"Pepe": A Novel Low Cost Drifting Video System for Underwater Survey

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***Abstract*— Worldwide, the utilization of underwater video technologies has increased exponentially over the last decades for scientific and commercial purposes. The high quality and diversity coupled with the cost reduction of equipment's facilitated its utilization among scientists. Remote Operated Vehicles (ROVs) and Drift Cameras (DC) are the most used remote operated vehicles. In Argentina, despite cost reductions the use of remote operated vehicles is still scarce. On this work, a DC equipped with a novel system to measure objects is presented, together with data acquisition protocols and processing and a precision & accuracy test. The DC was built at low cost and operated satisfactorily from small boats up to 82 m deep in a wide range of visibility conditions. It was possible to identify and measure animals up to 2 cm of total length with an accuracy of 8%, estimate their abundances accurately and geolocalize any object or animal captured on video imagery with an error of 5 +- 2,16 m.**

***Resumen*— A nivel mundial, el uso de cámaras de video submarinas para fines científicos y comerciales tuvo un gran crecimiento en las últimas décadas. La mejora en calidad de equipos y la reducción de sus costos, sumados a una gran diversidad de sistemas de toma de datos ampliaron significativamente su utilización en el ambiente científico. Los vehículos operados a distancia (ROVs) y las cámaras de deriva (CD) son los vehículos controlados remotamente más utilizados. En nuestro país son pocos los antecedentes del uso de este tipo de tecnologías a pesar de la reducción de sus costos. En este trabajo se muestra un equipo CD de bajo costo equipado con un sistema novel de medición por medio de cables, los protocolos necesarios para procesar las imágenes capturadas y los resultados de una prueba de precisión. El equipo se utilizó satisfactoriamente desde pequeñas embarcaciones hasta los 82 m de profundidad y en condiciones de baja luminosidad y visibilidad. Fue posible identificar y medir animales de hasta 2 cm de longitud con una precisión media del 8%, estimar su abundancia de forma precisa y geolocalizar cualquier objeto o animal registrado en las imágenes de video con un error de 5 +- 2,16 m.**

I. Introduction

Underwater video systems (UVS) have been incorporated for a wide range of human activities in recent years ([2] and [3]). Regarding scientific activities, on the last 60 years UVS were incorporated into studies in which traditionally sampling methods present limitations (such as traps, trawls, diving, and even fishing) ([1], [2], [3], [4] - [9]) and, furthermore, became in powerful tools for habitat mapping and resources monitoring ([5], [7] and [9]). The video imagery allows the extraction of information about the populations and environments nondestructively; the sizes of the organisms can be estimated objectively and unbiased, and its permanent record allows repeated estimates and multiple analysis [2]. Drawbacks of video imagery have low probability of recording small (< 2 cm) or cryptic species and its limited utilization on turbid waters (>1 meters of horizontal visibility is necessary).

The equipments used to conduct studies in underwater environments could be divided into two groups: those which require a diver to be operated and others remotely operated. The ROVs (Remote Operated Vehicles), which have their own propulsion, and cameras that are towed from boats (e.g. drift cameras or sleds), are the most common devices operated remotely. Despite the multiple application of ROVs, its spatial coverage is limited compared to an autonomous vehicle or drift cameras (DC) [9]. The DC can provide clear images of benthic habitat and its inhabitants, covering large areas rapidly, without causing impacts on the environment at a lower cost than ROVs, even in places with current and/or low visibility ([10], [11], [5], [6], [8] and [12]). These factors coupled with recent technological advances related to video quality, costs reductions and geographic positioning systems improvements, makes the DC a tool with high potential to quantify biophysical variables of large underwater areas.

In order to estimate the size of objects on the video imagery with all types of video devices, two main techniques are used: (I) pairs of parallel laser pointers attached to a camera or support structure (e.g., [12], [13] - [17]) and (II) stereo-video systems ([18] - [21]). The stereo-video systems enable highly accurate determinations of objects size, at expense of high costs of the equipments and the post-processing of images. In the case of single camera devices, the lasers pointers are traditionally used to insert on the video imagery a reference of known size. However, this reference should be at the same distance of the measured object to produce accurate estimates [22].

In Argentina, despite the cost reductions, the usage of video systems for the characterization and mapping of benthic communities is scarce [23]. In this work a DC equipment is presented with a novel system to estimate abundance, size and/or area covered by any animal, algae or objects *in situ*, using a single camera. This system incorporates a fixed scale as size reference on the video imagery captured over the seabed (steel cables). In addition, technical details of the DC, video imagery capture,post processing protocols and preliminary results of an accuracy test are shown.

