Monitoring beach usage with a coastal video imaging system: an application at Paralia Katerinis, Greece

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Abstract

This contribution presents a framework for automatic monitoring of beach usage and its relation to weather conditions, using a coastal video imaging system installed at a 250 m beach stretch of Paralia Katerinis, Greece. The video feed is automatically scanned to detect beach users and their spatiotemporal distribution over the monitored area. Preliminary results suggest that patterns of beach attendance depend not only on weather conditions, but also on recreational facilities and beach accessibility. The study demonstrates that coastal imaging systems can produce quantitative, long-term beach usage metrics that are critically needed for integrated coastal management.

Keywords: integrated coastal management, tourism, beach monitoring, beach use, weather conditions

1. Introduction

Beaches provide dynamic protection to the coastal ecosystems and infrastructure they front; they are also used for recreation, particularly at popular tourist resorts. Management of such areas requires high resolution monitoring of several environmental and socio-economic factors, including coastal physical processes, weather conditions, economic parameters, as well as spatio-temporal metrics of beach usage. However, very little of the relevant information is quantified and available to coastal managers (Guillén et al., 2008), and insights into beach usage patterns are typically based upon beach user questionnaires and/or interviews (e.g. Jurado et al., 2009). In some cases, information is provided by manual analysis of webcam data that are visually assessed to produce qualitative classes of “high”, “medium” or “low” beach occupation (Moreno et al., 2008; Hasiotis et al., 2013; Zang & Wang, 2013). In this context, automated processing of coastal imaging data is scarce, although invaluable for providing quantitative metrics of beach usage patterns (Guillén et al., 2008; Baluin et al., 2014). Such beach user detection methods operate by data pre-conditioning and conversion of source frames into binary images via intensity thresholding; practically, the key assumption is that beach users are dark pixels over a bright background. This assumption, however, breaks easily in coastal settings, where variability in brightness, weather conditions and background is the norm, rather than the exception. Studies have reported severe detector degradation under cloudy conditions (Baluin et al., 2014), or due to dark sand patches resulting from routine beach activities, such as sand plowing (Guillén et al., 2008).

In this contribution, we present preliminary results from a newly-developed methodology for the automatic detection of beach users in large volumes of coastal imagery data. Detection is performed in quasi-real time, using composite images that quantify the time-variance, rather than the intensity of image pixels. Beach usage results from eight selected days during the summer season of 2014 in Paralia Katerinis (Greece) are presented, and their relation to weather conditions is briefly discussed.

2. Materials and methods

The study site is the beach fronting a hotel installation in Paralia Katerini beach, Greece (40°17'07"N, 22°36'23"E). Beach usage is monitored using a monoscopic coastal imaging station installed on the roof of a seafront lodging facility (location: 40°16'58"N, 22°36'15"E, height: 10.35 m, Fig. 1). The monitoring system consists of a Vivotek IP8362 network camera and a Davis Vantage Pro2 Plus weather station, both controlled by a dedicated PC located in the hotel's datacenter. During daylight, the camera records for 10 minutes every hour at 5 frames per second and 1920x1080 resolution. The camera's field of view covers a cross-shore beach width of 70 m, and a longshore length of 250 m.

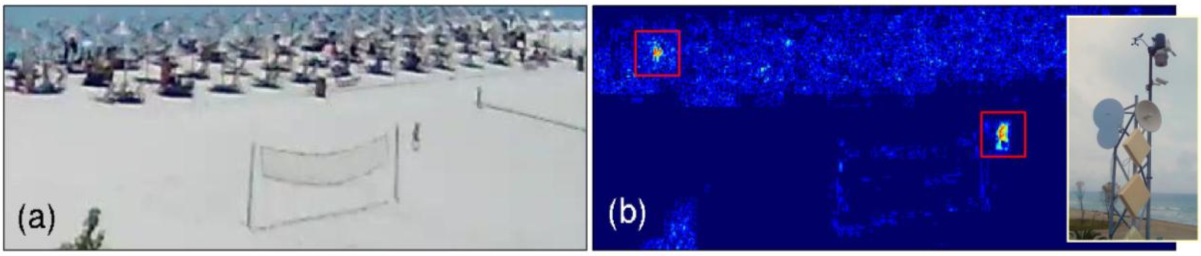

Fig. 1. (a) Detail of a raw video frame, as acquired from the coastal imaging system. (b) Corresponding composite image, pseudo-colored by time variance over 5 successive frames (≈1 s). Higher variance maps to warmer colors; red squares mark the detected targets. The imaging equipment installation is also shown (inset).

