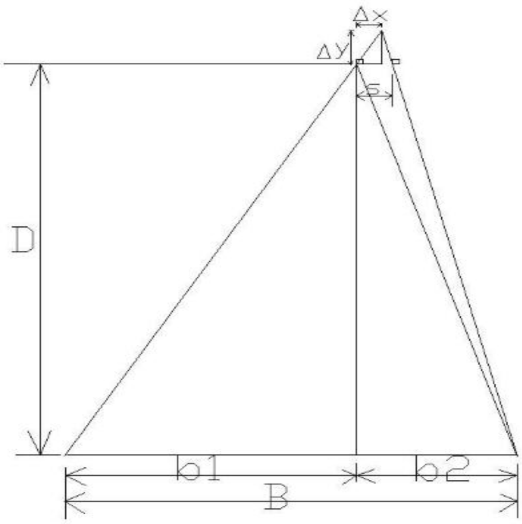


Figure 2. Horizontal errors in point locations due to object moving.

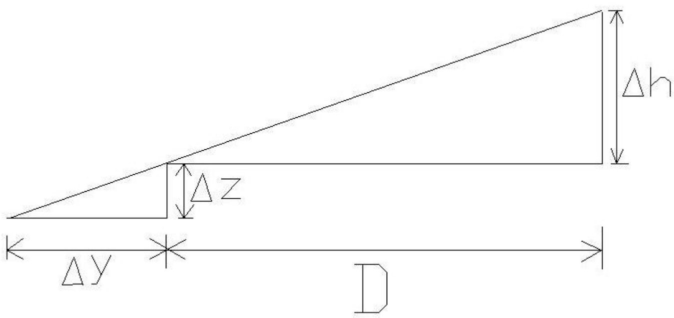


Figure 3. Vertical errors in point locations due to object moving.

In figure (2), the object moved from its original position to the new position by a distance equal to (S) which caused errors in the sight ray intersection ΔX & ΔY in both directions X & Y.

From figure (2) it can be found that:

$\Delta X/b1 = \Delta Y/D$
$\Delta Y/(\Delta Y+D) = S/B$
So, $\Delta Y \,.\, S + D \,.\, S = \Delta Y \,.\, B$
$\Delta Y\,(B - S) = D \,.\, S$
$\Delta Y = D \,.\, S / (B - S)$ ………………………………………….(1)

$\Delta X/\Delta Y = b1/D$
$\Delta X = S \,.\, b1 / (B - S)$ ………………………………………..…...(2)
From figure (3), it can be found that:

$\Delta Z/\Delta Y = \Delta h/D$

So, $\Delta Z = \Delta h \,.\, S / (B - S)$ ……………………………………….…(3)

From equations (1), (2), and (3) it can be concluded that the errors in the 3D measurements due to object movement are depending on the object distance (D), the object movement distance (S), the base line (B), the distance of the left camera from the perpendicular line to the base line (b1), and the average of the differences of the cameras levels and the object level (Δh).

From the above, it can be noted that the cameras configuration is very important to minimize the errors. Also, the object movement speed is influencing in the errors ΔX, ΔY, and ΔZ as distance (S) is equal speed multiplied by the time. The time is fixed as the camera frame speed rate is fixed to a certain amount which means that the object speed is a main factor affecting in the errors.

PRACTICAL TEST

Along with the above theoretical analysis, a practical test has been done to find out the influence of miss-selection of the image(s) frame(s) on the 3D measurements accuracy according to different object speeds.

Ebrahim M. A-B and Farrag F. 2001 have proved that the CAD environment (3D Studio software) can be an excellent tool for accuracy studies. The CAD environment has a wide use in close range photogrammetry. Kraus K. 1997 mentioned, "A representation of the object surface based on edges and points is indeed possible and usable in CAD-system". There are a lot of researches that involved in using the CAD system in photogrammetry. For example: Ebrahim M. A-B, 1998 used both AutoCad and 3D studio software to proof the digital projector approach. Coppola, F. et al 2000 has used both AutoCAD and 3D Studio as a CAD environment to display volumes as solids, rendering, and animation of the object. Vogtle, Th. and Steinle, E. 2000 used CAD environment to visualize objects in 3D city models.

With the great progress of the computer science, there are additional tools that enable to make accuracy studies easier and more efficient. CAD environment is a very suitable tool for such studies. Using such kind of software will enable to obtain an accurate 3D model without any field measurements. In this case, point's co-ordinates can be obtained directly from the model because the object with its accurate 3D dimension is available in the computer. To do the foresaid practical test, a computer Lorry model simulation has been done through CAD environment using 3D studio max software.