II. MATERIALS AND METHODS

A. Development of the drift camera and operation protocol

A.1 Prototype development

The DC structure Fig. 1 sustains two cameras simultaneously, one vertically oriented on the seabed (slave) and other forward oriented (in the forward direction or drift) (exploratory). The structure has 177 cm total length, 50 cm of maximum width and 28 cm height. The exploratory camera is connected to a color monitor of 7 inch with a class 5 FTP (Foiled Twisted Pair, with overall screen and supporting steel wire).

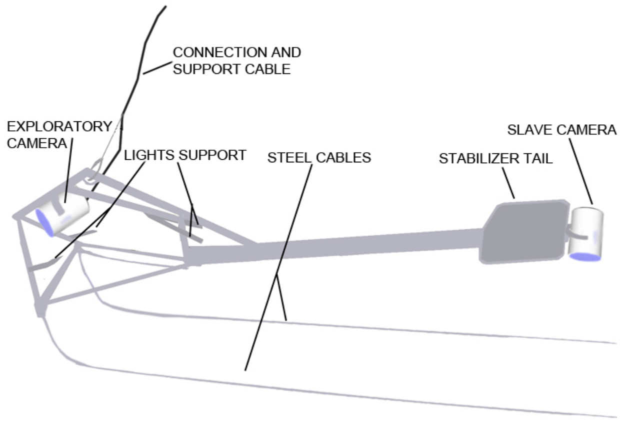

Fig. 1 Detailed diagram of all parts of the DC from left to right: exploratory camera, support and connection cable, support for lights, steel cables, stabilizer tail and slave camera.

The exploratory and slave cameras are hold on plastic matrixes inside compartments built to withstand large depths (tested to 100 m deep) that has enough space to incorporate laser pointers, lighting or other tools or sensors that may be required. Compartments are entirely made of stainless steel with an acrylic lid of 20 mm. The slave camera is located on the back of the DC and does not have a wire connection to surface. The DC has steel cables attached to the front of the structure. The parallel cables of 4 meters length maintain a fixed distance to the sea bed and are used as scale in the video imagery captured by the slave camera (Fig. 2).

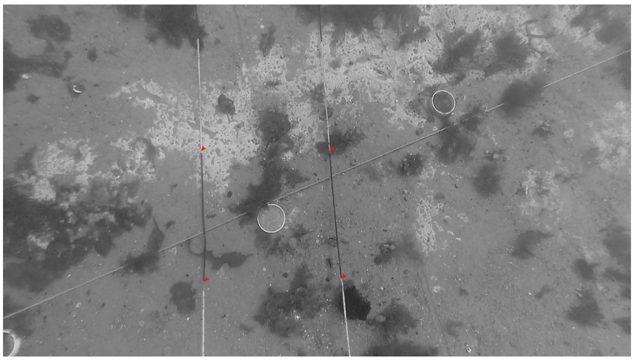

Fig. 1 Detail of steel cables captured by the slave camera. The cables are separated 500 mm. Red triangles mark intervals of 500 mm along each cable.

All video cameras used in this experiment were GoPro (Hero 3 and 3+ silver edition models), video resolution was selected at 1080p = 1920x1080 pixels (16: 9).

A.2 Data collection

Data is collected on video-transects. The DC is slowly towed (up to 2.5 knots) at 1 m height from the seabed. This height could be regulated manually or by a winch. For this study a small semi-rigid boat was used, however, larger vessels can be used. During deployments, video imagery and GPS data recording are synchronized by time in order to geo-reference images.

A.3 Data analysis

The following protocol was used for the video analysis:

1. *Processing videos*. Sony Vegas software (SVS) is used to generate a plain text where each of the "records" or "events" is associated to the time line of the video imagery. The "edit details" tool is utilized to create a template that records events by using a "hot key" (in this case animals or objects in the background). The registries are saved in an output file (e.g."events-time.txt"). If only the size of the objects is required, the following step of the protocol should be skipped.

2. *Reproduction and counting*. Counts are performed directly on video playback. The SVS allows the operator to reduce or increase the playback speed. Objects in the visual field of the camera could be registered at regular intervals (e.g.: 3 seconds). When counts are based within the area bounded by cables, an instant estimate of immediately density is obtained, since the width and the length of transect are known by GPS tracking and the separation of cables.

3. *Extracting images*. To estimate the size of the objects on the video imagery it is necessary to obtain a snapshot image of the object. The plain text of data produced on the step 1 of the protocol is used for an automatic extraction process performed with the tool *avconv* Libav using a script written in bash. Snapshots of each of the registries are obtained as result of this procedure.

4. *Images edition*. Image quality adjustments (Brightness and contrast) of snapshots using image editing software's could facilitate the sizes estimation by improving the details in the boundaries of objects. This step in the protocol is not always necessary.

5. *Measuring objects*. Size estimates are made on snapshots (taken on step 4) using the free software ImageJ. The "Straight" tool and the "Analyze" option of the ImageJ are used to set scale on the basis of an object or scale of known size. This procedure re-scales the whole picture and thus it is possible to measure any other object. In this design, the novel steel cables system (spaced 500 mm) was used as shown in Fig. 2. Measurements are made with the "Straight Line" tool. The program automatically calculates the distance between two points and stores the values in a text file format.

