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Using citizen science to collect coastal monitoring data

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ABSTRACT

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Coastal monitoring is becoming increasingly important as coastal hazard risks increase due to factors such as climate change. Traditional survey methods are often expensive and require technical skills and special equipment which restricts the amount of data that can reasonably be collected. Results from two citizen science projects are presented to assess what data can be extracted from imagery collected by the public. Schemes which incorporate members of the public in the data collection phase of a project offer the opportunity to engage local groups/communities with important coastal issues, while collecting valuable scientific data which can be used by coastal managers to assess the vulnerability of the coast to coastal hazards.

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ADDITIONAL INDEX WORDS: *coastal monitoring, citizen science, beach management, coastal imagery.*

INTRODUCTION

Tourism and population pressures make coastal areas important for social, economic and environmental reasons. Coastal monitoring is therefore essential in order to understand and protect these environments from coastal hazards such as coastal flooding and erosion. Traditional survey methods use equipment and techniques which require specialist knowledge and skills, and do not lend themselves to engagement with the public and wider coastal groups. This paper presents workflows which use images submitted by the public for coastal monitoring purposes. Citizen science projects, like those discussed here have the ability to collect useful and reliable coastal data, while engaging local communities with important coastal issues.

Background

Contemporary coastal monitoring techniques such as LiDAR (Almeida *et al.,* 2013), ARGUS cameras (Holman and Stanley 2007), GPS (Cooper *et al.,* 2019) and UAV surveying (Mancini *et al.,* 2013; Turner *et al.,* 2016) all require the use of specialist equipment and skills. They also are expensive and do not offer much scope for use and engagement with people who have no prior experience of using them. Some of these methods do not realistically allow the collection of data at regular intervals (days-weeks) over long periods and are often only deployed bi-annually/annually. By incorporating and involving members of the public in coastal monitoring, knowledge transfer can be better targeted and thus provide the basis for informed coastal management decisions which are understood by, and have approval from all stakeholders.

Citizen science is a term used to describe a project which engages members of the public with scientific data collection. It has grown in popularity over the last 5 - 10 years and is now used in a range of different disciplines including ecological monitoring, coastal hazard identification and heritage monitoring (Hecker *et al.,* 2018). The main advantage of such schemes is the ability to collect large datasets which require a reduced input from academic/scientific partners, while engaging local communities with key scientific issues and data relevant in the field (Bonney *et al.,* 2009). Limitations such as data quality control and the timing of data collection have been widely acknowledged.

This paper presents two workflows for obtaining valuable coastal monitoring data by processing of images of beaches collected through citizen science projects.

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METHODS

Images are taken, typically using smartphones, by members of the public at fixed camera points that provide an elevated view over a beach and images are submitted via email and Facebook. The camera cradle at both sites consists of a frame (which fits around the side of a smartphone) mounted on a wooden post. The frame is positioned to ensure the same part of the beach is within view for every image submitted. Images from two camera stations are presented, Newgale (Pembrokeshire, Wales, U.K) and Bournemouth (Dorset, England, U.K). The Newgale site (Figure 1a) is part of the Changing Coasts project run by Pembrokeshire Coast National Park, while the Bournemouth site (Figure 1b) is part of the wider CoastSnap project (Harley *et al.,* 2019). CoastSnap now (as of September 2019) has 40 sites in 9 countries worldwide. Images are sent in from members of the public, along with the date and time of each submission.

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Newgale cobble ridge

The Newgale images were used to monitor the movement of the cobble ridge toe which forms part of the composite beach at Newgale. This ridge provides protection to the inland area behind which is vulnerable to flooding. 136 images were collected between May 2016 and December 2018. The Newgale images were initially quality controlled to remove those that didn't meet the image quality requirements: image quality, shoreline seaward of the ridge toe, visible Ground Control Points (GCPs). Images were aligned, cropped to the same size and resampled to the same resolution. They were then rectified using surveyed GCPs and the technique outlined in Harley *et al.,* (2019). The distance between known points and the camera is calculated and a bird's eye view is created, producing a rectified image which uses the camera position as a point of origin in a local coordinate system. Examples of oblique and rectified images are shown in Figures 2 and 3 respectively. The position of the 900m long pebble bank toe was then manually digitised in every rectified image to establish the coordinates of the ridge toe in every image. Automated techniques similar to those discussed by Harley *et al.*, (2019) were tested but were found to be unsuitable because of the frequent presence of water pooled at the base of the ridge which led to erroneous detections.

