Coastal Engineering Technical Note

A REMOTE SENSING SYSTEM FOR MONITORING BEACH MORPHOLOGY

PURPOSE: This note discusses a technique of remotely monitoring nearshore sand bar morphology using video image processing. The technique permits inexpensive monitoring of changes in nearshore sand bar morphology, and requires as little as a camcorder and tripod. A description of the image processing technique and its application is presented.

BACKGROUND: The remote sensing technique measures the sand bar morphology based on incident wave breaking over the shallows of the bars. As waves propagate across a barred profile, wave breaking dissipates energy, producing bubbles and foam that are highly reflective to light. These patterns of light intensity can be recorded on video and used to determine the underlying morphology. This is done by *time averaging* video images for approximately ten minutes using an image processing system. The time averaging removes the fluctuations of incident wave modulations and produces a more statistically stable image of the wave breaking pattern (Figure 1).

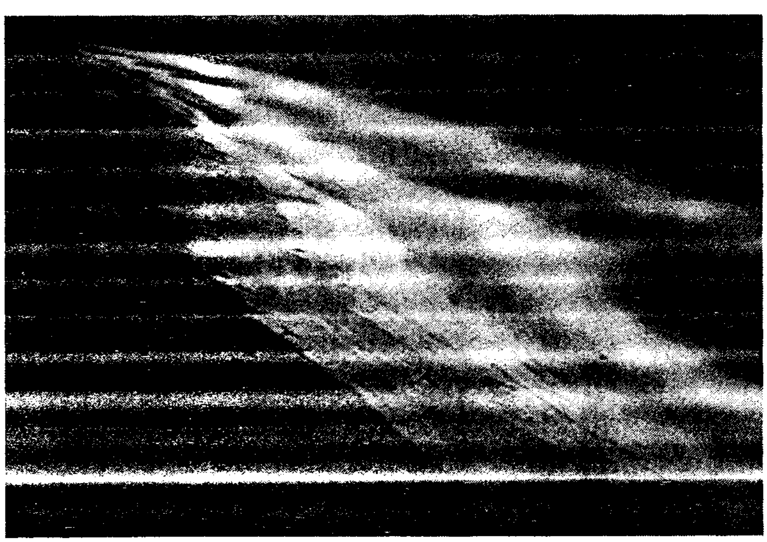

Fig. 1 Time averaged video image of waves breaking over sand bars.

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Dr. Holman of Oregon State University pioneered this remote sensing technique; first using time exposure 35 mm photographs, and later improving the technique with a computerized video image processor. Lippmann and Holman (1989) developed a model relating the visible signal of the wave breaking patterns to the underlying bar morphology. Light intensities reflected from the foam and bubbles of breaking waves are assumed to be directly proportional to the local incident wave energy dissipation. Lippmann and Holman (1989) modeled the wave energy dissipation over a barred profile based on random wave fields having a Rayleigh probability distribution (Thornton and Guza, 1983). They found that the time exposures generally provided a good mapping of underlying morphology, and were able to determine the cross-shore and longshore length scales of the bar, but not the depths.

If residual foam persists in areas that do no have active wave breaking, then the time averaging technique will be biased in its estimate of energy dissipation in those areas. This problem can be eliminated by subtracting video frames separated in time by 0.5 to 1.0 seconds, yielding a *time difference image*. Regions with little contrast change, such as areas without wave breaking or with persistent foam, will have small differences in image intensity. Areas with active wave breaking have large changes in contrast, producing large differences in image intensity. Similar to the time average video, the differencing time exposures give a more stable image and a better estimate of the bar position when averaged for about ten minutes. Lippmann and Holman (1989) observed that the differencing time average method was superior for locating the bar position during high wave conditions, while the time averaging method works best for low wave conditions when the waves are just barely breaking over the bar.