6. *Georeferencing*. To calculate the geographical position of any object or animal captured on video imagery, the track recorded by the GPS (on the towing vessel) should be synchronized with video time. The point in time of registries obtained in step 3 this protocol are used to locate this event on the GPS recording (track points). This procedure permits to quickly obtain the position of the captured snapshot.

B. Calibration

The protocol mentioned above together with the equipment developed and novel measurement system was tested in the field to assess the precision in estimates of size, abundance and geographical position of objects. To this end, 200 objects of known size (PVC pipe sections) were arranged regularly in the seabed at 8 m depth. A rectangular grid of 12 X 50 meters was delimited by four buoys in which the object of known size was deployed tied in four main lines. Twenty five objects were identified by numbers and geo-referenced in order to evaluate the error of the position estimated by the DC. Fifteen video-transects were performed inside the grid. Counts and size estimations of the objects were performed following the previously mentioned protocol.

III. Results

The inflatable boat used for this experiment (4.9 m semi-rigid) was a suitable platform for the handling and use of the DC designed. The deployment requires the joint work of two operators, one that manually graduates the camera height from the seabed and the other controls the depth of the camera via the monitor and the GPS and video data recording. The DC operation is simple and can even be conducted with waves and with low visibility conditions (to <80 cm). The video connection to the surface and manual traction cable were suitable for DC control and effectively avoid collisions in rocky areas. The possibility to control from a Smartphone or tablet the cameras used in surface via Wi-Fi and GoPro App facilitated the development of the camera housing reducing costs and complexity. On the other hand, the high light requirements of the GoPro cameras demanded the usage of high power lighting when natural light was poor.

The incorporation of artificial light was needed at depths greater than 40 meters (depends on local conditions).

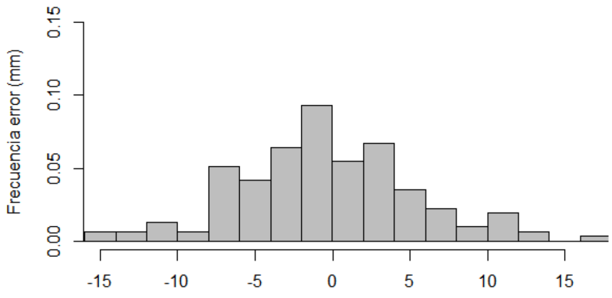

Fig. 2 Histogram of frequency of absolute error in estimating sizes for DC developed.

Unbiased estimates of size with a relative accuracy percentage of 8% in objects ranging between 110 and 25 mm in diameter was obtained Fig. 2. However, it is remarkable that smaller objects and invertebrates are identified and measured. The abundance estimated by direct counts on video-transects was 0.38 + - 0.073 discs / m^2. The standard deviation of this estimate includes the actual abundance (0.33 / m^2 per square meter). On the other hand, the position of objects was estimated with an average error of 5.15 meters and a standard deviation of 2.16 meters Fig 4.

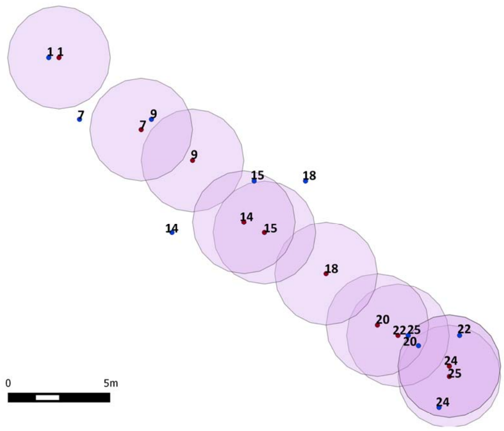

Fig. 3. Red points show the position of tube pipes sections geo-referenced to evaluate the geo-referencing error with the DC. Blue points show the position estimated using the DC. Violet circles shows a buffer of 5 m (considered as error GPS).

IV. Conclusion

This paper shows that the developed DC can be an efficient and economical method to determine *in situ* the size, density and location of mobile and sessile benthic organisms. The main advantage of the system, not shared with other DC systems previously described in the literature, is the novel system used as fixed reference scale. This system allowed in simply and low cost manner to determine the width of the video-transects and thus reduce post processing time and costs. Cables are of easy maintenance, replacement and do not contain any electronic or electrical component susceptible to failures or maintenance. In addition, the DC developed was built with materials readily available and inexpensive (or recycled material) and the processing protocol of the images can be applied entirely using free software's.

Finally, remains left to explore the usage of cameras suitable for low lights conditions to diminish the requirements of artificial light, and thus reducing the costs of equipment's and operation, including the processing for optical correction.

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