In fact, 3D Studio software is designed to enable numerous creative professionals to work on specific aspects of the same project while easily combining discrete elements into complex shots, animations, or game levels. There are some works through 3D Studio software must be done to have the photographs that will be used in this study. These works are:

- Create a test field model.
- Define a camera.
- Configure the cameras.
- Render the scene each time using a camera position.

Two video movies have been filmed by two video cameras configured to the left and right of the moving Lorry (object).

Space Coordinates System

A right hand Cartesian coordinates system was used to represent the object space coordinates in case of the theoretical and the practical studies. The X-Axis is horizontal while the Y-Axis is perpendicular to the X-axis and the two axes lie in the horizontal. The Z-Axis is vertical and normal to the X-Y plane.

The Test Field

The created computer test field is a kind of Lorry shape with 75 check points lying on left-lower corner of 75 posts arranged on the Lorry body. The check points arranged in rows and columns spaced 50 & 100 cm respectively. The check points heights are vary from 50 to 150 cm. Twenty two control points have been arranged around the Lorry precise photogrammetric solution. Figure (4) and figure (5) show the computer test field model and the check points arrangements respectively.

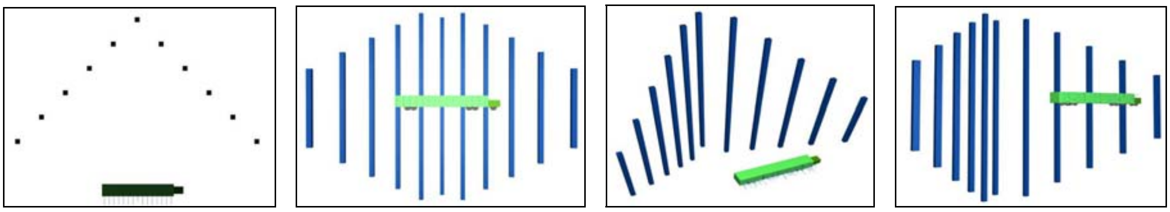
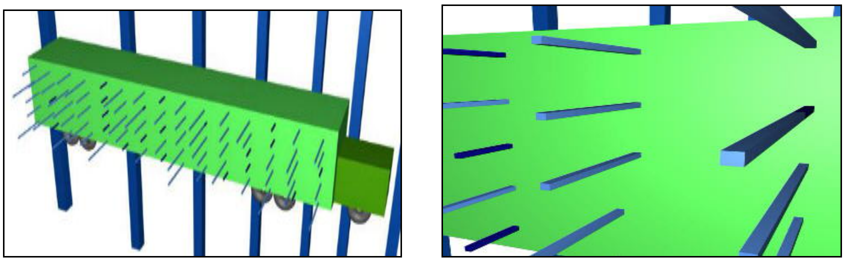


Figure 4. The computer test field model.



(a) General (b) Detailed

Figure 5. Points arrangements.

Obtaining the Photographs

Two target video cameras were used throughout this test that configured for the best frames through out the Lorry moving and to include most of the control points. Also, the cameras configured to give the best 3D measurements accuracy with the right images frames selections (Figure (6)). Two video movies were filmed from each video camera for the moving Lorry with several Lorry speeds. The lorry speeds were 30, 36, 45, 60, 90, 180 Km/h. The filmed movies were opened using Windows Movie Maker software to select the images frames. One image frame was selected from the left movie and six images frames were selected from the right movie. One of the six images frames was the right frame and the other five were shifted frame by frame. Figure (7) shows some samples of the selected images frames.

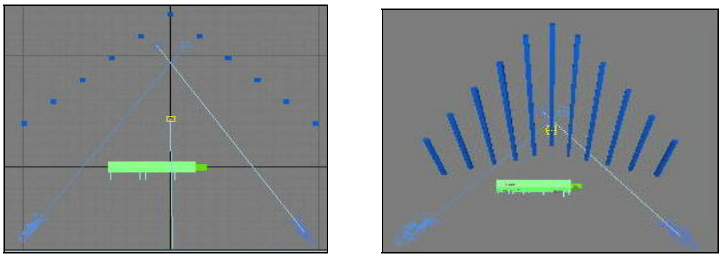
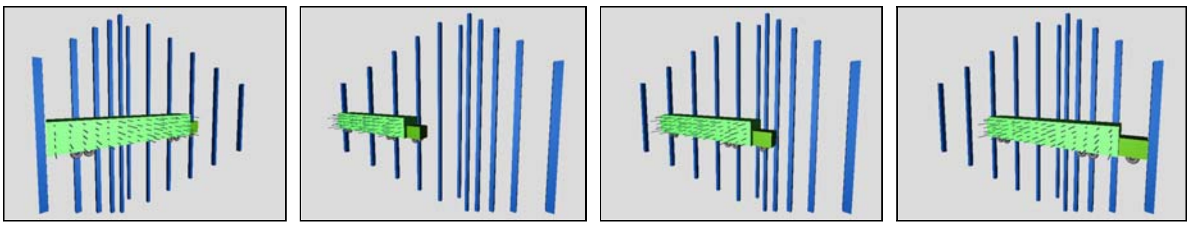


Figure 6. Camera configuration.