An important capability of this video imaging technique is the determination of the ground coordinate positions of features in the image. The process of mapping from the two dimensional image plane to the three dimensional ground plane is called rectification. If the geometry of the camera and ground coordinates are known, then rectification is possible. However, since the image is only a two dimensional representation of a three dimensional surface, in order to rectify the image, it must be assumed that the horizontal plane is at sea level, and that errors associated with wave amplitudes can be neglected relative to the height of the camera. If the position of two or more points are known in both the ground coordinates and in the image plane, then the mapping from the image plane to the ground plane is possible. Thus, to determine ground coordinates of morphology features in the image, the camera height and the location of at least two points in the image must be known.

<u>APPLICATIONS</u>: Sand bars contain enormous quantities of sand, are very dynamic, and thus are of great interest to coastal engineers. Typical methods of measuring morphology are to infrequently survey the region using conventional surveying techniques. However, traditional survey methods, which use boats and survey crews on the beach, do not permit accurate surveying of the morphology under the surf zone. Moreover, surveying is not feasible during storms, when dramatic changes in morphology can rapidly occur. This remote sensing system overcomes these problems and allows daily or even hourly monitoring of the complex morphology in these dynamic areas. Although the technique does not give depths, it can provide a cost effective method of measuring the length scales of morphology features in regions that are generally not surveyable. A typical area of interest might be an inlet, where knowing the locations and shape of moving shoals is desired, but where surveying is often hazardous or impractical.

<u>SYSTEM REQUIREMENTS</u>: The equipment required for data collection is minimal, usually just a black-and-white video camera and video cassette recorder (VCR), or a camcorder. Typically, ten minutes of video are sufficient to produce a reasonable time averaged or difference averaged image. Time exposures are computed by using the output video signal from the VCR during playback as input to the image processor.

The camera can be positioned wherever an adequate vantage point of the viewing scene exists. Sufficient spatial coverage of the longshore and offshore scales of sand bars generally requires the use of oblique camera angles. At view angles approaching horizontal, the image processing technique becomes inaccurate for determining positions. Increasing the camera elevation results in a more vertical perspective, which will reduce errors in determining positions of features in the image. Camera shake can blur time averaged images and reduce the resolution. Mounting the camera high above ground and on a stable platform achieves the best results.

<u>SYSTEM LIMITATIONS</u>: The accuracy of determining a position of a feature depends on several parameters that affect the transformation from the image plane to the

ground coordinates. First, the errors associated with measurements of the camera height and the position of the known survey points are neglected since these can be surveyed to a high degree of accuracy. Second, the image processing system digitizes the image into a 512-by-512 array of pixels. This quantification of the video image determines the fundamental limit on the angular resolution for the system, which in turn sets limits on the accuracy of calculating the ground positions of objects. Accordingly, reducing the apparent distance between the camera and area of interest, either with a telephoto lens or closer, will improve estimates of the position.

Other limitations on the resolution of the system are the camera and the recorder. Several types of cameras are physically moving the resolution of manufactured with greater resolution than that of the image processor (512 lines), therefore, the camera should not be a limiting factor in the system. Several formats –for recording video exist, unfortunately, none of the conventional formats provide 512 lines of resolution. However, some types of VCR's have resolutions sufficient for most image processing applications. Both Super-VHS and Super-Video 8 mm have resolutions exceeding 400 lines, and are recommended over standard 8 mm, Beta, or VHS formats.

AVAILABILITY: The Corps obtained a video image processor which is located at the Coastal and Hydraulics Laboratory (CHL) Field Research Facility (FRF) in Duck, NC. Daily videos collected at the FRF monitor changes in nearshore morphology, supplementing the conventional surveys that are done at intervals of approximately two weeks. This system records the videos in Super-VHS format. For additional information, contact Mr. Kent K. Hathaway, CHL Field Research Facility, at (252) 261-6840, ext 224, Kent.W.Hathaway@erdc.usace.army.mil
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Thornton, E. B. and Guza, R. T. 1983. Transformations of wave height distribution. J. Geophys. Res., 88: 5925-5938.