Videometry applied to impact weather characterization: coastal risk in Basque Country

S.Gaztelumendi[1,2], P.Liria[3], A. Diaz de Arcaya[1,2], R.Ruiz[1,2], J.Egaña[1,2],J.Moreno[1,2], I.Epelde[3], A.Picon[4], J.Echazarrra[4], J.A.Aranda[1,3]

1 - Weather and Climate area, Tecnalia BRTA, Vitoria-Gasteiz, Basque Country, Spain
2 - Basque Meteorology Agency (EUSKALMET) Vitoria-Gasteiz, Basque Country, Spain
3 - Operational Oceanography, AZTI BRTA. Pasaia, Basque Country, Spain
4 - Computer Vision area, Tecnalia BRTA, Derio, Basque Country, Spain
5 - Emergencies and Meteorology Directorate, Security Department, Basque Government. Vitoria-Gasteiz, Basque Country.

Abstract

In this contribution we present a local application of videometry for impact weather monitoring, in the field of "maritime-coastal risk: impact on the coast" as defined by the Basque Meteorology Agency (Euskalmet) operational severe weather protocol.

Based on KOSTASystem video imagery, images processing and computer vision algorithms, we have developed an automatic real time wave run-up impact monitoring system in some representative locations for Basque shoreline.

Here we present some details of the operational implementation of automatic recognition systems using computer vision techniques and other relevant aspects for the operational implementation and use of such system. We summarize key characteristics for the videometry system, the generation of different images and products and their integration in the automatic monitoring system and in the operational intranet in Euskalmet/Tecnalia. Finally, we present some conclusions focusing on usability for different operational tasks like analysis, surveillance, prediction and validation.

Introduction

The analysis of coastal environments using video images have proven to be an efficient methodology in different operational and research areas. Videometry systems have been used worldwide to monitor the morphological configuration of beaches, dunes, channels and bars, but in recent years also to obtain reliable information on sea conditions and in the characterization of waves on beaches, among others applications (Liria et al 2021, Epelde et al 2021, Holland et al 1997). In the Basque case, the so-called "KOSTASystem", (see Fig 1) developed by AZTI in collaboration with different institutional agents, allows monitoring different aspects of coastal dynamics in some locations of the Basque Coast based on videometry (AZTI 2022, Liria et al 2021, Epelde et al 2021).

In Basque Country area, Euskalmet (Basque Meteorology Agency) is in charge of impact weather surveillance and forecast, including coastal risk (GV 2018, Gaztelumendi et al 2016, Gaztelumendi et al 2021). To this end, during those last years together with AZTI and TECNALIA, different projects have been undertaken for a better characterization of coastal impact in Basque Country and to develop methodologies for the analysis, surveillance and prediction of this type of phenomenon (e.g. Gaztelumendi et al 2009, 2011, 2014, 2020, Ferrer et al 2009, Egaña et al 2020).

Currently, three main types of maritime-coastal risks are distinguished in the operational impact warning system: those derived from "galernas", those derived from the state of the sea, and those derived from the impact of waves and tides on the coastal strip (GV 2018, Gaztelumendi et al 2012, 2016, 2020). In this paper we focus on the last one.

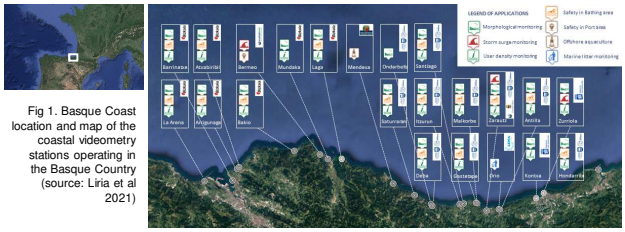

Fig 1. Basque Coast location and map of the coastal videometry stations operating in the Basque Country (source: Liria et al 2021)



Fig 2. Video cameras used in run-up and overtopping surveillance in Bermeo, Mutriku, Donostia- Zurriola, Donostia-Igeldo and Zarautz (from left to right)



Kostasystem description

Videometry system

This coastal videometry system consists of cameras installed on the coast that allow images to be captured and spatially referenced. The KOSTASystem videometry system covers different points of the Basque coast (see Fig 1) including ports and promenades areas. As far as the coastal impact is concerned, videocameras from Zarautz (1 camera), Bermeo (3 cameras), Mutriku (4 cameras) and Donostia (2 cameras) are currently active (see Fig 2).