Left photos Sample of the right photos

Figure 7. Obtained Photographs.

Photogrammetric Solutions

Common Photogrammetric software has been used to carry out the photogrammetric solution. The images of each case were imported to the software. The points were marked in the left image and referenced in the other image. A run for the images of each case was done and the space coordinates were obtained in the form X, Y, and Z coordinates. The obtained space coordinates from the photogrammetric solution were compared with those from the original computer model.

It is known that the photogrammetric works concerning the steps to be done to obtain object co-ordinates or other desired results by using the photogrammetric technique. In this study the following steps have been photogrammetrically done:

- Importing the photographs into the used photogrammetric software.
- Marking the object points in the tested photographs (the left-lower corner of the post's top).
- Photogrammetrically solving for the chosen photographs.
- Marking the residual error for the obtained points' co-ordinates.
- Readjusting the marked points.
- Solving the photographs once again for final solution.
- Exporting the object points' co-ordinates in ASCII format.

The previous steps have been done for the different Lorry speeds and shifted. Sixty six cases have been studied to obtain the accuracy for each case.

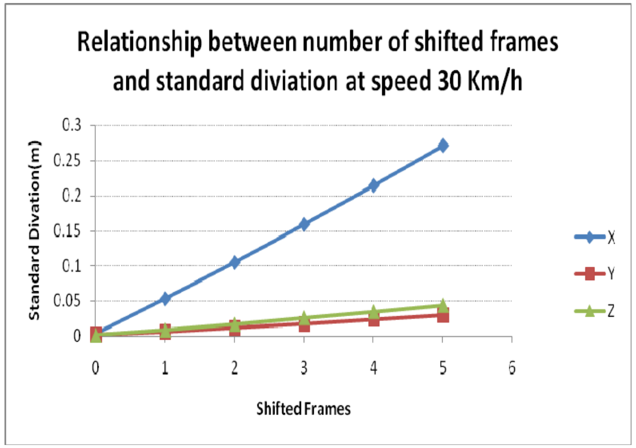
RESULTS

The results are a kind of the standard deviation of the errors in X, Y & Z directions. The results have been arranged and tabulated to draw the relationships of the factors affecting the accuracy for further analysis.

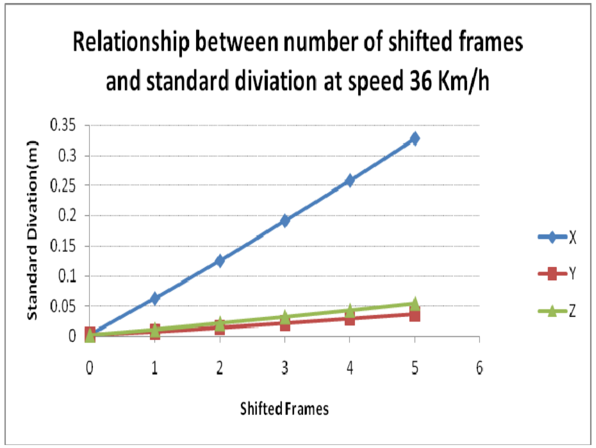
Table 1. Relationships of the factors affecting the accuracy

Speeds	Shifts	St. Div.		
		X	Y	Z
30	0	0.002421	0.001248	0.001462
	1	0.052993	0.005946	0.008634
	2	0.104633	0.011665	0.016911
	3	0.158865	0.01719	0.026001
	4	0.214307	0.023497	0.034804
	5	0.271535	0.029707	0.044164
36	0	0.002065	0.001467	0.00146
	1	0.062833	0.006895	0.010438
	2	0.125089	0.013704	0.020815
	3	0.191577	0.020802	0.031184
	4	0.258335	0.028341	0.042209
	5	0.328186	0.035861	0.053627
45	0	0.001979	0.001111	0.001159
	1	0.078715	0.00876	0.012718
	2	0.158473	0.017573	0.025722
	3	0.242175	0.026725	0.039588
	4	0.327998	0.036212	0.053489
	5	0.417564	0.046062	0.068345
60	0	0.001734	0.001255	0.001127
	1	0.105564	0.011818	0.017135
	2	0.21419	0.023822	0.034944
	3	0.328781	0.036522	0.053799
	4	0.448179	0.049685	0.073414
	5	0.573134	0.063474	0.094048
90	0	0.00191	0.001198	0.002271
	1	0.159104	0.017677	0.026074
	2	0.327487	0.036349	0.053699
	3	0.507449	0.056375	0.083424
	4	0.698965	0.077654	0.114923
	5	0.902296	0.100479	0.148645
180	0	0.0016	0.001147	0.001219
	1	0.330695	0.03643	0.054115
	2	0.706854	0.077943	0.11583
	3	1.135038	0.126137	0.186461
	4	1.616958	0.180894	0.266613
	5	2.150555	0.242648	0.355908

