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Development and validation of a video analysis software for marine benthic applications

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ABSTRACT

Our aim in the EU funded JERICO project was to develop a flexible and scalable imaging platform that could be used in the widest possible set of ecological situations. Depending on research objectives, both image acquisition and analysis procedures may indeed differ. Up to now the attempts for automating image analysis procedures have consisted of the development of pieces of software specifically designed for a given objective. This led to the conception of a new software: AVIExplore. Its general architecture and its three constitutive modules: AVIExplore — Mobile, AVIExplore — Fixed and AVIExplore — ScriptEdit are presented. AVIExplore provides a unique environment for video analysis. Its main features include: (1) image selection tools allowing for the division of videos in homogeneous sections, (2) automatic extraction of targeted information, (3) solutions for long-term time-series as well as large spatial scale image acquisition, (4) real time acquisition and in some cases real time analysis, and (5) a large range of customized image-analysis possibilities through a script editor. The flexibility of use of AVIExplore is illustrated and validated by three case studies: (1) coral identification and mapping, (2) identification and quantification of different types of behaviors in a mud shrimp, and (3) quantification of filtering activity in a passive suspension-feeder. The accuracy of the software is measured comparing with visual assessment. It is: 90.2%, 82.7%, and 98.3% for the three case studies, respectively. Some of the advantages and current limitations of the software as well as some of its foreseen advancements are then briefly discussed.

Software availability

Name: AVIExplore
First available: 2015
Language: Microsoft Visual C# and C++
Requirements:
-Hardware: Pentium PC or equivalent with at least 2 Gb of RAM
-Software: Microsoft Windows 7. Microsoft Framework v4.5. The AVI standard is used and the compression format selected is Microsoft MPEG4 Version 2
Software size: 77 Mb
Availability: on request to authors
Free for research and educational purposes.

1. Introduction

Imaging technologies are currently used to address different questions related to marine benthic ecology (see Solan et al., 2003 for review) including: (1) the assessment of benthic biodiversity (Mallet and Pelletier, 2014; Spencer et al., 2005), (2) the study of faunal composition (Cuvelier et al., 2012; Duffy et al., 2014), (3) habitat mapping (Williams et al., 2012), (4) the characterization and quantification of behaviors and biological activities (Grémare et al., 2004; Jordana et al., 2000; Maire et al., 2007a; Matabos et al., 2011; Matabos et al., 2015), (5) the quantification of sediment reworking (Bernard et al., 2012; Maire et al., 2007b), and (6) ecological quality assessment (Rosenberg et al., 2009).

Imaging is a non-destructive technique that: (1) allows for the saving of initial raw information and thus for potential re-analysis, and (2) records both visible benthic organisms and other biological/biogeochemical parameters resulting from biological activity such as the apparent Redox Potential Discontinuity on Sediment Profile Images (Romero-Ramirez et al., 2013). The reasons for choosing imaging technologies differ depending on the aim of each study. As an example, benthos and epibenthos sampling strategies at deep seabed present some difficulties (Jamieson et al., 2013): (1) the use of trawls and sleds does not allow for quantitative samplings, (2) the use of traps and suction samplers result in biased samplings due to differences in feeding regimes and motility, and (3) the deployment of grabs and box corers is complicated by the use of long wires and possible heterogeneities in sediment penetrability. Furthermore there are several

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designs for sampling epibenthos and their efficiencies are substrate-dependent (*i.e.* beam trawls for soft bottoms or suction samplers for hard bottoms). None of the sampling gears are recommended as a standard for a quantitative epibenthos assessment across all substrate types (Rees and Service, 1993). Moreover, some species from the epibenthos community are very mobile, making them difficult to capture when sampling. In this context, video and image analysis has proven to be an alternative and sometimes the only (*i.e.* hydrothermal vents, Cuvelier et al., 2012) *in situ* tool adequate to assess the epibenthos at all substrate types in a qualitative and/or quantitative manner.

In or *ex situ* imaging devices for benthic surveys can be deployed from different platforms (Smith and Rumohr, 2013), which can be divided into two main types: static platforms such as benthic landers (Roberts et al., 2005), and (2) mobile platforms such as remote operated vehicles (ROV) or autonomous underwater vehicles (AUV). Each type of platform provides image sequences with their own specificities that have to be taken into account during processing. Both static and mobile platforms produce series of images often acquired under different light conditions (especially when deployed in shallow waters) because of: (1) changes in water turbidity, (2) changes in the intensity of natural light, and/or (3) the development of biofilms. In addition the series of images derived from mobile platforms need to be geo-referenced to produce sound habitat mapping.