The control of the KOSTASystem videometry stations is based on the Sirena code developed by IMEDEA. The original code has been modified to include GigE cameras. The current system includes cameras with Gigabit Ethernet interface, with ARM processors. Among the main characteristics of the cameras, the following stand out: 1. resolutions of up to 5 megapixels, 2. CCD and CMOS sensors, 3. speeds of up to 309 frames per second, 3. monochrome, color and NIR capabilities (Liria et al 2021)

Initially, the data is received from each station through a dedicated 4G connection and is synchronized with AZTI using Rsync commands. AZTI periodically transfers the data to the DAEM facilities, synchronizing a system of folders exchange (Gaztelumendi et al 2022)

Images and products generation

For the monitoring and surveillance of the coastal impact, and particularly for the analysis of run-up and overtopping, it is necessary to transform original images captured by videocameras, we highlight here two of the most relevant:

- As long as original images are captured from cameras located on elevated position, we must apply different photogrammetric techniques in order to convert oblique images (from the beach perspective) to plane metric images. For this purpose, at least two visible markers (Ground Control Points) spaced at a known distance perpendicular to the beach are positioned in order to define a range and scale that allow the transformation of horizontal to vertical coordinates.
- The sequences of plane metric images are used for the generation of instantaneous images and integrated in time (timestack) by accumulating over a certain period of time rows of pixels from a defined transect on the image, previously defined for each camera view (see Fig 2). Four time-stack images are generated for Zarautz, Bermeo, Mutriku and Donostia (Igeldo and Zurriola) in order to characterize run-up and overtopping in different key points, based on multiples videocamaras (see Fig 3 and 4).

As long as these transects are properly determined, they will reflect the temporal evolution of the wave run-up and the flooding or overtopping of the body of water in the predefined dry area for different positions into the image (see Fig 3).

Different types of raw and derived images as snap, stack, timex and var (see Fig 4 and table) files are transferred to Euskalmet each ten minutes.

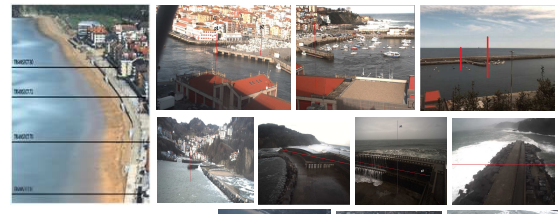

Fig 3. Transects defined for different cameras/location: Zarautz (4), Bermeo (4) , Mutriku (4) and Donostia (Ondarreta (2), la Concha (1) and Paseo de Salamanca (1))

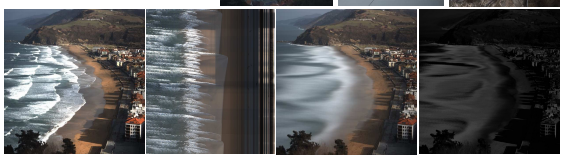

Fig 4. Examples of snap, stack, timex and var images (from left to right) in Zarautz

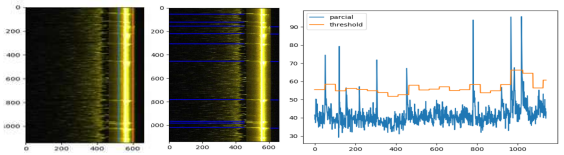

Fig 5. From left to right. Eample of virtual barriers defined in transect 2 in Zarautz for overtopping calculation. Automatic partial (left blue lines) and total (right blue lines) overtops detected. Intensity signal (L channel) in the partial barrier and threshold surpass.

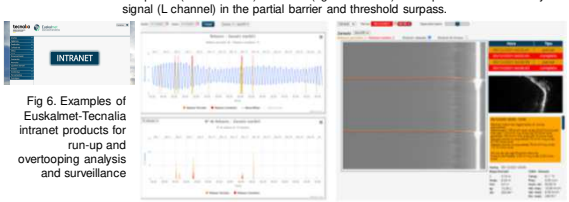

Fig 6. Examples of Euskalmet-Tecnalia intranet products for run-up and overtooping analysis and surveillance

Acronymous	Name	Description	Usage
Snap	snapshoot images	instantaneous capture corresponding to the frame in the middle of the capture interval	Wave fronts, beach occupation, sea state overview
Timex	time averaged images	Image obtained doing the mean of the intensity in the 3 RGB channels in all the pixels along the capture interval.	Mean sea level, coastline evolution, mean wave energy dissipation, beach morphology.
Var	Variance images	Image obtained with the deviation of the intensity in the 3 RGB channels in all the pixels along the capture interval	Maximum run up, maximum breaking zone extension
Stack	time stack	Images composed by the accumulation of rows of pixels along a defined transect with all the frames of the capture interval	Wave evolution monitoring along predefined transects, wave height, wave period, wave run up, wave overtopping

Operational integration in Euskalmet

Once the different images are available on the Euskalmet servers, they are exploited operationally, by integrating them into the different available analysis, surveillance and monitoring systems. Likewise, certain algorithms are applied that allow automatization of identification and characterization of the overtopping events present in the timestack images.

Automatic overtopping detection

Automatic identification of run-up, partial and total overtopping is made, applying to different timestack images some computer vision algorithms like the Otsu`s optimal thresholding and Radon Transform methodologies (Otsu 1979, Almar et al 2012, 2014). Such methodologies are applied to timestack images defined in Zarautz, Bermeo, Mutriku and Donostia (see Fig 3).