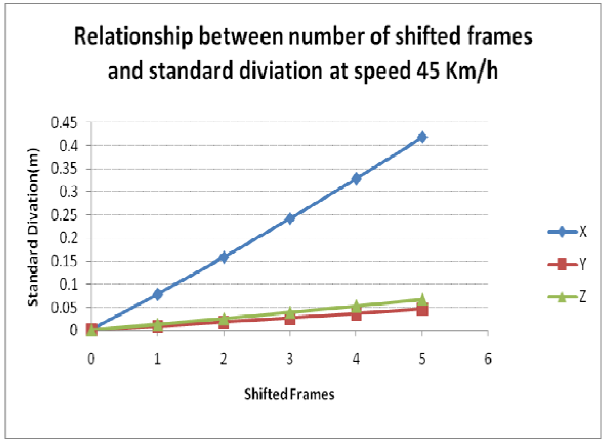
Shifts	Speeds	St. Div.		
		X	Y	Z
0	30	0.002421	0.001248	0.001462
	36	0.002065	0.001467	0.00146
	45	0.001979	0.001111	0.001159
	60	0.001734	0.001255	0.001127
	90	0.00191	0.001198	0.002271
	180	0.0016	0.001147	0.001219
1	30	0.052993	0.005946	0.008634
	36	0.062833	0.006895	0.010438
	45	0.078715	0.00876	0.012718
	60	0.105564	0.011818	0.017135
	90	0.159104	0.017677	0.026074
	180	0.330695	0.03643	0.054115
2	30	0.104633	0.011665	0.016911
	36	0.125089	0.013704	0.020815
	45	0.158473	0.017573	0.025722
	60	0.21419	0.023822	0.034944
	90	0.327487	0.036349	0.053699
	180	0.706854	0.077943	0.11583
3	30	0.158865	0.01719	0.026001
	36	0.191577	0.020802	0.031184
	45	0.242175	0.026725	0.039588
	60	0.328781	0.036522	0.053799
	90	0.507449	0.056375	0.083424
	180	1.135038	0.126137	0.186461
4	30	0.214307	0.023497	0.034804
	36	0.258335	0.028341	0.042209
	45	0.327998	0.036212	0.053489
	60	0.448179	0.049685	0.073414
	90	0.698965	0.077654	0.114923
	180	1.616958	0.180894	0.266613
5	30	0.271535	0.029707	0.044164
	36	0.328186	0.035861	0.053627
	45	0.417564	0.046062	0.068345
	60	0.573134	0.063474	0.094048
	90	0.902296	0.100479	0.148645
	180	2.150555	0.242648	0.355908



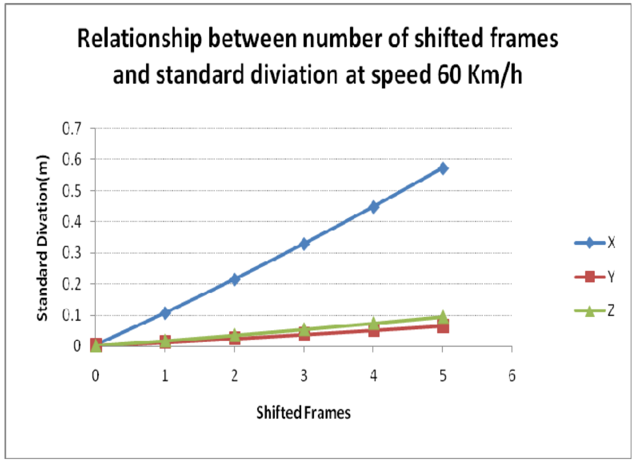
(a)



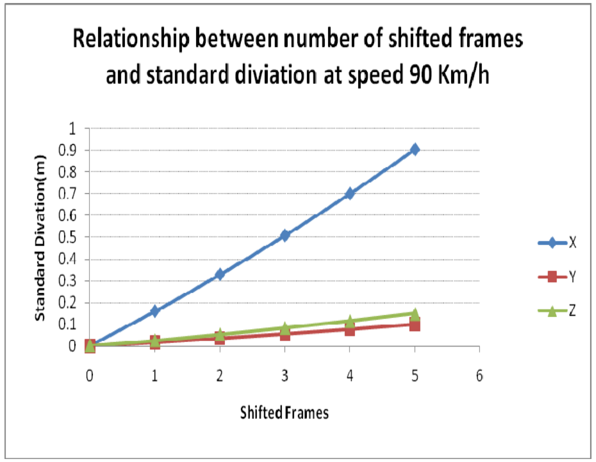
(b)



