CLOSE RANGE PHOTOGRAMMETRIC MAPPING OF SEA WAVES FOR BETTER HARBOR DESIGN

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ABSTRACT

This research study includes platform design and image correlation to obtain a suitable cloud of points which will represent the sea wave surface in three dimensions, by applying close range Photogrammetry methods. The synchronization of two digital cameras for obtaining simultaneous stereo exposures is discussed and analyzed. Periodical experiments involving the wave entrance into the harbor, the wave propagation and the wave strike and reflection due to the existence of sea walls is to be analyzed. Monitoring of the potential wave spectrum energy distribution, within the harbor basin, is also studied through this research.

KEYWORDS: close range Photogrammetry, image correlation, 3-D wave mapping, harbor design

INTRODUCTION

Seawaves affect many environmental, industrial, economic and planning functions and their detail behavior is necessary to be known in order to face corresponding problems. Subsequently, many processes are affected by seawave energy such as, coastal erosion, harbor design, ship building, tourism, coastal planning, etc. Seawaves are dynamic bodies of water and a fundamental parameter of their behavior is their three dimensional shape at specific time intervals. The importance of sea wave measurement and actually the estimation of the significant sea wave height incorporates two significant issues. The first one has to do with the efficiency of harbor design in terms of cost benefit ratios and the second one includes the validation of sea wave propagation models (e.g. Boussinesq equations, which are based on partial differential equations taking into consideration the simultaneous sea water movement into the 3 (x,y,z) dimensions (Karambas & Koutitas, 2002).There are many methods developed for seawave measurements usually based on buoy platforms on the water to measure wave height (G. Grigoropoulos, T Loukakis, 1995), some others use satellite images (Krogstad, H.E. & S.F. Barstow, 1999), fusion of satellite, model and buoy wave and wind data (Barstow, S.F., et al, 2003), using numerical models (Galanis G., 2009). These methods measure mostly wave height in one dimension, in addition, the use of buoys disturbs the water surface. However, photogrammetry can provide three dimensional measurements of seawaves without having any contact with the object photographed.

This research started at the Laboratory of Remote Sensing and GIS (RSLUA) back in 1996 when the Lab was involved in a research project for harbor design (Papadopoulos E., E. Papapanagiotou and J. Hatzopoulos, 1997, Hatzopoulos J. N., E. G. Papapanagiotou, 2000). At that time imaging technology was rapidly changing from analog film to direct digital image sensors (CCD array chips) and although the effort was limited at that time on analog images it was placed on the future plans of the RSLUA to work on digital image technology provided that there will be available an interested researcher (PhD candidate) and there will also be available some fundamental infrastructure. At present time these conditions are met and the effort for seawave mapping is on the way still waiting for some better quality SLR digital cameras but in the mean time working with two low costs Nikon Coolpix S3000, S3100, of 12 and 14 Mpixel cameras. Since 1993 there also was an effort at RSLUA to work on image correlation methods for automatic DEM generation developing at the same time a polynomial based sensor model (Papapanagiotou E. G., Hatzopoulos J. N., 2000, Papapanagiotou E., 2000). The results of image correlation will also be used for this present research. By the mean time significant work on this direction was developed by many researchers such as Santel F., Linder W., Heipke C. 2004, Gallego G., et al, 2011, MacHutchon K. R., P. C. Liu, 2007, Raguse K., C. Heipke, 2006, Remondino F., C. Fraser, 2006, Howard Schultz, 1996, De Vries S., et al, 2009. Past experience was also available on relevant applications since late 1970's for photogrammetric measurements of dynamic objects (S.A. Veress and J.N. Hatzopoulos, 1979) and developing analytical photogrammetric systems (Hatzopoulos J. N., 1985). Accordingly, some advanced software packages were also developed such as the Photomodeler in USA, the iWitnes in Australia, the LISA in Germany, etc., which greatly facilitate close range photogrammetric applications.

This present research started last summer (2011) and at the present has integrated the project and platform design and construction and it is in the process to obtain some preliminary results with low costs cameras.

PROJECT AND PLATFORM DESIGN

The general design of the project is based on a window of seawave view which is surrounded by specially designed targets to facilitate automatic accurate orientation of the cameras. This target frame is shown in Figure 1 and has external dimensions 200x200 cm and internal clean view dimensions 156x156 cm.

