COASTAL MANAGEMENT AND ENGINEERING MONITORING

The Advanced Argus System

Coastal managers aim for sustainable development of coastal systems, including protection of the hinterland against flooding, swimmer safety, beach recreation and nature conservation. The design and evaluation of coastal-policy measures and engineering interventions are hampered by the dynamics of any natural system. Remote-sensing techniques can provide low-cost support information.

A natural system such a coastal zone is subject to the vagaries of natural conditional variation. Within in a matter of weeks to months beach nourishment adopts an equilibrium profile through phases that may be both unexpected and pose temporary problems. Rip currents may even develop within days, forming a serious threat to swimmer safety. Effective decision making and engineering design in this complex field thus demands the availability of detailed coastal-state information at small scales of days to weeks and metres to kilometres. With the advent of digital imaging technology, shore-based remote video techniques like the advanced Argus system developed at Oregon State University (USA) are increasingly being used to monitor coastal processes in support of coastal management and engineering. Unmanned, automated video stations (Figure 1) guarantee the collection of video data at spatio-temporal scales of decimetres to kilometres and hours to years. Under continual improvement since 1992, the system now features fully digital video technology that provides high-quality imagery.
An Argus monitoring system typically consists of four to five video cameras spanning a 180Âº view and allowing full coverage of about three to six kilometres of beach. The cameras are mounted at a high-lying location along the coast and connected to an ordinary PC onsite that in turn communicates with the outside world using broadband internet. Data sampling is usually hourly, although any schedule can be specified, and continues during rough weather conditions. As the process of data collection is fully automated, marginal operating costs are virtually none. For full flexibility, a self-contained system has been developed with a low-power computer embedded in the camera housing.

Data Collection
Each standard hourly collection usually consists of three types of images. A snapshot image (Figure 2a) serves as simple documentation of ambient conditions but offers little quantitative information. Time-exposure images (Figure 2b) average out natural modulations in wave breaking to reveal a smooth pattern of bright image intensities which are an excellent proxy for the underlying, submerged sand-bar topography. Time exposures also â€˜removeâ€™ moving objects such as ships, vehicles and people from the camera field of view. Variance images (Figure 2c) help identify regions changing in time, like the sea surface, from those which may be bright but are unchanging, like the dry beach. Panoramic (Figure 2d) and plan-view (Figure 2e) merged images can be composed by geo-referencing the images from all Argus station cameras. Plan-view images enable measurement of length scales of morphological features like breaker-bars and the detection of rip currents. Besides time-averaged video data, data sampling schemes can be designed to collect time-series of pixel intensities, typically at 2Hz, with which wave and flow characteristics can be investigated.

Video Coastal State
Successful use of video-monitoring techniques in support of coastal management and engineering involves quantification of relevant coastal-state information from video data. Sophisticated operational video-analysis methods nowadays enable:

- quantification of shoreline evolution and beach width to evaluate potential for recreation or to assess morphological impact of a storm (cf. Application 1)
- quantification of erosion and accretion sediment volumes at an inter-tidal beach, for example to evaluate morphological impact of coastal structures, to investigate seasonal fluctuations in beach dynamics and beach nourishment or to study the behaviour of morphological features such as sand-spits and tidal-flats near a harbour entrance (cf Application 2)
- quantification of sub-tidal beach bathymetry to evaluate coastal safety, assess behaviour and performance of shore-face nourishment or even to facilitate military operations (cf. Application 3)
- quantification of wave run-up to evaluate stability of coastal structures such as seawalls, harbour moles and revetments (cf. Application 4).

Video-monitoring techniques have been applied in a research context to quantify along-shore flow velocities, wave characteristics such as wave angle and period, the occurrence of algae-bloom, distribution and persistency of rip currents and the monitoring of visitor density on a beach. Future applications may involve the prediction of rip currents. The continuous collection of long-term, high-resolution datasets carries the additional advantage of posteriori data selection, for instance for consistent assessment of storm damage to public and private property and early recognition of important trends in erosion.

Application 1: Storm-driven Shoreline Change

At Barcelona a shoreline detection model was used to assess storm-driven shoreline change in front of Puerto Olimpico. The model derives the location of the shoreline from time-exposure images on the basis of colour contrast between the dry and wet beach (Aarninkhof et al, 2003). Detailed observations show shoreline retreat of up to tens of metres during a single storm.

Application 2: Intertidal Morphological Change
At Egmond inter-tidal beach bathymetry was determined on a monthly basis by mapping a series of video-derived shorelines at different water levels throughout a tidal cycle. The mean vertical offset of this model is less than 15cm along 85% of the 2km-wide study region. The resulting bathymetry (e.g., Figure a) was used to quantify patterns of erosion and accretion after combined beach and shore-face nourishment. Example results are presented in the graphs (Figures b and c), which show means of the monthly volume changes VIB per metre coastline (bars), as well as the cumulative morphological changes (lines). Negative values denote erosion. Figure (b) presents the volume changes at a location 400m to the south of the Argus station; Figure (c) presents volume changes at a location 400m to the north of the station. The analysis shows a tendency towards erosion during the first year. High-resolution video monitoring indicated that the additional beach nourishment implemented in the left-hand section (b) in July 2000 disappeared from the inter-tidal beach within a few months.

Application 3: Surf Zone Bathymetry
At Egmond Argus video imagery was used to monitor the evolution of surf-zone bathymetry after implementation of shore-face nourishment in July 1999. The bed elevation is continuously updated on the basis of a comparison of video-derived and model-computed patterns of wave dissipation (Aarninkhof et al, JGR 2005). This approach yields marginal deviations in the order of 10 to 20cm at the seaward face of the bars, which increase up to 20 to 40cm near the bar crest. The results show a shoreward migration of the outer bar after deployment of the shore-face nourishment, in combination with net accretion of sediment along the shallow part of the beach profile above the -2m depth contour, thus confirming the beneficial impact of nourishment.

Application 4: Wave Run-up on Coastal Structures
Wave run-up and wave overtopping are two mechanisms that may cause damage or even failure of coastal structures such as seawalls, harbour moles and groins. High-frequency video observations (typically at 2Hz) can be used to determine the statistics of wave run-up on beaches and coastal structures. The figure below shows an example of a â€˜time-stack imageâ€™, where pixel intensities are sampled along a cross-shore array in the swash zone and stacked over time. The position of the swash edge can be visually identified by the sharp change in intensity between the darker beach surface and the lighter â€˜foamyâ€™ edge of the swash bore (after Holland and Holman, 1993). This type of monitoring yields information on wave attack on structures during a single storm or throughout the year.

Further reading

- Aarninkhof, S.G.J., Ruessink, B.G. and Roelvink, J.A., 2005. Nearshore subtidal bathymetry from time-exposure video images. Journal of Geophysical Research, Vol. 110, C06011, doi:10.1029/2004JC002791, 2005.
- Holland, K.T. and Holman, R.A., 1993. The statistical distribution of swash maxima on natural beaches. Journal of Geophysical Research, 98, pp 10271-10278.
- Holman, R.A. and Stanley, J. (in press). The history, capabilities and future of Argus. Accepted for publication in Coastal Engineering.
- Turner, I.L., Aarninkhof, S.G.J. and Holman, R.A., 2006. Coastal imaging applications and research in Australia. Journal of Coastal Research, pp 37-48, doi:10.2112/05A-0004.1.