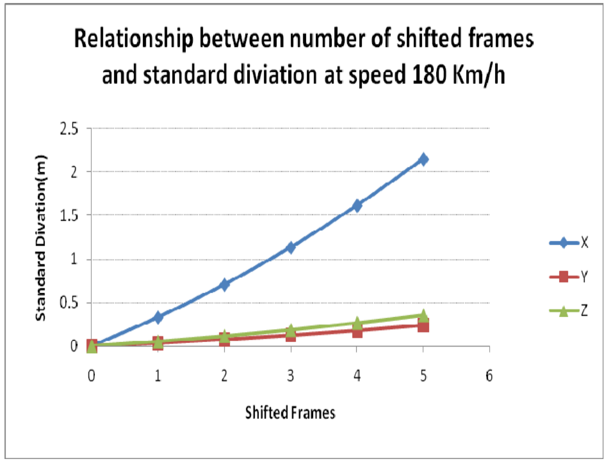
(c)



(d)

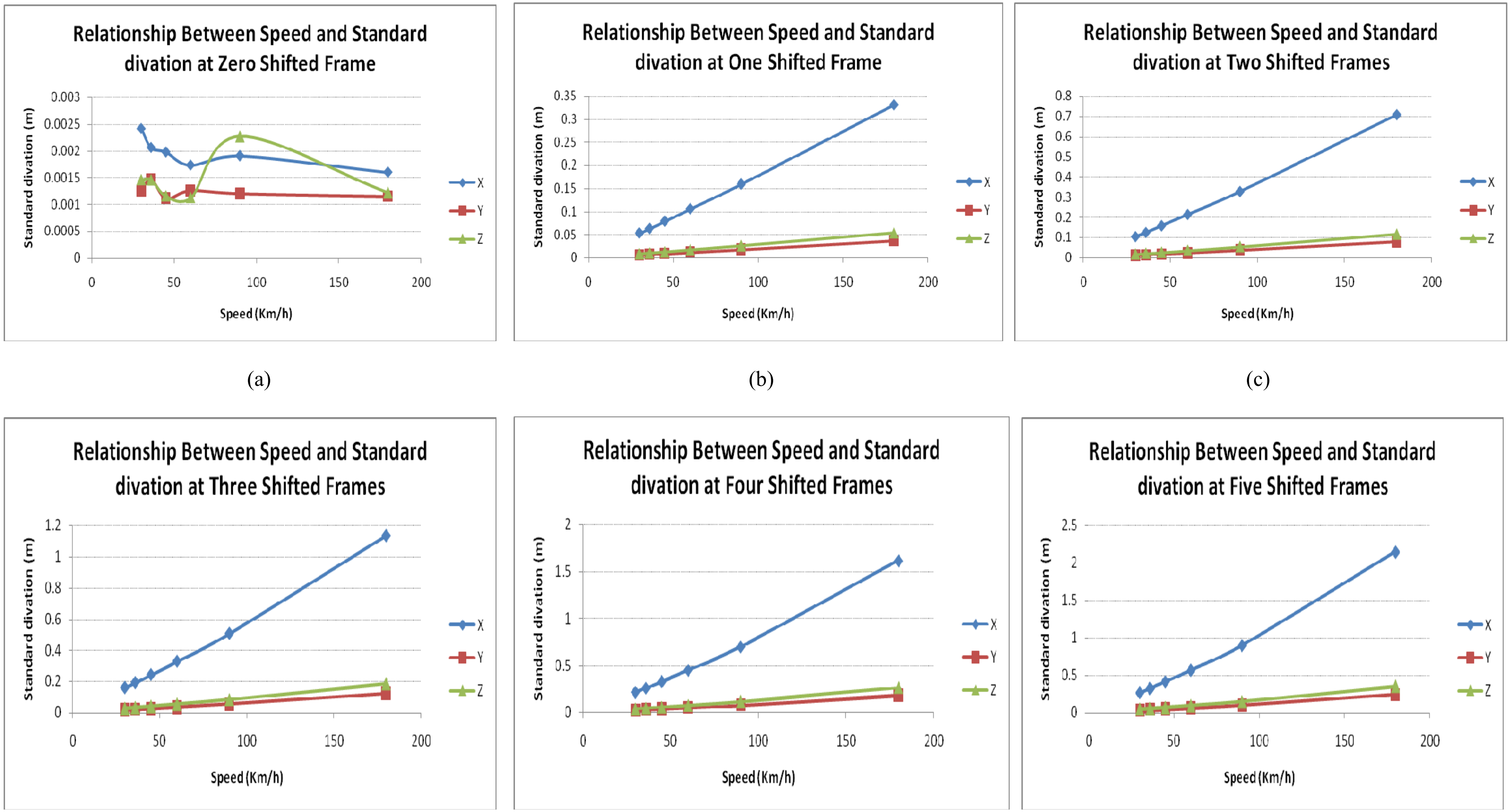


(e)



(f)

Figure 8. Relationship between the shifted frames and the standard diviation according to different object speeds for X,Y & Z directions.