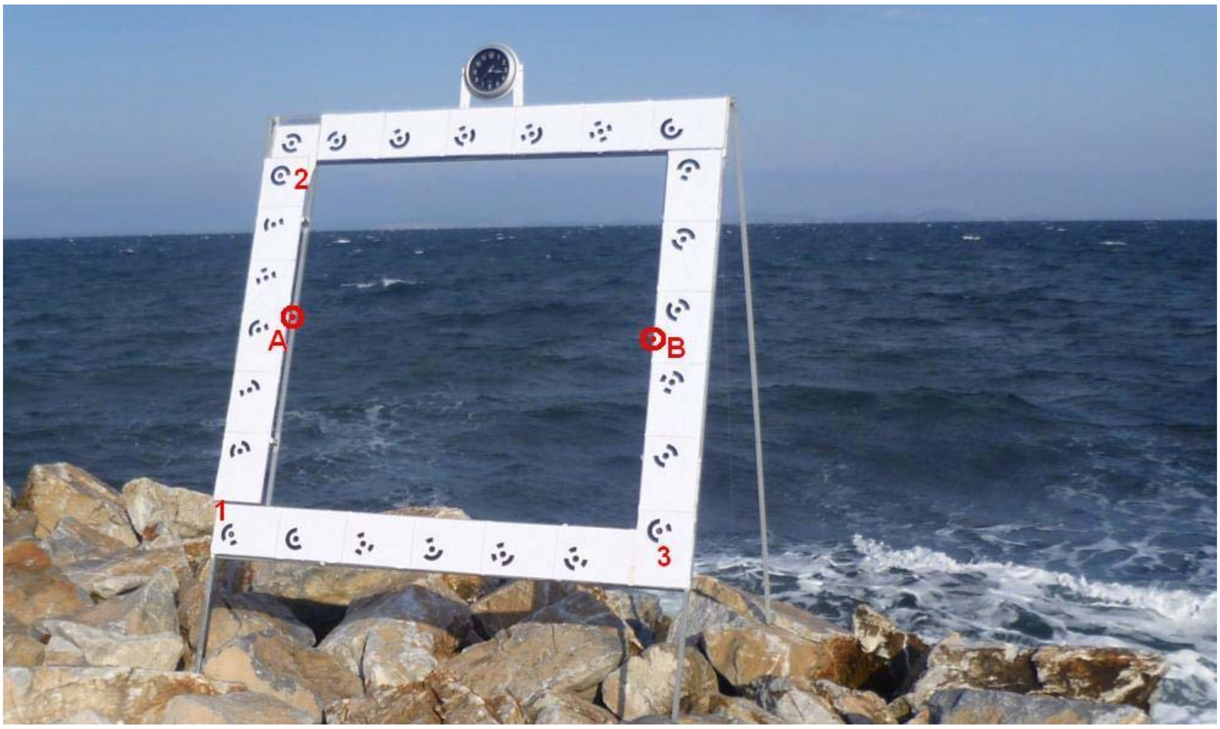

Figure 1. Target frame with 25 targets and internal window view dimensions of 156x156 cm.

This target frame is currying 25 specially designed targets printed from the Photomodeler software to facilitate automatic orientation of the cameras. On top of the frame there is a clock to help the synchronization of the cameras. The frame carries also four legs and for more stability over windy conditions it is tighten up with four wires. All targets are located in one plane except the left vertical line ones which are about 10 cm up. Accordingly, the camera base is also 156 cm to obtain good quality stereo pictures, and the camera axis is centered at frame point A for the left camera and at point frame B for the right camera as shown in Figure 1. Three of the target points (1, 2, 3 shown in Figure 1) are also control points measured by total station to carry an official (i. e., sate plane) coordinate system.

The design was based on using SLR cameras with 24 mm focal length lens with 23.6 x 15.8 mm image sensor which covers the clean window area from a distance of 5 – 6 meters. The situation of the entire system is shown in Figure 2, where the target frame is located at about 6 meters distance, the camera platform is supported with well designed shoes and there is also a specially designed stand for pointing and operating the cameras. The cameras are mounted on a metallic bar with 40 mm square cross section. The camera bar can be lifted up and down using a rope and it can be also firmly tied up using in both ends appropriate screws. Furthermore, the camera bar can be rotated around its axis to obtain the necessary tilt so that the camera axes point the target frame in the right locations A and B (see Figure 1) and then another pair of screws is used to fix this correct camera position. The total camera platform height is 3.0 meters while its width is 2.0 meters.