Although the use of automated image acquisition systems is clearly currently spreading worldwide (Mallet and Pelletier, 2014), corresponding analyses are still most often achieved visually (Cuvelier et al., 2012; Matabos et al., 2011; Sarrazin et al., 1997; Spencer et al., 2005; Vertino et al., 2010). Significant efforts have been made to automatically or semi-automatically process isolated images using either generic (Birchenough et al., 2012; de Moura Queirós et al., 2011) or specific software (Teixidó et al., 2011; Romero-Ramirez et al., 2013). With the arrival of newer video sensors, the tendency towards increasing video duration, image resolution and time frequency acquisition, makes corresponding image analysis very time-consuming (Edgington et al., 2006). Locating sequences of images containing important information would lighten this task (Lebart et al., 2003). Moreover, the complexity of the information contained in each image makes it highly operator-dependent (Cuvelier et al., 2012; Germano et al., 2011). There have been some attempts to generate automated image-analysis procedures (Aguzzi et al., 2011; Edgington et al., 2006; Kannappan and Tanner, 2013; Lebart et al., 2003; Mane and Pujari, 2014; Nowak et al., 2008; Romero-Ramirez et al., 2013; Teixidó et al., 2011). These have included both the automatic detection (Aguzzi et al., 2011; Edgington et al., 2006; Kannappan and Tanner, 2013) and in some cases even the identification of large epibenthic organisms on videos using either fixed (Aguzzi et al., 2011) or mobile cameras (Edgington et al., 2006). Given the large variety of possible applications of imaging in benthic ecology, a flexible software, which could provide users with an assistance for the widest possible set of all applications is however clearly still missing.

One of the aims of the JERICO project (http://www.jerico-fp7.eu/) was to develop the use of image analysis techniques to monitor a large set of biological components and processes recorded either at high frequency and/or over large spatial scales using automated or semi-automated procedures. In this context, we report here on the AVIExplore software that provides a unique flexible environment for automated video analysis. AVIExplore proposes different interfaces to analyze videos originating from imaging devices set on mobile and/or fixed platforms. The principal features of AVIEplore are: (1) to provide image selection tools allowing for the division of videos in homogeneous subsections, (2) to allow for the automatic extraction of targeted information, (3) to propose solutions for long-term time-series as well as large scale image acquisition, (4) to allow for real time acquisition and in some cases real time analysis, and (5) to provide a large range of customized image-analysis possibilities through a script editor. This paper presents the principles and the structure of the AVIExplore software. Its capacities are also illustrated *via* the presentation of several case studies for which it has already been used. These include an: (1) automated search for coral colonies in a video recorded using a mobile imaging platform, (2) automated behavior identification of *Upogebia pusilla* within the sediment column of a thin aquarium based on a video recorded using a fixed device, and (3) automated assessment of temporal changes in the filtering activity of a passive suspension feeding benthic species based on a video of the sediment surface recorded with a fixed device.

2. AVIExplore software description

2.1. Generalities and common features

AVIExplore is a software that allows acquisition and analysis of standardized AVI videos. It presents a graphical user interface (Fig. 1) that allows access to three different modules:

(1) AVIExplore — Mobile. This module allows the extraction of information from videos taken with mobile sensors and cameras. It has two working modes: real time and recorded video.
(2) AVIExplore — Fixed. This module allows for the survey of activity on surfaces by using videos taken with a fixed camera. It has two working modes: real time and recorded video.
(3) AVIExplore — ScriptEdit. This module can be seen as a tool that allows writing and testing scripts in view of their use in the other two AVIExplore modules. It is however a standalone module that can be used to compute data from videos or images.

The three modules of AVIExplore use a similar internal structure (Fig. 2). Images are extracted from video sources; each incoming image being called ‘Origin Image’. The result of applying an operation (for example contrast enhancement) on an ‘Origin Image’ is saved as a ‘Work Image’. If the user needs to apply a second operation, he can either save it as ‘Secondary Work Image’ or rewrite on the initial ‘Work Image’. In order to speed up operations, it is possible to work with grayscale images, which are then saved as a ‘Gray Image’. Operations can be bidirectional as a ‘Work image’ can become an ‘Origin Image’. However, in this case, this transformation is not reversible as the return to the initial ‘Origin image’ is impossible. A mask is a tool used to select a subset of pixels in an image. These masks can be directly drawn by the user or computed using a script. Binary hexadecimal masks are used as internal structures to store intermediate information. They can be saved and loaded using an external file (*.msk). Other regions of interests (ROIs) can also be drawn by the user and saved in a different external file (*.roi). ROIs can be converted in internal binary regions for computations.

External files are similar within the three modules. They gather different types of information (Fig. 3): (1) the AVI input file (main input), (2) script files to process images (processing), (3) ROI files to store working areas (service), (4) mask files to get fast mask loading (service), (5) data and companion files to store intermediate results (information), (6) time and position files which can be of interest for image tracking collected with mobile carriers (information), and (7) export information in text files.

The graphic user interfaces of each of the three modules share a similar structure with: (1) a displayed window, (2) a strip menu, and (3) a scrollbar for video timing. However, depending on the module, the functionalities present on the left side of the window may differ (Fig. 4).

AVIExplore can be used for different purposes namely: (1) image acquisition, (2) testing of image-analysis procedures and image analysis *per se* (Fig. 5). The user may consider AVIExplore real time acquisition mode (which is present within both the AVIExplore — Fixed and the AVIExplore — Mobile modules) for acquiring a video to be analyzed with another module. During testing, different functions can be tried