(a) (b) (c)

(d) (e) (f)

Figure 9. Relationship between the object speeds and the standard diviation according to different shifted frames for X,Y & Z directions.

ANALYSIS

The results were drawn in curved line chart as shown above to show the relationship between the different factors affecting the 3D measurements accuracy. Figure (8) shows the relationship between the shifted frames and the standard diviation according to different object speeds for X,Y & Z directions. Figure (9) shows the relationship between the object speeds and the standard diviation according to different shifted frames for X,Y & Z irections. Also figure (10) hereunder shows the relationship between the object speeds and the standard diviation for X,Y & Z directions.

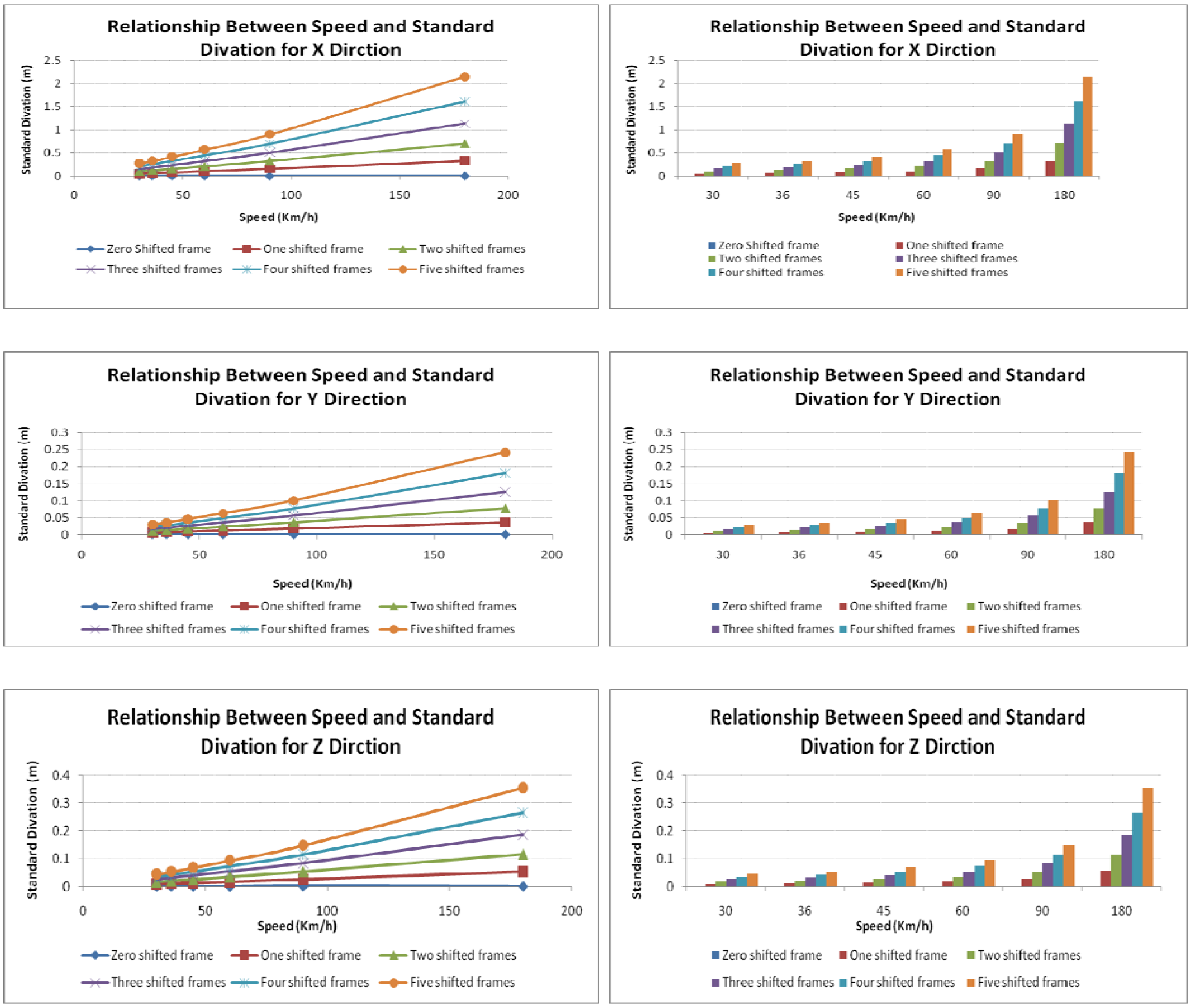


Figure 10. Relationship between the object speeds and the standard diviation for X,Y & Z directions.

