XeoTV: 1080p Underwater Geotagged Video with Deferred Filtering

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Abstract – *we present a system to record high definition underwater video with geotagging information. This system allows the user to detect salient features of the seabed and map them accurately. Those features are often difficult to perceive due to the complex recording environment, therefore image filters are used to highlight them. However standard compression algorithms do not store enough information to apply the most sensitive filters, and if he video is compressed with wrong filter settings some details are lost. Our system is designed to compress high definition video while retaining most raw data, and thus allows the user to apply different image filters offline. With this system, it is possible to analyze and cartography sections of the seabed with an unprecedented amount of detail.*

Keywords – *Video, Geotagging, Cartography, Seabed.*

I. INTRODUCTION

XXI century is said to be the century of our seas. The XX century saw an incredible technological development, but only a small part of was devoted to the seas. And when it was, it exploded the marine and subsea resources. XeoTV is a tool we hope that will contribute to make people perceive the enormous richness of the seafloor and how much all of us depend on it.

II. SEABED RECORDINGS UNTIL NOW

Although there are many records of the seafloor, those cannot be used to track the evolution of the seafloor because they were stored in analog formats (VHS, Beta, etc.) and lacked geotagging information. There are systems designed to allow manual insertion of GPS coordinates in the streams, but the task is difficult due to the lack of visual references in the seabed.

In 2010 we developed XeoTV [1], an application to record submarine video to a computer, and its complementary visualization tool: Visor XeoTV (Fig. 5), which shows the submarine video and linked to a georeferenced map. The map shows a line with the route where the video has been recorded (*i.e.* trac) and a dot showing the location of the frame being currently displayed.

Fig. 1. Underwater skate equipped with the XeoTV system, used to record the status of the seafloor.

III. HIGH DEFINITION VIDEO RECORDING

The underwater recording system (Fig. 1) binds a 3.1MP custom designed camera to a 4-core ARM Cortex-A9 CPU used for compression, filtering and communication purposes.

The camera provides 1080p video at 12fps or 720p at 24fps, dynamically selected by the camera operator. The image provided by the CMOS sensor captures color through a bayer pattern [2] which provides distinct red, green1, green2 and blue channels 8(Fig. 2)).

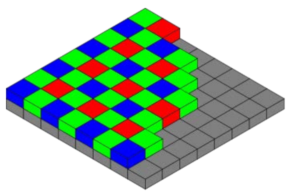

Fig. 2. Bayer pattern provided by the CMOS sensor.

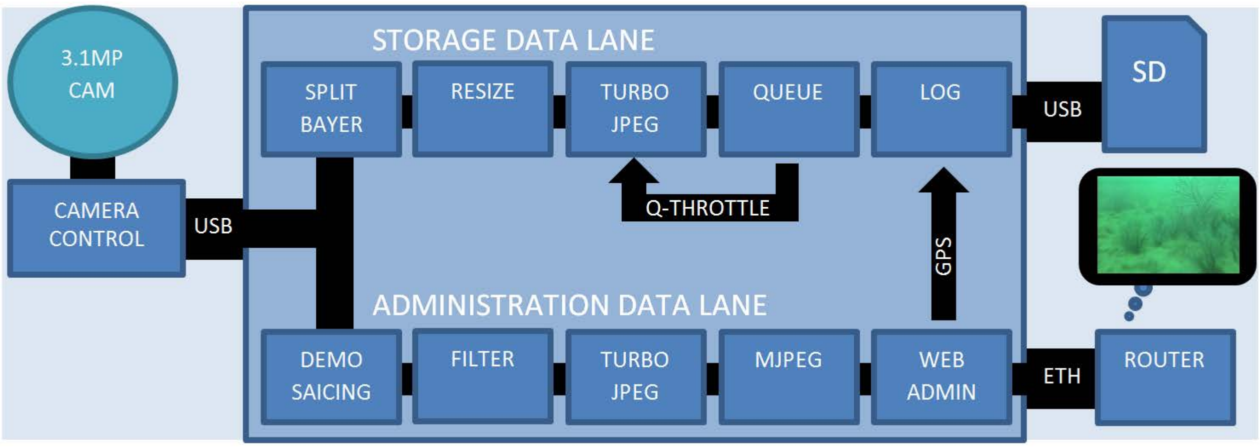

Fig. 3. The recording system. Video is captured at high resolution from the camera and sent raw to the processing board (center box). There is split in two lanes. The storage lane stores the raw data in a SD card. JPEG compression is throttled using the Queue length as indicator. The admin lane sends a live feed to the operator using Ethernet and WIFI.