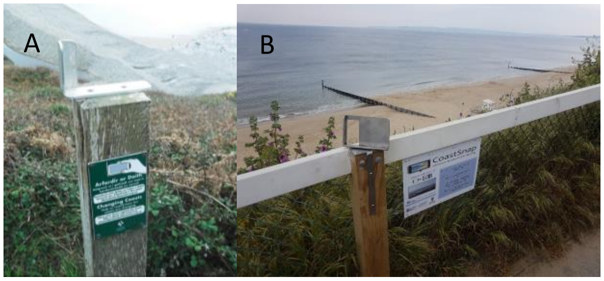

Figure 1: a. The Changing Coasts camera station at Newgale, Pembrokeshire (set up in May 2016). b. The CoastSnap Bournemouth camera station at Boscombe, Bournemouth (set up in May 2018).

Figure 2: An example of an oblique image from Newgale.

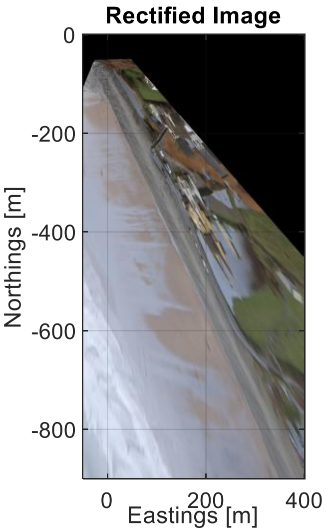

Figure 3: An example of a rectified image from Newgale.

Bournemouth Sand Levels

For the images collected at Bournemouth (Figures 1b and 4), the beach profile against a groyne was detected. Images were again quality controlled and aligned, resampled and cropped to the same size. The sand-groyne interface was identified by detecting the largest pixel contrast between manually defined limits at every pixel along the groyne. A vertical distance-pixel transfer function using the top of the groyne as a known datum was established for every pixel along the groyne using GPS survey data for a series of calibration images. These functions then allow a calculation of the elevation of the sand level along the groyne to produce a cross-shore profile (Figure 5).

Figure 4: An example of an oblique image from Bournemouth.

Figure 5: Sand level detection at Bournemouth with sand level (red line) identified and top of groyne highlighted (yellow line).

RESULTS

Newgale Cobble Bank Toe Movement

To determine the accuracy of the results obtained from the images, the extracted ridge toe positions were compared with GPS data. This was done for two images (5th January 2018 and 4th February 2019). The positions of both lines were compared at 1m intervals and the difference between them was calculated. RMSE was 1.24m and 0.70m for the 2018 and 2019 images respectively. This is comparable with other error/difference metrics reported in similar image rectification procedures (Pugliano *et al.*, 2019, Harley *et al.*, 2019).

Figure 6 shows how the position of the pebble toe varied in relation to its initial position in the first image (image date: 24/5/16). It shows that the position of the toe is very dynamic and changes by up to ±15 m over small temporal scales (days-weeks). Despite this, overall change over the complete monitoring period is small suggesting that the toe is relatively stable in the longer-term.

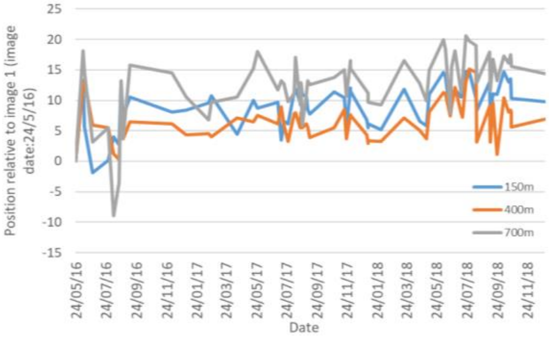

Figure 6: Cumulative pebble toe position at different distances from the camera. 63 images were used. Positive numbers indicate bank retreat and erosion, while negative numbers represent accretion and movement seaward.

