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Digitization of Wave Run-Up Using Video Records

Troels Aagaard[a]
Jörgen Holm[b]

[a,b]Institute of Geography
University of Copenhagen
Oster Voldgade 10
DK-1350 Copenhagen K, Denmark

ABSTRACT

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Digitization of photographic records of wave run-up has proved a simple and economic alternative to more traditional methods of analyzing fluid motions in the surf zone. In this note, a new digitization technique using video images of wave run-up is described, together with an example from a multiple bar system on the northern coast of Zealand, Denmark.

ADDITIONAL INDEX WORDS: *Remote sensing, infragravity waves.*

INTRODUCTION

It has recently been shown that infragravity wave frequencies ($T \approx 20-200$ sec) may be prevalent in the surf zone during storms (*e.g.* WRIGHT *et al.*, 1982; GUZA & THORNTON, 1982; SALLENGER & HOLMAN, 1985; HOLMAN & SALLENGER, 1986). Thus these waves have a potential ability of exerting a significant impact on the morphological development under these conditions.

Furthermore, while incident wave heights are limited by breaking, infragravity wave amplitudes often increase towards the shoreline and may totally dominate the energy spectrum near the beach face (GUZA & THORNTON, 1982; GUZA *et al.*, 1985). These low-frequency swash oscillations may cause severe erosion of the beach and foredunes by allowing bores to penetrate to the backbeach where erosion and dune scarping occurs (WRIGHT, 1980; SHORT & HESP, 1982). It is therefore of interest to quantify these phenomena, which are in fact standing waves of the leaky mode or trapped mode (edge wave) regime (GUZA & THORNTON, 1985; KOMAR & HOLMAN, 1986; SALLENGER & HOLMAN, 1987; OLTMAN-SHAY & GUZA, 1987), in terms of amplitude as well as frequency, as their cross-shore length scales (and in the edge wave case, the longshore length scales as well) are frequency dependent.

Studies of waves in the surf zone have chiefly been conducted through spectral analysis of current meter and/or wave sensor records. These instrumental arrays are vulnerable in high-energy situations and rather expensive. Furthermore, the spectral structure of these records depends somewhat upon the location of the instrument relative to the standing wave structure, with spectral valleys occurring at nodes. To obtain a true picture of the standing wave structure, synthetic spectra must be computed numerically (SALLENGER & HOLMAN, 1985, 1987). In addition, large arrays are necessary to get a good coverage of the surf zone.

Therefore, other techniques have recently been developed. One such is photographic records of swash oscillations using either time-lapse photography (HOLMAN & BOWEN, 1984; HOLMAN & GUZA, 1984) or movie cameras (HOTTA *et al.*, 1981; BRADSHAW, 1982; CARLSON, 1985). While these techniques may be of lower accuracy, they are cheap, logistically simple and may contain data from a large number of points alongshore, as the distance between camera and the point in question is limited only by the photographic resolution. Run-up records during storms do not constitute a good representation of incident wave frequencies but are well suited for the detection and quantification of infragravity

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waves, this being due to the dissipation of incident wave energy in the surf zone and the progressive growth of infragravity wave amplitude towards the shoreline.

Time-lapse photographs are projected frame by frame on a screen, and the water level position digitized (HOLMAN & GUZA, 1984). Determination of the backwash position may be difficult due to percolation into the beach face, but often the shoreward edge of the receding wave is indicated by colour changes or foam retreating down the beach. HOLMAN & GUZA (1984) reported a time-span of 30 minutes for the manual digitization of a 2048-point time series, with a standard deviation on swash height of about 10%.

In this note, an alternative technique using video records of run-up is described. This computer-assisted technique samples a given line in the video image at specified time intervals. After the film has been replayed, the picture lines are displayed below each other on the monitor. Thus a time series of the run-up position is presented.

PROCEDURE

In the field, transects are marked by reference stakes placed at the berm ridge and step. Cross-shore distance between stakes and profile gradients are determined, using standard surveying techniques, for later conversion of run-up length to run-up height. Longshore distance between transects is measured as well. The video camera is positioned to overlook the stakes; a 90 degree angle between direction of view and the orientation of the transects is preferable in order to minimize perspective problems. The camera is mounted in a transparent plastic box with a photographic plate inserted in the front, for protection against moisture and salt spray. Effective camera range for satisfactory resolution of swash and stakes depends on run-up length, diameter of transect stakes, elevation of the camera and weather conditions. With a maximum horizontal run-up length of about 15 m, ½-inch stakes and the camera mounted on a tripod on the foreshore, camera range is about 75-100 m.