A. *Deferred Filtering through Chromatic Splitting*

The process of extracting an RGB image from a bayer patterned image is called demosaicing [2] and consists on interpolating the missing color components from neighboring pixels. Although the process is conceptually simple, the basic approaches deal poorly with edges and, in general, some color information is lost during the process (*e.g.* chromatic resolution)[3].

This problem is exacerbated by further compression algorithms (*i.e.* JPEG [4]) which makes impossible to recover cleanly the original image. Most compression algorithms use human vision models to determine which information is unlikely to be detected by the human eye, and thus can be safely dropped. As we are more sensitive to luminance than chrominance, the chromatic artifacts introduced by the compression algorithm are not noticeable.

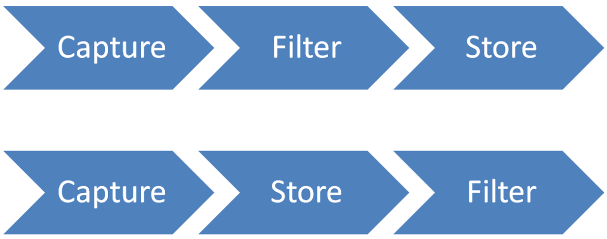

Fig. 4. Top: common seafloor recording mode. The filter is adjusted online and, once stored, can not be re-filtered without a considerable quality drop. Bottom: Approach used by XeoTV HD. Camera information is stored almost raw and filtered *a posteriori*, this allows to apply different filters to the same sequence with no quality drop. This functionality was impossible until now.

However colorspace equalization (*e.g.* filtering) is required to compensate for the degrading image conditions common in seafloor recordings. Depending on the depth of the recording, water turbidity and sunlight, the colorspace must be modified to enhance the contrast of the interesting seafloor features in order to inspect them. This operation is not unlike the white-balancing engine that most sensors have embedded to compensate for illumination changes in open air photography, but being more complex in nature, needs human intervention and deep knowledge of the environment.

Due to the not-reversibility of the compression operation, current seafloor recording systems apply analog or digital color filters before the image is being compressed for storage. Therefore the filter settings chosen at the time of recording cannot be modified afterwards, and if a feature is undistinguishable at those filter settings, it cannot be recovered independently of the postprocessing operation applied *a posteriori* to the video: the information is lost (Fig. 4).

The easiest solution to enable deferred filtering capabilities to a system is to store the data from the sensor without any modification (*i.e.* raw, lossless coding). However, the sheer amount of data coming from the sensor causes memory transfer bottlenecks between the communication channels of the full system (DMA, USB, storage, etc.). Furthermore, the storage requirements would be too high and the management times (*e.g.* downloading the videos from the device) would be unacceptable.

In XeoTV HD we use an intermediate format where each different color channel is independently stored using JPEG compression as if they where a 4 different luminance images. The quality settings of the JPEG compressor are set to near-lossless compression. This system allows to record images at almost raw quality, and without any chrominance based artifacts while obtaining a compression ratio between 10 and 15.

The key of this format is the splitting between the bayer patterns. This allows to skip the demosaicing step, and allows us to apply complex edge-aware demosaicing algorithms *a posteriori*.