For an efficient detection of run-up and overtopping at any time(day, night) or in presence of artifacts that could affect brightness, the first step is to convert the image from RGB to LAB color space, and to focus in the intensity of the image processing the L channel (see Fig 5).

The algorithm is based on the detection of the points where the intensity changes, and this is done according to a pre-established criterion. The threshold is defined depending on the deviation of the lighting intensity in the transect and the area considered in each timestack (Medela et al 2018). There are also a series of special conditions to avoid camera flashes and dark areas in case of using infrared cameras (Gaztelumendi et al 2022).

The outputs of the automatic overtopping events identification algorithm is a marked image with partial and total overtopping (see Fig 5) and a csv file that contains a text line including the date, hour and minute of the each overtopping detected. Based on this information available for each timestack image, different aggregate files are built with the characteristics of the overtops for each location (levels, times, number of partial and total surpass, etc.) in order to be exploited as indicated in the following sections.

Integration in Euskalmet-Tecnalia intranet

The EUSKALMET/TECNALIA Intranet is one of the most relevant applications that supports operational tasks, particularly in relation to analysis, prediction and surveillance. This tool is a key point access to all available information; images, graphs, tables, texts and maps; with full interaction capabilities for historical searches, real-time observation and forecast. In relation to the exploitation of the information on overtopping , highlight three sections that we can summarized as follows:

1) **Overtopping representation graphs.** This section allows to consult all the information through different composites images with the relevant information from the automatic overtopping characterization system (see Fig 6)
2) **Products from each location.** Is this section we include all images for all the products in each available camera in Zarautz, Bermeo, Mutriku and Donostia for a efficient consultation in real time and for historical events (see Fig 5 and 6).
3) **Supervised validation of automatic overtopping.** This tag is designed for the human validation of the automatic system in deferred time. Identifying false overshoots and relabeling images is important for validation purposes and the improvement of the automatic system (see Fig 6).

Surveillance and real time monitoring

Among other applications and operational tools, TECNALIA has developed a monitoring system for hydro-ocean-atmospheric variables (EMER) in order to assist during real-time surveillance of severe situations in EUSKALMET. This system, together with other tools that are executed in the TECNALIA/EUSKALMET surveillance and prediction room, conform the basis for 24x7 operations. The EMER application is designed for data collection from the automatic weather stations, coastal platforms, marine buoys, overtopping system and any other instrument or system that could be actionable for monitoring severe events (radar , meteosat, etc..). Observational data are compared with certain previously established thresholds, if exceedance s detected, different acoustic and optical signals are emitted in order to evaluate potential risk and real time impact under the supervision of the expert staff. The new automatic overtopping detection system is included in EMER, considering the location and the rate and amplitude of the overtopping detected. For this purpose specific algorithms are included for full exploitation of the different files produced by the overtopping automatic recognition system each ten minutes. Incidences are presented in the screen as color code in a coastal map and in tabular format for an easy consult (Fig 7)



Fig 7. Example of EMER interface

Remarks and Conclusions

✓KOSTASystem began working in 2010 in Zarautz, through the collaboration of different public institutions and AZTI. This system was also pioneer (since 2015) in applying different photogrammetric techniques that allow the monitoring of flood situations on the promenade.

✓The sequences of images captured by the cameras are used for the generation of instantaneous images and integrated in time (timestack) by accumulating over a certain period of time rows of pixels from a defined transect on the image.

✓As long as these transects are properly determined, they will reflect the temporal evolution of the wave overruns, that is, the overtopping of the body of water in the dry area of the promenade or port in different positions of the image.

✓An operational automatic system have been set up for run-up and overtopping events detection in different key ports and promenades areas (Zarautz, Bermeo, Mutriku, Donostia). Such data are used in the context of impact monitoring in Euskalmet, with the same philosophy that the coastal risk operational warning system, based on overtopping indexes.

✓Full exploitation of available images and products is based on the direct human examination of images and products for the visual detection of impacts (Intranet) and for the automatic detection of overtops (EMER and Intranet) both with real time and deferred time capabilities.

✓Validation mechanisms have been implemented in order to expand the catalog of labeled images and improve the automatic detection system.

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EUSKO JAURLARITZA GOBIERNO VASCO
HERRIZAINGO SAILA
Herrizaingo Saiburuordeza
Larrialdiei Aurre Egiteko eta Meteorologiako Zuzendaritza
DEPARTAMENTO DE INTERIOR
Viceconsejería de Interior
Dirección de Atención de Emergencias y Meteorología

Euskalmet
EUSKAL METEOROLOGIA AGENTZIA

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Contact info:
santiago.gaztelumendi@tecnalia.com
TECNALIA
Parque Tecnológico de Bizkaia
C/ Geldo Edificio 700
E-48160 DERIO (Bizkaia) Spain
www.tecnalia.com

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