This observation is in agreement with an analysis of a limited number of historical beach profiles. Changes in toe position between two consecutive images are frequently observed to be comparable to the overall change during the timeseries, indicating that the ridge is dynamic but stable overall. In general, comparable changes are observed at all locations along the ridge.

Bournemouth Sand Levels

To assess the validity of the profiles extracted, a comparison with GPS data and profiles obtained by taping from the groyne top was undertaken. RMSE between the profiles and GPS data was 0.09m (Figure 7).

54 beach profiles were extracted between May 2018 and July 2019. It is acknowledged that the sand level against the groyne may not be an ideal representation of levels in the groyne bay as a whole because the shoreline rotates within the groyne bay depending on wave direction. Nonetheless, the profiles extracted enable insight into the condition of the beach including the spatial and temporal patterns of beach profile change including berm development and removal. Comparison with adjacent high-resolution Lidar data (not shown) at the center of the groyne bay indicates that the image-based method captures similar patterns of morphological change.

Figure 8d shows the variation of the beach profile throughout the measurement period. Wider bands identify periods where only one image is available. This plot suggests that the berm and the lower part of the beach are more dynamic when compared to upper sections of the beach which is only rarely reached by wave runup. The data suggests that sand movement at the top of the berm (between 10 -30 m along the groyne) can be attributed to more powerful waves (Figure 8c). The upper beach is noticeably stable during the summer (until approx. 1/10/19) and more dynamic during the winter/spring period when wave power is typically larger.

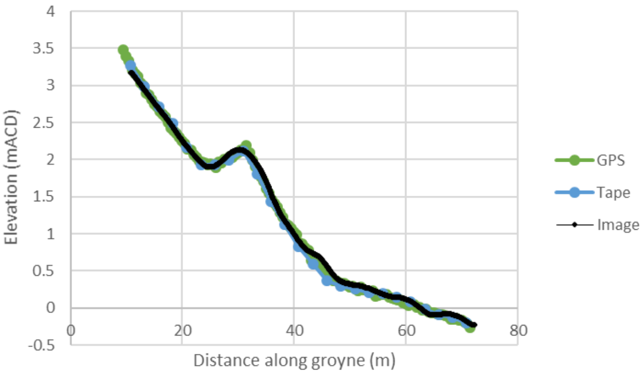

Figure 7: Image profile, GPS profile and tape measurements from 16th May 2018 plotted.

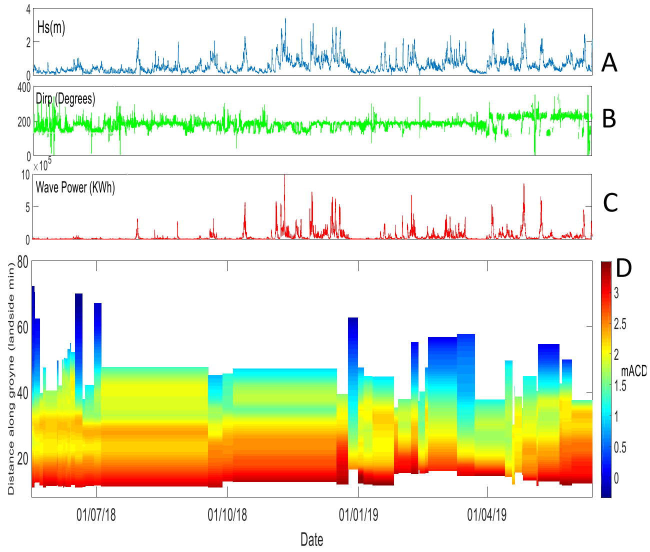

Figure 8: Elevation plot of the 54 profiles. a..H_s, b. wave direction, c. wave power from buoy data obtained by the Boscombe wave buoy up until March 2019 and Poole Bay buoy from April 2019 onwards. Data from Cefas 2019. d. beach profiles (mACD), larger time windows represents period where no other image could be used.