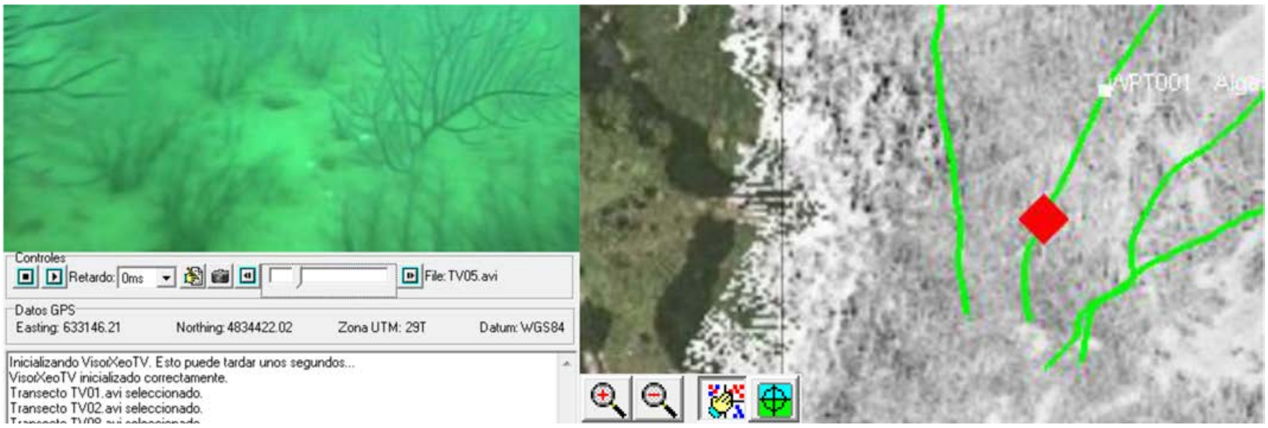

Fig. 5. The XeoTV Visor interface. It links the video recordings (left) with the map (right). The current visualized frame is highlighted in the map as a red dot, and all recorded trajectories are marked with green lines. Note the white marks denoting Points-Of-Interest (*i.e.* WPT001).

B. Online Visualization

Although the main contribution of XeoTV HD is the ability to apply deferred filtering to seafloor recordings in an unprecedented quality, the system has the capacity of applying the usual pipeline in order to operate the device. In this case a potent but efficient demosaicing algorithm is applied, the resulting image is filtered, resized and transmitted (through MJPEG compression) to the operator. The visualization and the operating interface are web-based, so a wide variety of devices can be used to operate the device. Also multiple concurrent operators, and remote operators are supported (see Fig. 3).

C. System Architecture

We used a power efficient quad core ARM processor to keep the power usage and temperature low.

The system runs a linux based operating system with enhanced power-balancing abilities. This system disables cores that are not being actively used, and keeps their cpu frequency low to further diminish consumption.

To use this capabilities, our smart controlling agent throttles the demand of the CPU through the variation of the JPEG compression settings: a higher quality setting creates bigger images and thus uses more resources and power. Usually 1 core is fully utilized to store the recorded image in the internal solid state storage, and .7 cores are used per each visualizing operator that is connected to the device.

D. Communication

Natively XeoTV HD provides Ethernet communication, this allows 100m length copper cables or even larger distances when using fiber. Onboard the surface platform, the cable can be optionally connected directly to the operator computer, but it most cases it is preferable to use the integrated router that provides WiFi access, therefore the system can be operated using a tablet device.

IV. GEOLOCALIZATION

GPS data is captured on the surface and transmitted to the underwater system through the management link. This link is also used to ensure correct clock synchronization between GPS and the recording system, required for accurate seabed localization. The underwater system compensates for distance and depth, and stores modified GPS coordinates corresponding to the current seabed location alongside the video. Interpolation is used between GPS updates to tag accurately each frame.

V. ANALYZING RECORDED VIDEOS

The geotagged video is added to the XeoTV Visor environment where it is linked to a map provided by the user. The XeoTV Visor interface is split in two main widows (see Fig. 5). The browsing window (right) allows the user to navigate the map and displays each recorded trajectory; the user can select the seabed section that needs to be analyzed and it will be displayed in the video window (left) alongside relevant information regarding that section. Several browsing capabilities are provided, including temporal and spatial displacements, different zoom options and several filtering capabilities, and the interface can be used to annotate and highlight interesting events which will be reflected in the map (*i.e.* PoI).

VI. CONCLUSIONS

The XeoTV and XeoTV Visor tools released by HCTech in 2010 eased the task of keeping track of the seabed status. With XeoTV HD and its deferred filtering, we provide greatly improved image quality while simplifying further the recording procedure. We hope this technology will encourage more and better seafloor inspections, thus providing better ecologic treatment for our seas upon we all depend.

REFERENCES

[1] Hércules Control S. L., "Xeo-Tv Program a Powerful Tool that Allows the Realization of Submarine Goereferenced Video" http://www.herculescontrol.com/plantaexterior/files/catalogos2011/folleto_xeotv_en.pdf

[2] Bryce E. Bayer, "Color imaging array" US Patent US3971065 A Mar. 1975.

[3] Sina Farsiu, Michael Elad, Peyman Milanfar "Multi-Frame Demosaicing and Super-Resolution of Color Images" IEEE Trans. on Image Processing 2006

[4] ISO/IEC JTC 1/SC 29 "ISO/IEC JTC 1/SC 29/WG 1 Coding of Still Pictures (SC 29/WG 1 Structure)"