Figure 2. The general system configuration with the target frame, the camera platform and the total station.

The seawave area to be covered by this configuration is about 1.5 meters in the parallel to the frame direction and about 10 meters in the perpendicular to the frame direction. Although this configuration seems to create a weak geometry, the high resolution of the images and the calibration of the cameras seem to provide quality results. On the other hand, the dynamic nature of the object and the rapid change in shape is better covered by a relatively small camera base.

Part of the project infrastructure is to obtain good quality SLR cameras which are on the way of purchase through the University budget and hopefully they will be soon available and therefore, at the present, some low costs cameras are used for preliminary results. The SLR cameras will have the ability to take continues pictures of 1-5 frames per second with remote control so that to achieve good synchronization. Synchronization of the cameras is very important especially for seawave mapping because of the rapid change of wave shape (Raguse K., C. Heipke, 2006). Using the low costs cameras synchronization has to be performed manually (see Figure 2) with a precision about one second and a frame sequence exposure every seven seconds. This type of synchronization relies on the ability of the operator, as shown in Figure 2, to look at the clock and fire manually every seven seconds at the same time both cameras.

The interesting of photogrammetric approach of seawave mapping is the ability to obtain cloud point surface coordinates in an official reference system. In this project, a baseline of two permanent total station points was established and was given official coordinates to these points using differential GPS. Consequently, the total station was centered at both baseline points to measure horizontal and vertical angles on three control points 1, 2, 3 as shown in Figure 1 and the coordinates of control points were calculated by intersection (Hatzopoulos J. N., 2008). In Figure 3 is shown a view of total station measurements and the greater area of Paralia Thermis harbor of Lesvos Greece where the experiments take place.

Figure 3. Total station surveys to establish control on the target frame.

PELIMINARY RESULTS

Preliminary results were based on low costs cameras Nikon Coolpix S3000, S3100, of 12 and 14 Mpixel accordingly, which have about 5 mm focal length. These two cameras were calibrated using the Photomodeler software and using special targets printed through the same software. The calibration reports are shown in Figure 4.

The coverage of the two cameras through the clean window view of the target frame is of a relatively small scale due to the very small focal length (5 mm) of the cameras while the project design is for 25 mm focal length. This coverage is clearly demonstrated in Figure 5. Notice the clean stereo coverage about 1.5 meters horizontally (North – South) by 2-5 meters vertically (East – West) as shown on the lower right of same Figure. In Figure 5 is also shown a kite surfing passing during the camera exposure and recorded by the two synchronized cameras.