From figure (8) it can be noted that with increasing of the shifted frames, the accuracy is decreased. The value of decreasing the accuracy is increasing with the increase of the object moving distance (S) in figure (2) which reflected in the object speed. These relationships are complying with the theoretical analyses that have been done herein. The relationships in figure (8) assure that as the miss-selection of the image frame moves away of the right frame the accuracy of the 3D measurements become worse. The values of accuracy decreasing in X direction is more than that in both Y & Z directions. This result is normal as the standard deviation of the X values is affected directly by the object moving speeds in the form of the object moving distance (S) and the distance of the points from the left camera location in the direction of the base line. This, of course, effect directly and by a huge magnitude in the X measurements accuracy while the accuracy of Y direction is affected by the moving object speed and the object distance which is fixed for all points. In case of the accuracy of Z direction, it affected also by the moving object speed and the difference between the camera level and the points levels which are fixed too.

Also, from figure (9), the speed of the object is affecting strongly in the 3D measurements accuracy. It can be noted from chart (a) that the values of the standard deviations are random and very low because it is for the zero shifted frame which means it came from the right frames. As the miss-selection of the frames is increased, the accuracy of the measurements in all directions, X, Y, & Z, are decreased. It can be noted that the accuracy of the measurements in X direction is lower than the other directions for the same reasons as above.
From figure (10), it is clear from both chart types (Curved lines and columns) that as the object moving speed increases the accuracy of 3D measurements decreased especially for X direction. The decrease of the 3D measurements accuracy is decreasing with the increase of the miss-selection of the images frames.

CONCLUSION

Using video cameras in photogrammetric 3D measurements is an important image acquisition tool. To obtain accurate 3D photogrammetric measurements from video cameras, extra care must be taken to avoid any decrease in the 3D measurements accuracy due to miss-selection of the images frames.

A theoretical analysis and practical test have been done through this research to find out the influence of the miss-selection of the images frames on the 3D measurements accuracy. The study shows that not only the miss-selection of the images frames is affecting the accuracy but also the moving object speed and the cameras configuration are became additional factors affecting in the accuracy of the 3D measurements due to the miss-selection of the images frames.

To decrease the influence of the miss-selection on the 3D measurements, the used video camera must have high frame speed rate to decrease the moving object distance (S) if any miss-selection of the image frame has happened. Also, extra care must be taken especially with the high speed objects.

REFERENCES

Atkinson, K.B., 1996. *Close Range Photogrammetry and Machine Vision*, Whittles Publishing.

Bräger, S., A. Chong, S. Dawson, E. Slooten and B. Würsig, 1999. A combined stereo-photogrammetry and underwater-video system to study group composition of dolphins, *Helgoland Marine Research*, Springer Berlin / Heidelberg, Volume 53, Number 2 / November, 1999, pp. 122-128.

Coppola, F., M. Brutto, P. Midulla, and B. Villa, 2000. Urban 3-D models for planning of mobile telephony systems, *International Archives of Photogrammetry and Remote Sensing*, Vol. XXXIII, Part B3, Amsterdam.

Ebrahim, M. A-B., 1992. Using Close Range Photogrammetry for Some Engineering Applications", M. Sc. Thesis, Assiut University, Egypt.

Ebrahim, M. A-B., 1998,. Application and Evaluation of Digital Image Techniques in Close Range Photogrammetry, Ph.D. Dissertation, Innsbruck University, Austria.

Ebrahim, M. A-B., 1999. Effect of The Images Resolution on The Accuracy Of 3-D Measurements in Digital Close Range Photogrammetry, The Third International Conference on Civil and Architecture Engineering, the Military Technical College, Egypt.

Ebrahim, M. A-B., 2000. Determination of the Islamic Art Accuracy by Using Digital Close-Range Photogrammetry, ISPRS Congress, Amsterdam.

Ebrahim, M. A-B. and F. Farrag, 2001. Using CAD as a new technique in digital close range photogrammetry for accuracy studies, *Faculty of Eng. Journal*, Al-Azhar University, July.

Ebrahim, M. A-B., 2004. Using mobile phone digital cameras in digital close range photogrammetry, *The Photogrammetric Journal of Finland*, Vol 19, No.1.

Ebrahim, M. A-B., 2005. Studying the Effect of Some Image Enhancement Features on the Accuracy of Close Range Photogrammetric Measurements Using CAD Environment, the FIG 8th International Conference on the Global Spatial data, Semiramis Intercontinental Cairo, April 2005.