The key concept is that beach user detection is performed on SIGMA composite images. SIGMA images are common products of coastal imaging systems that quantify the variance of each pixel over the image stack (Vousdoukas et al., 2011). Prior to processing, a site-specific region of interest is defined, marking the detection area and excluding irrelevant parts of the image, such as the sky, off-beach installations, and the nearshore zone (seawards). Note that the swash zone is *not* excluded, so that beach usage near the shoreline can be monitored. The system processes each 10 minute-long recording burst separately, and beach user detection is performed in short time-windows of 5 sequential frames (≈1 s). A global SIGMA (S_G) is initially calculated for the 10 minute-long stack, by randomly sub-sampling the frames. Within S_G, areas with persistent, localized sources of variance are highlighted, typically the swash zone or tree boundaries in windy conditions; random or short-term variance sources due to beach user movement are "smoothed-out" by definition. For each 5 frame time-window, a running SIGMA S_5 is also calculated, and S_G is subtracted from it. A typical result of this stage is shown in Fig. 1b, illustrating the detection of beach users irrespective of the underlying background variability. At this point, standard image operators are applied to S_5, such as thresholding to keep the high variance pixels, image opening to remove random small blobs, and image dilation to uniformly expand the remaining shapes (beach users). The result is a binary image, with the foreground being the beach user pixels. A connected component detector is applied, resulting to a pair of X/Y image coordinates per detection. The process is repeated until the entire frame stack is exhausted. Note that beach user tracking is not performed, i.e. successive detections are not associated in time to form a particular beach user track. Four days with sunny, and four days with overcast/windy weather conditions were selected for analysis with the above methodology, using records from July 2014 (10am to 7pm, 248818 frames in total).

3. Results

Fig. 2 shows the spatio-temporal distribution of beach usage and its relation to weather conditions for a typical, sunny summer day (14^{th} July, 2014), tabulated by hour. The corresponding plot for the following, rainy day (15^{th} July 2014) is illustrated in Fig. 3. The density plots confirm the prominent impact of weather conditions on beach usage patterns. Beach occupation was significantly higher during the sunny day, with most activities concentrated on the beach face. Morning rain resulted to zero beach usage and a shift to recreational activities away from the shoreline during the afternoon.

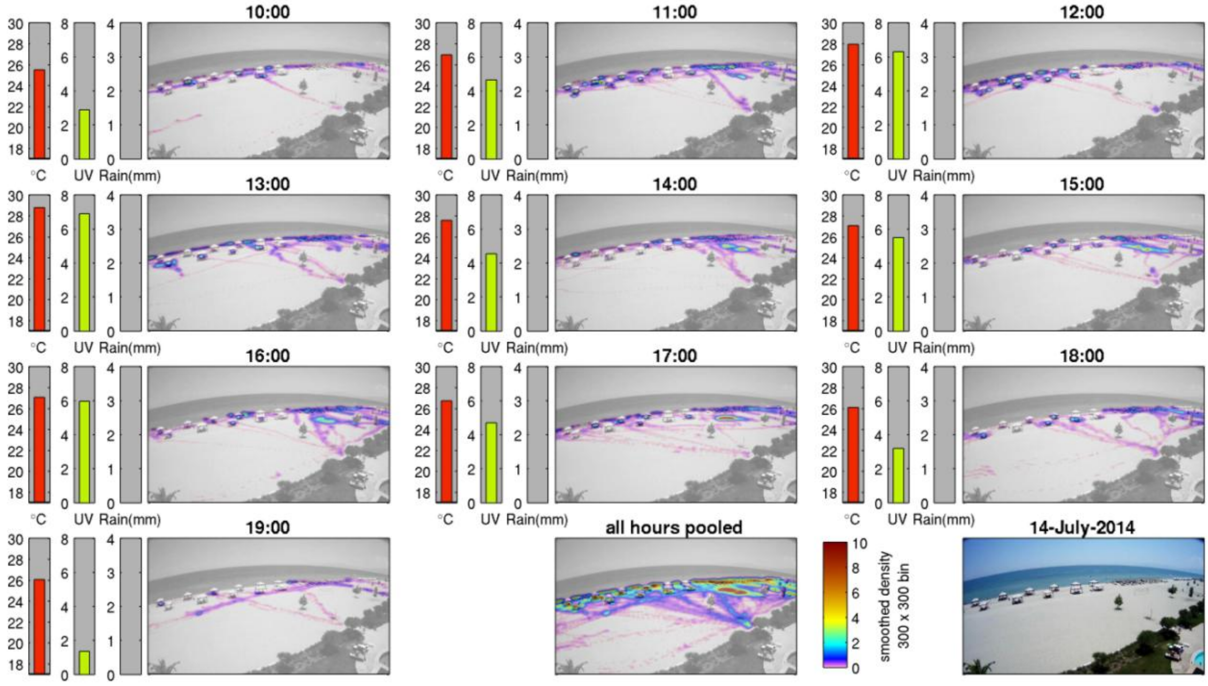

Fig. 2. Hourly beach usage and corresponding meteorological conditions for 14 July, 2014. The image frame is split into 300 equally spaced bins in both directions, and the superimposed pseudo-colored surface is a smoothed, two-dimensional density plot of the total number of beach user detections within each bin. Warmer colors map to higher number of beach user detections; the color scale is the same across all subplots. For each hour, vertical bars show the air temperature (^{o}C), ultraviolet radiation (UV Index), and total hourly rain (in mm).