Analysis of the video records is accomplished through the use of an IBM-PC, a PCVision board fitted with a real-time Frame Grabber and a monitor (Figure 1). The film is displayed on the monitor; the picture line between reference stakes in a transect is specified and the screen coordinates at the intersections of stakes with the beach surface are fed to the computer. When the video tape is replayed, the Frame Grabber converts the analog TV-signal to digital values and stores the data in the frame memory. The computer scans the specified picture line at discrete time intervals chosen in advance and stores the data on disk. Subsequently, the picture lines are loaded onto the monitor and displayed beneath each other, the system reconverting the data from digital values to an analog TV-signal. The screen thus presents a two-dimensional picture of the run-up time series in the specified transect (Figure 2).

The position of the water level is digitized, using a PC-mouse. A step factor may be specified, enabling the cursor to jump a given number of lines so that points at desired intervals (*e.g.* 0.5 sec) are sampled.

After digitization of the first screen, the next 512 picture lines are loaded onto the screen, and so forth.

The entire procedure takes about 75 minutes for a 2048-point time series, of which the digitization process in itself constitutes about 45 minutes. Software required for this procedure has been developed at the Institute of Geography, University of Copenhagen.

Finally, the digitized time series is transformed to vertical run-up heights and subjected to spectral analysis, in this case using the SAS-package.

EXAMPLE AND DISCUSSION

Figure 2 is a 100-second segment of a record taken at Staengehus in northern Zealand, Denmark on September 19, 1987. This is a sandy shore with three nearshore bars. Mean grain size is ~ 0.35 mm and the nearshore gradient is 0.014, while the gradient between the shoreline and the inner edge of the second bar is 0.023.

On September 19, the estimated breaker height was 1.2 m (using the stake and horizon method (PATTERSON & BLAIR, 1983)) with an estimated breaker wave period of 4.5 seconds. Waves broke over the second bar by plunging/spilling. After reforming in the trough, they broke over the inner bar and proceeded as dissipative bores to the beach face.

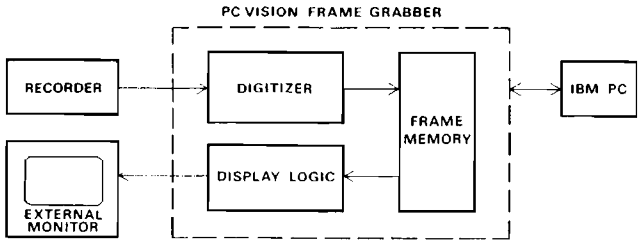

Figure 1. Components of the digitization system.

Significant run-up height, defined as 4σ, where σ is the standard deviation of the digitized run-up time series (HARRIS, 1972; THOMPSON, 1974), was 0.55 m.

The inner bar was crescentic with an in-phase relationship between bar horns and megacusps on the shoreline. Rhythmic wavelength was about 110 m.

As appears from Figure 2, the swash is clearly defined by heavy white lines originating at the left (seaward) edge of the photo and moving obliquely downwards to the right. The backwash is somewhat more indistinct, although retreating foam is indicated by more steeply inclined lines directed from upper right to lower left. The dark area at the right hand side of the photo is the unsaturated beach surface, while wet sand is indicated by the lighter grey colour. White vertical lines are stationary foam patches, stranded on the foreshore.

It is readily apparent that swash/backwash interactions and bore capture tend to decrease the incident wave period. Only seven swash maxima seem to be present in this 100-second segment, corresponding to a swash period of about 14 seconds. Two large swashes are seen in the picture. These swashes appeared regularly at low frequencies throughout the record.

The power spectrum from this record appears in Figure 3. It is based on a 34.1 min. (4096-point) record. Two dominant peaks occur at 0.021 Hz (48 sec) and 0.042 Hz (24 sec), respectively. There is no energy at incident wave frequencies, while a small peak around 0.077 Hz probably corresponds to the swash period apparent in Figure 2. Interestingly, a standing mode 1 edge wave with a frequency of 0.021 Hz would have a longshore wavelength of about 245 m, according to the formula

$$L_e = (g/2\pi)\, T_e^2 \sin(2n+1)\,\beta$$

(GUZA & INMAN, 1975), where L_e is edge wave wavelength, T_e the edge wave period, n is the mode number and β the gradient between the shoreline and the inner edge of the second bar. This is close to twice the rhythmic wavelength of bars and megacusps, indicating that a relationship might exist between this spectral peak and the morphology.