Ebrahim, M. A-B., 2006. 3D aource for Egyptian monument information system, *GIS Development Middle East Magazine*, June 2006.

Ebrahim, M. A-B. and R. Khalil, 2008. New Mobile Road Mapping System Using Digital Sensors, Integrating Generations, FIG Working Week, Stockholm, Sweden, 14-19 June 2008.

Ebrahim, M. A-B. and A.A. Al-Sonbaty, 2008. Space Coordinates of Computer Models Details Using Digital Close-Range Photogrammetry, Integrating Generations, FIG Working Week, Stockholm, Sweden, 14-19 June 2008.

Farrag, F.A. and M. A-B. Ebrahim, 2003. Digital photogrammetric analysis of stereo images obtained by zoom lenses, *Faculty of Eng. Journal*, Al-Azhar University, October 2003.

Fraser, C.S., 1990. Film Unflatness Effects in Analytical Non-metric Photogrammetry, ACSM-ASPRS Annual Convention, Vol. 5.

Gruen, A. 1992. Tracking moving objects with digital photogrammetric systems, *Photogrammetric Record Journal*, Volume 14, Issue 80, pp. 169 - 387 (October 1992).

Hanke, K. and M. Ebrahim, 1997. A low Cost 3D-Measurement Tool for Architectural and Archaeological Applications, International SIPA Symposium, Goeteborg, Sweden.

Hans-Gerd, Maas and T.P. Kersten, 1994. Experiences with a high resolution still video camera in digital photogrammetric applications on a shipyard, *ISPRS Intercongress Symposium*, Melbourne, Australia, March 1-4, 1994 IAPRS, Vol. 30, Part V, pp. 250-255.

Hottier, Ph., 1976. Accuracy of close range analytical restitution: Practical experimental and prediction, *Photogrammetric Engineering and Remote Sensing*, 42(3).

Jordan, P., J. Willneff, N. D'Apuzzo, M. Weishaupt, T. Wistner, and J. Auer, 2001. Photogrammetric measurement of deformations of horse hoof horn capsules, Videometrics and Optical Methods for 3D Shape Measurement, *Proceeding of SPIE*, San Jose, California, Volume 4309, pp. 204-211.

Joshua, S. Greenfield, 1993. Applications of video-photogrammetry for transportation studies, American Congress on Surveying and Mapping (ACSM); American Society for Photogrammetry and Remote Sensing (ASPRS).

Kraus, K., 1997. *Photogrammetry: Advanced Methods and Applications*, Vol. 2, 4th edition, Ferd. Duemmlers Verlag, Bonn.

Mikhail, E. and G. Gracie, 1981. *Analysis and Adjustment of Survey Measurements*, Van Nostrand Reinhold Company.

Page, A., P. Candelas, and F. Belmar, 2006. Application of video photogrammetry to analyses mechanical systems in the undergraduate physics laboratory, *European Journal of Physics*, April 2006, Volume 27, No. 3, pp. 647-655.

Page, A., P. Candelas, and F. Belmar, and H. DeRosario, 2007. Analysis of 3D rigid-body motion using photogrammetry: A simple model based on a mechanical analogy, *American Journal of Physics*, Volume 75, No. 1, pp. 56-61.

Peipe, J. and C.T. Schneider, 1995. High resolution still video camera for industrial photogrammetry, *The Photogrammetric Record Journal*, Volume 15, No. 85, April 1995, pp. 135-139.

Pollefeys, Mark, 2003. Video Photogrammetry, *SIGGRAPH*, 2003.

Shorties, M.R., S. Robson, and H.A. Beyer, 1998. Principal point behavior and calibration parameters models for Kodak DCS cameras, *Photogrammetric Record*, Vol. 16, No. 92, pp. 165-186.

Tzivanaki, K., E. Tournas, and R.J. Sobey, 2001. Wave measurement by digital video-photogrammetry, *Procs., PACON 2001*, Burlingham, pp. 244-247.

Vogtle, Th. and E. Steinle, 2000. 3D modelling of buildings using laser scanning and spectral information, *International Archives of Photogrammetry and Remote Sensing*, Vol. XXXIII, Part B3. Amsterdam.

Warner, W.S. and B.R. Slaattelid, 1997. Multiplotting with images from The Kodak DCS420 digital camera, *Photogrammetric Record*, Vol. 15, No. 89, pp. 665-672.

William, T.C., Neale, S. Fenton, S. McFadden, and N.A. Rose 2004. A Video Tracking Photogrammetry Technique to Survey Roadways for Accident Reconstruction, SAE International, SAE World Congress, Detroit, Michigan, March 8-11, 2004.