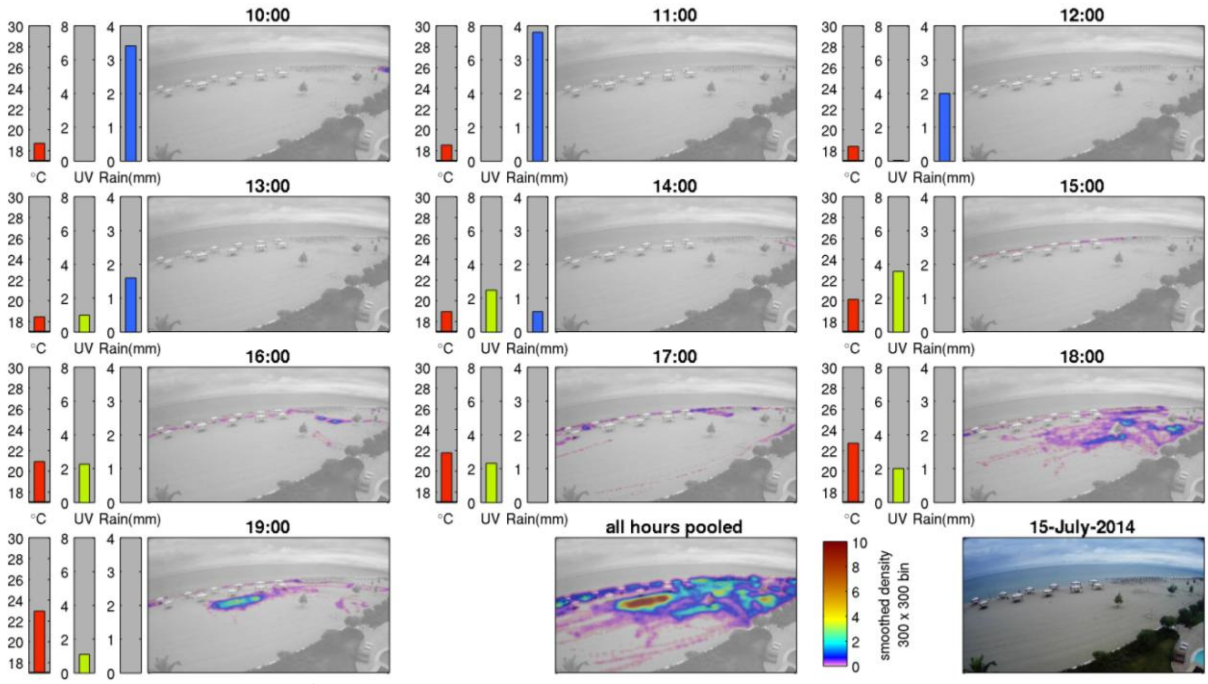

Fig. 3. As in Fig. 2, but for 15th July, 2015; weather conditions were rainy until 14:00, overcast later.

The distribution of total beach usage (Fig. 4a) reveals that most beach users are found within the first 10-15 m from the shoreline, even though the beach width averages to 70 m. Moreover, the results show that locating most tourist facilities in the south part of the beach results to a disproportionate spatial distribution of beach users. Peak beach usage is observed around 11:00 and

17:00 hours, with a noticeable drop during midday (Fig. 4b). This hourly temporal pattern is not observed during rainy or windy days, for which beach attendance appears to be controlled by the meteorological conditions.

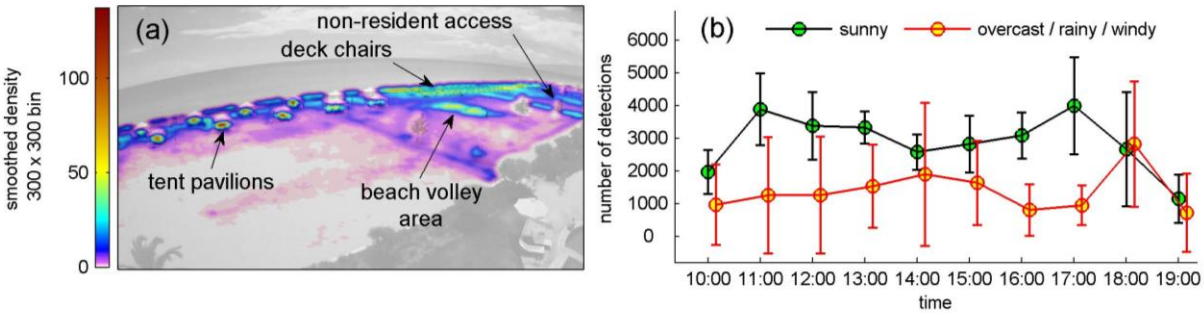

Fig. 4. (a) Distribution of total beach usage, using data from all days analyzed. (b) Number of beach user detections vs. time, pooling data from the 4 sunny days, and from the 4 days with overcast, rainy or windy weather. Note that a single beach user typically contributes to multiple detections over the image acquisition period.

4. Conclusions

Identifying spatio-temporal patterns of beach usage and their relation to weather conditions or coastal infrastructure is critical for managing tourist coastal settings. The results demonstrate that the developed system can provide the necessary information in an efficient manner and help identify high-usage areas. This information is critical for evaluating the implications of beach usage on beach sediment budget or morphological modifications caused by human activities.

5. Acknowledgements

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