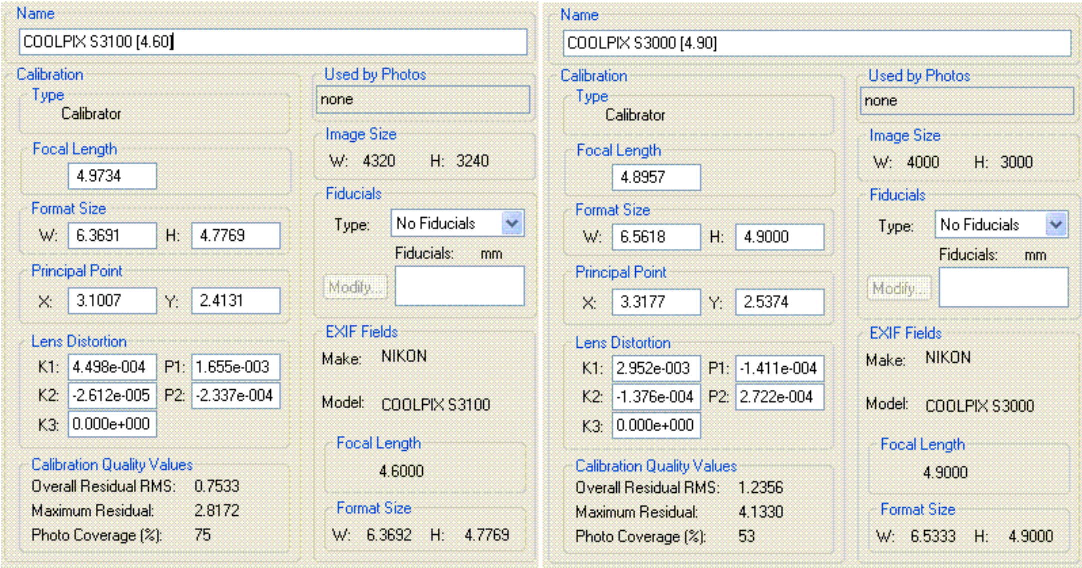

Figure 4. The camera calibration reports.

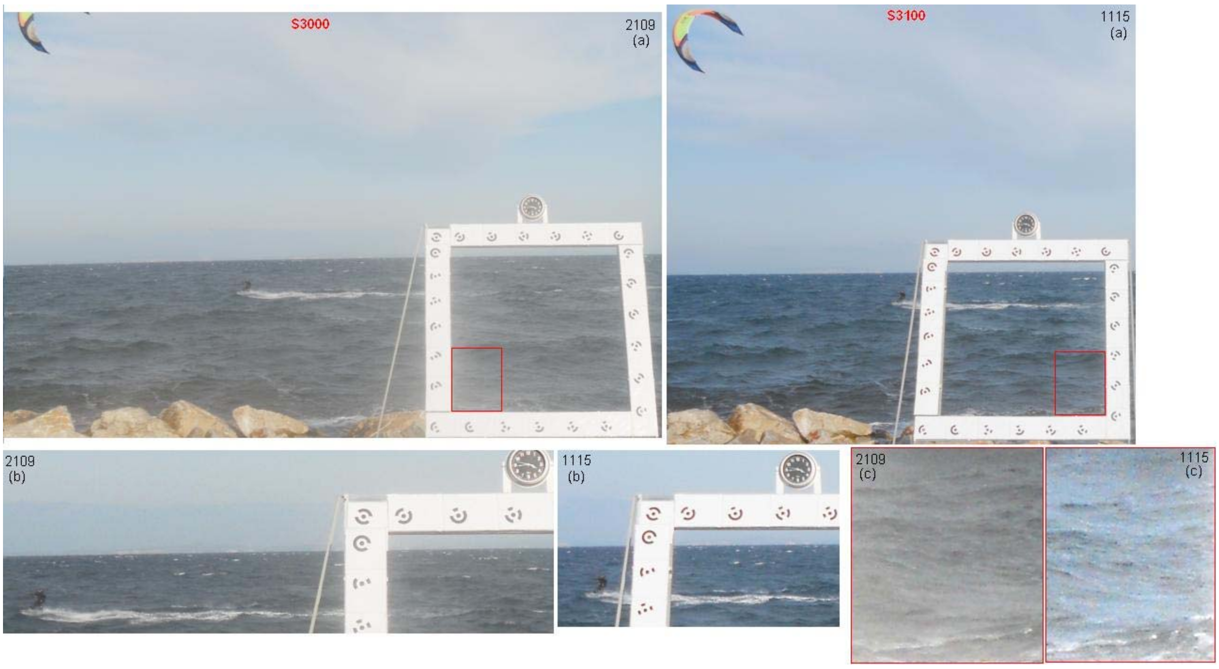

Figure 5. A view through the target frame window and the clean stereo view on the right.

SURFACE EXTRACTION

Photomodeler software, was used in order to extract as many 3-D cloud points as possible through a photogrammetric image correlation method among a stereopair of synchronized photos. The above, mentioned software follows a specific process which consists of three steps. First is the idealize step for resampling the image by clearing the lens distortion, the second step includes the automated marking mode and referencing of the

