A new system for breakzone location and the measurement of breaking wave heights and periods.

Christopher Lane [1], Yaniv Gal [1], Matthew Browne [1], Andrew Short [1], Darrell Strauss [2], Katherine Jackson[2] & Clarence Tan [3]

[1] CoastalCOMS Pty Ltd, Australia

[2] Griffith Centre for Coastal Management, Griffith University, Australia

[3] School of Information and Communication Technology, Griffith University, Australia

Introduction

This paper presents a new system for measuring breakzone locations, breaking wave height and wave periods across the surfzone from a digital video sequence. The aim of the system, called Wave Pack, is to detect the breaking wave zone and measure breaking and rebreaking wave heights and incident through infragravity wave periods, based on digital video data that is streaming from a low altitude camera, located on the investigated beach. The system circumvents the need for expensive equipment, labour intensive and complicated installation presently used in hardwired surf zone sensors and inshore waverider buoys. Yet, it can supply reliable results in most weather and sea conditions.

Methodology

General System Structure:

The Wave Pack system consists of the following main components (Figure 1): (i) digital video camera, located and fixed a few metres above sea level at the target site; (ii) video pre-processing unit that converts the streaming video into aggregated 'timestack' images (Browne et al. 2005); (iii) analysis unit that processes the extracted timestack and produces measurements of break zone location, wave heights and periods; and (iv) output unit that displays the analysis results to the user.

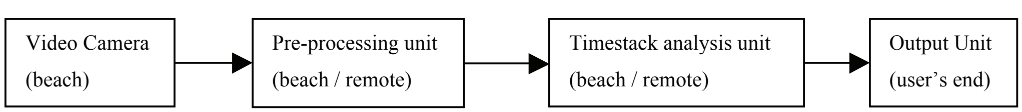

Figure 1: The Wave Pack system structure

The camera is located and fixed on the investigated beach at an altitude of at least 7 metres above mean sea level, while the output unit is located at the user's end. The pre-processing and analysis units can be located either with the camera or remotely. Locating one or both unit on the camera site will dramatically reduce network communication and will prevent communication bottlenecks. However, locating both units remotely will increase resolution and sampling rate of the timestack also allowing remote processing of multi camera input and thus reduce the costs of buying a processing unit for each camera.

Methodology of data analysis:

Data analysis is performed on the timestack image and consists of the following stages: (i) convert the timestack image from RGB colour to gray scale; (ii) normalise illumination along the temporal axis; (iii) detect main break zones; and (iv) calculate wave height and wave period for each breakzone detected.

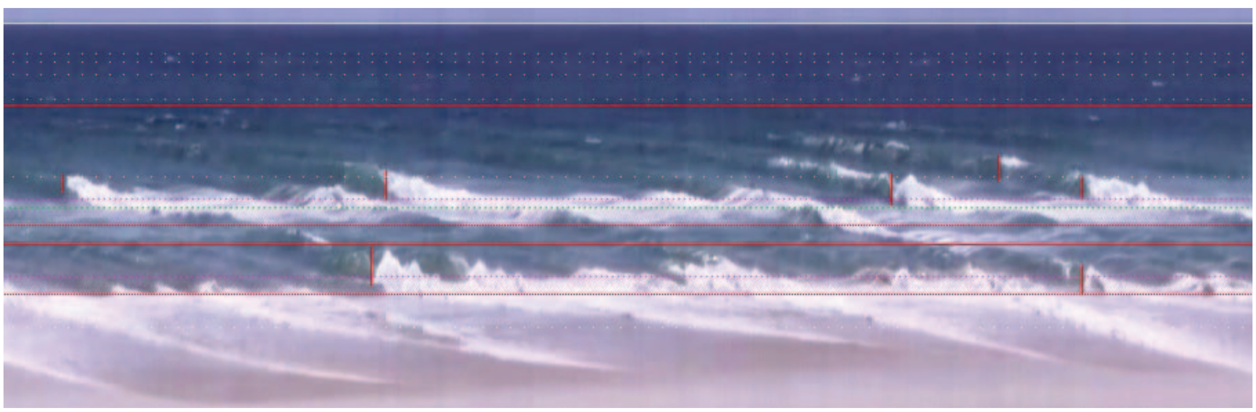

Figure 2: Section of timestack image with breakzones detected (between each solid and dotted horizontal red lines), swash zone (horizontal dotted green line), outer break point (horizontal dotted purple line) and measured breaking wave heights (vertical red segments). The horizontal dotted white lines represent different distances while the solid white line represents the calculated horizon.