DISCUSSION

The data presented indicate that imagery collected by members of the public can be used to collect data which can be used to monitor coastal processes at a fraction of the cost of traditional survey methods.

Despite this, a potential problem with citizen science schemes is the ability to control the quality of data collected (Hecker *et al.*, 2018). At Bournemouth, 396 images were collected between 16th May 2018 and 31st July 2019 (Figure 9). The first two months of image collection (May and June 2018) proved to be most popular with 45 images each. July 2018 and November 2018 had the lowest number of submissions with 14 each. Out of the 396 images collected, 54 images could be used to produce a beach profile. The reasons for images being discarded are shown in Figure 10. The biggest factor in images not being used for processing was image quality. For the image to be passed, painted lines on the groyne needed to be easily seen and all GCPs within the image had to be clear. Other external factors such as the tide (not allowing the beach to be seen in the image), the presence of people close to the groyne (not allowing the sand-groyne interface to be seen) and lighting (image too dark for sand level detection) reduced the number of useable images further. Despite this, 54 profiles over a period of 14 months still represents data of a good frequency when compared to typical survey intervals for LiDAR flights (annual) and GPS surveys (monthly) for data extraction.

The production of other outputs from the project such as time-lapse imagery and simple two image comparisons were found to be good at conveying information to public audiences. It could be argued that simple approaches (that do not require technical methods) may be more useful for providing information to wider groups and audiences. From a public engagement perspective, the initial act of taking the image can also be seen as important in getting participants to think about wider coastal issues and the reasons why coastal monitoring may be important. A survey as part of this research found that when asked if images collected for the project could be useful for beach/environmental monitoring, 65% of people responded saying the images could be “extremely useful” and 82% said the images were either “extremely useful” or “very useful”. This suggests people who take an image for the project see value in sharing images and thus they are much more likely to contribute further in the future. 91% of participants from the survey who had already taken an image said they would be “very willing” to take an image again for the project.

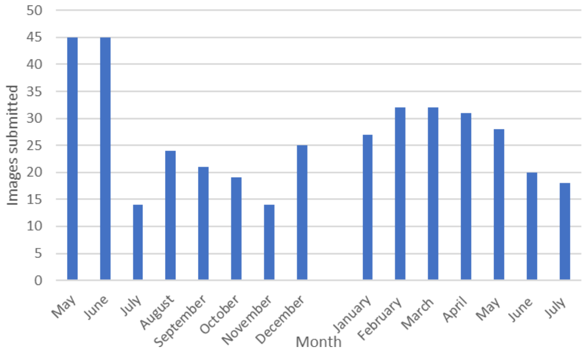

Figure 9: Number of image submissions for CoastSnap Bournemouth from 16th May 2018 to 31st July 2019.

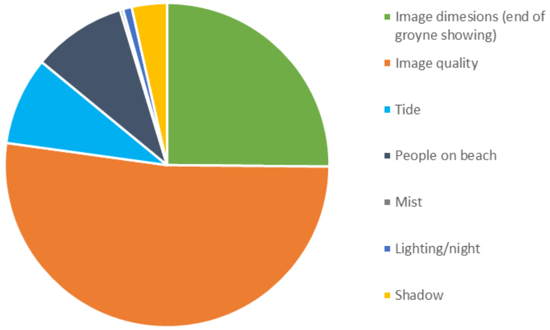

Figure 10: Factors making images unusable for sand level processing at Bournemouth.

CONCLUSIONS

This paper has shown how imagery collected by the public can be used to collect data useful for coastal monitoring purposes. Two citizen science schemes have been introduced, from which different types of data have been extracted, both beneficial for management of these locations. The two methods discussed focus on features with different spatial extents (900m long cobble bank and 70m long groyne) and display good error metrics proportional to the scale of the environment. Issues associated with the usability of images collected are acknowledged, however the importance of incorporating wider groups/people in the data collection phase of projects cannot be underestimated. Projects which require input from the public have great potential for conveying detailed information to a wider audience, while providing a platform for discussion of important coastal issues. Schemes like Changing Coasts and CoastSnap Bournemouth allow the collection of coastal data in a low-cost, simple manner, while promoting the importance of coastal monitoring to local communities.

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