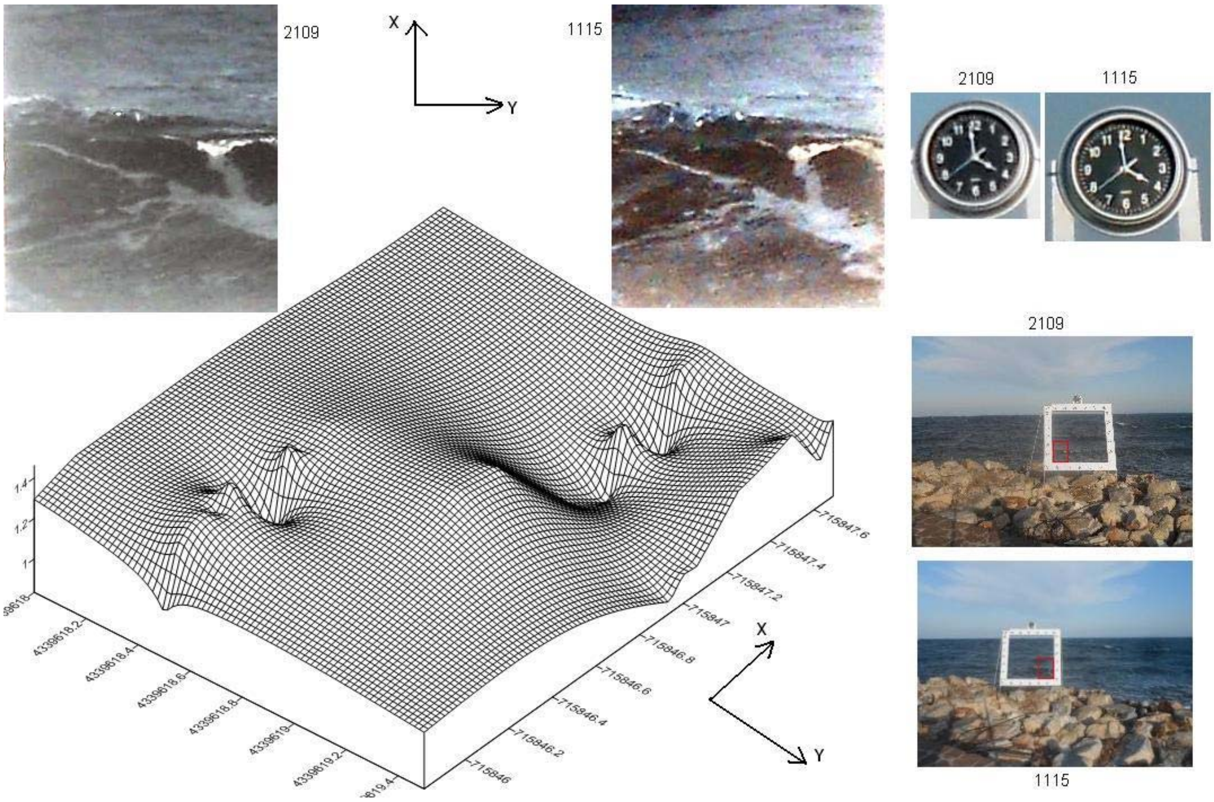

Figure 6. Three dimensional wave surfaces from one sereopair of photographs.

coded targets ,the third step consists of georeferencing and scaling of the stereopair using the control points measured by theodolite and the last step is the 3-D process method to perform image correlation and create a dense surface. For better optimization of the point meshes Surfer 9 software was patched with the ASCII files containing the point meshes attributes which were extracted before. In Figure 6 are highlighted the 3D sea wave surfaces of one stereopair where the z axis is scaled in meters and the x and y - axis have been configured in EGSA'87 which is for the time being the Greek Grid National Projection system except that the y – axis has opposite direction to compatible with corresponding images.

By studying Figure 6, one may observe that the wave height on sea surface varies due to the wind velocity and the time that measurements took place. In situ direct measurements, the minimum wave height was found about 0.40m and the maximum wave height was found around 1m**.**

CONCLUSIONS

At this point, the infrastructure of the project has been designed and taken into operation except the SLR cameras. Preliminary results with low costs cameras are encouraging and indicate the potential which exists in surface sea wave mapping by close range photogrammetry. Therefore, several actions are on the way waiting for the arrival of the cameras. Such actions include periodical experiments involving the wave entrance into the harbor, the wave propagation and the wave strike and reflection due to the existence of sea walls to be analyzed, as well as, monitoring of the potential wave spectrum energy distribution, within the harbor basin. Other actions involve the development of appropriate software for image correlation to create 3-D cloud points, which will be adapted to the seawave mapping and will fit to this specific project design.

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