System Validation

In order to evaluate the reliability of the system, a validation study was performed, based on data from 39 daily video sequences taken from the double–barred beach of Narrowneck, Gold Coast, Australia. A total of 1466 waves were detected with only 76 detections discarded due to interference. Interference primarily resulted from human activities obstructing the image. The results of the Wave Pack were compared to several independent sources of near-shore wave height and period. These included output from Wavewatch III (Tolman 1997, 1999a, 2009), a waverider buoy located 1.2 km directly offshore, the empirically derived formula of Komar & Gaughan (1973), output from a SWAN (Booij et. al 1993, Holthuijsen et al. 1993) model of wave propagation to the surf zone and the observations of a professional surf reporter. An additional manual verification of the accuracy of the pixel representation of breaking wave height was performed by visual inspection of each detected breaking wave in each timestack.

Results

The manual counts of pixels and automated method corresponding to breaking wave height had a correlation of 0.6 and a mean absolute error of 5.1 pixels. The standard deviation of the manual counts of wave height in pixels was 6.05 pixels and the automated method was 6.64 pixels. The number of vertical pixels representing breaking wave height was converted to actual wave height by rectification of the visual field with the image co-ordinates. The results of the video derived and independent measures of wave height are presented in Table 1.

Table 1 Correlation matrix of video derived and independent sources of wave height data

	Max (Manual)	WW3 (Hs Anl)	Buoy (Hs)	Buoy (Hmax)	SWAN (Hs max)	KG73 WW3	KG73 Buoy	SR
Wave-Pack Max	.86	.85	.82	.80	.66	.86	.83	.77
Max (Manual)		.86	.88	.85	.70	.89	.89	.78
WW3 (Hs Anl)			.95	.94	.70	.99	.95	.83
Buoy (Hsig)				.98	.77	.94	.99	.80
Buoy (Hmax)					.71	.93	.97	.76
SWAN (Hs max)						.72	.78	.61
KG73 WW3							.96	.82
KG73 Buoy								.82
MAE meters (Wave-Pack Max)	*.33*	*.79*	*.77*	*.59*	*.42*	*.45*	*.65*	*1.01*
MAE meters (Manual Max)		*.88*	*.85*	*.54*	*.49*	*.50*	*.71*	*1.12*

The processed maximum wave period data was compared against two independent measures of peak wave period: the Gold Coast wave buoy (moored at a depth of 16m, approximately 1.2km offshore) and the closest available WW3 grid point. The manual estimates of wave period were derived by counting the number of visible waves at the identified break line in each time stack image and dividing the length of video (in seconds) by the wave count. Essentially this results in a mean period. Nevertheless, a reasonable correlation would be expected with peak period measurements but that is not the case. It appears that this highly subjective method for manually estimating the wave count is a poor choice for validation. The processed values for maximum wave period obtained from the time stacks result in correlations with the both the waverider buoy and Wavewatch III peak periods of 0.53 and 0.65 respectively. The highest correlation (with WW3) is equivalent to the wave buoy correlation with WW3. Mean absolute errors of processed wave period with the buoy and WW3 are less than 1.3 seconds whereas the manual calculation of wave period is greater than 3 seconds in all cases.

Conclusion

A new method of obtaining accurate measures of breakzone, wave height and period from video imagery is presented. It is calibrated and tested using a set of 39 timestacks covering a range of wave heights and periods. The relatively low percentage of rejected wave counts supports the flexibility of the wave height processing algorithm to perform in the highly variable wave conditions experienced at a field site. The processed wave heights correlated highly with the independent sources of wave height available. The empirical formulation of Komar and Gaughan (1973) was tested using Wavewatch III and waverider buoy data as input. While the calculated values also compared favourably with the processed values there is expected to be several restrictions on the application of the empirical model in more complex bathymetries. The Wave Pack system provides a low cost, robust, reliable and accurate system for measuring continuous wave height and period from a low elevation video camera aimed at the target beach. Field tests have verified the accuracy of Wave Pack in comparison to existing systems.

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