The spectrum thus resembles results from dissipative surf zones reported in the literature, although infragravity wave frequencies are somewhat higher than those occurring on open ocean shorelines.

Advantages and Disadvantages of Video Recording Digitization

This procedure may be somewhat more time-consuming than the method described by HOLMAN & GUZA (1984). Another drawback is the presently lower resolution in video images than in photographs, preventing a large number of widely spaced transects.

However, it is felt that it may be more precise, especially in the determination of the backwash position. When the backwash is blurred and indistinct in places, its position may be interpolated. A few tests performed by different operators indicate that the standard deviation on swash height is about 5%. Furthermore, the optional scan interval and step factor allow maximum resolution on the monitor, as well as providing an opportunity for digitization of records at desired intervals.

This method also permits an immediate visual inspection of incident wave and swash periods. Other possible applications could be studies of swash/backwash interactions, mea-

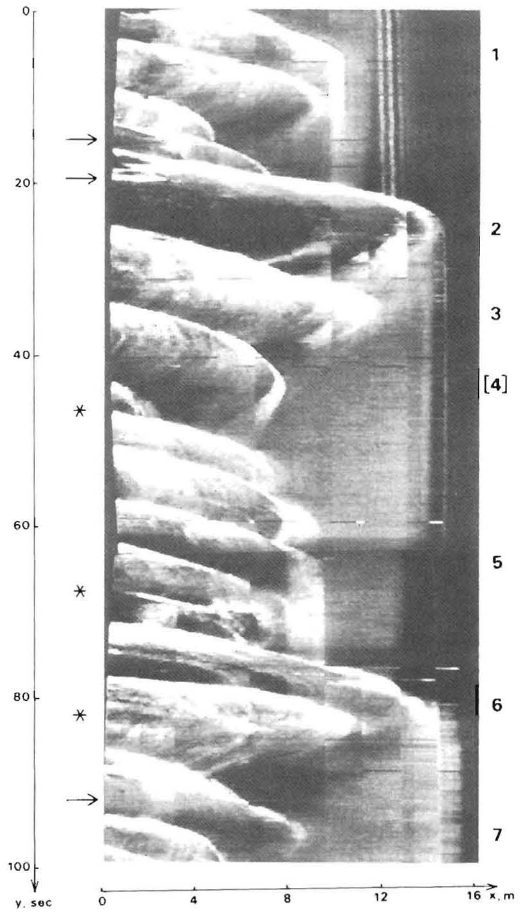

Figure 2. Photo of the monitor screen containing a 100-second record of run-up oscillations, taken on September 19, 1987. The line between reference stakes has been scanned at 8 Hz. The verticle axis (y) represents time, while the horizontal axis (x) represents distance, which in this case was 16 m (*i.e.* the distance between reference stakes in the transect). One and a half screen pictures have been joined in order to give an impression of the low frequency periodicity. Numbers mark visually estimated swash maxima, arrows show examples of bore capture and asterisks show examples of swash retardation by the preceding backwash. Due to reduction in size, the picture has lost a little detail.

surements of swash/backwash velocities and accelerations as well as it should be possible to digitize wave oscillations along transects in the surf zone.

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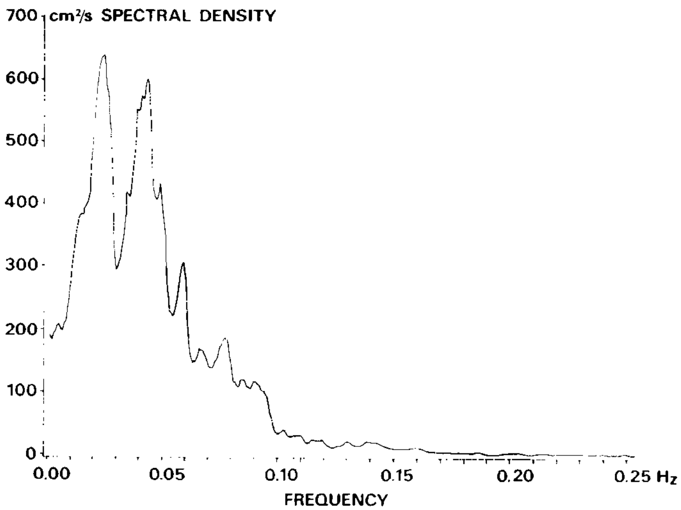

Figure 3. Power spectrum, September 19, 1987. The spectrum has a frequency bandwidth of 0.00049 Hz and 38 degrees of freedom. Spectral peaks at 0.021 and 0.042 Hz.

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