DaedalusNAV: A SOFTWARE PACKAGE TO DISPLAY IMMERSIVE IMAGES OF LUNAR CAVES

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Introduction: A spherical robot meant to explore lunar caves and lava tubes (Daedalus) has been funded within an ESA-OSIP call [1, 2] and then successfully subjected to the ESA-CDF (Concurrent Design Facility) study. The Daedalus robot hosts two payloads: a Lidar and an immersive stereoscopic camera (DaedalusCAM), the latter designed by INAF researchers [3]. Recently the Italian National Space Agency (ASI) funded the development of the software for displaying the immersive image of a lunar cave. In this paper we outline the software modules to be developed within this ASI financing effort got in the framework (call) of “scientific experiments for the moon”.

DaedalusCAM: The DaedalusCAM is composed of four hyper-hemispheric lenses [4], arranged in a crossed-shaped form, with bifocal capability. Each lens can frame a panoramic field of view of 360°x100° (engineering arm) and, simultaneously, a round higher resolution field of view of 20° (scientific arm).
During the CDF, the lunar cave has been assigned to be Marius Hill [1], a skylight 60 meter wide with a depth of approximately 50 m. The Daedalus robot is planned to descend the skylight by the top aperture by means of a crane (also part of the CDF study). During the descent it is planned to frame 400 images both in panoramic and scientific modes. While the scientific arm records a portion of the skylight with coloured (optical filters) capabilities, the panoramic (engineering) arm will completely sample the cave with stereoscopic capabilities. Indeed, due to the presence of four panoramic lenses, each point in the cave wall is seen by (at least) two cameras. This large number of images, although in a moderate resolution, must be displayed to make them useful also for scientific exploration, other than simultaneous localization and motion (SLAM) useful during the descent robotic operations. We describe here the flowchart of the planned work to build the off-line s/w package *DaedalusNAV* to display immersive/stereoscopic image of the cave.

DaedalusNAV: DaedalusNAV is an off-line software package to elaborate the DaedalusCam panoramic images and display the captured immersive image of the lunar cave. The input of DaedalusNAV are (see figure 1) the (approximately) 400 panoramic 12-bit depth images coming from the DaedalusCAM campaign. DaedalusNAV is composed of 4 subpackages dedicated to 1) the auto-exposure acquisition, 2) correct the image anamorphic distortion, 3) find out the stereoscopic matching points from the image mosaics and 4) display the final immersive cave image is a user-friendly interface.

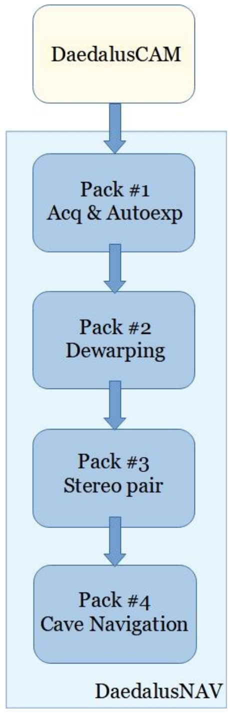

Fig 1: Flowchart of the DaedalusNAV package.

A typical (coloured) panoramic image is shown in next figure 2.

Fig 2: A typical image of the panoramic arm of one over the four DaedalusCAM sensors**.**

Pack#1: Acq and Autoexposure. Due to the extremely large field of view, the panoramic arm will necessarily work within an high-contrast scene, especially inside the cave pit. This imply that it is presumable to have both under and over exposed regions along the chipset, aside of a well-conditioned counts level. We have to study an as simple as possible auto-exposure algorithm to maximize the information recovery in such high contrast scene. Maintain a simple algorithm is important because it should be implemented into a FPGA to be used during the operational phase.

Pack#2: Dewarping. The original image shown in figure 2, is strongly affected by anamorphism and must be corrected for the optical distortion. The typical map of the lens projection used in the DaedalusCAM may be found in [4]. Figure 3 shows an equirectangular correction, just to have a quick look at the framed context.

Fig 3: Equirectangular projection (dewarping) of the original DaedalusCAM panoramic arm.

However, it must be underlined as a correct dewarping pass through an accurate laboratory calibration of the distortion, as described in [5].

Pack#3: Stereo Pair identification. Keeping in mind that each region in the cave is seen by at least two cameras, stereoscopic pairs may be found, and the distance of the cave point may be retrieved. We already started to develop such recognition. In the next figure, stereo pairs in the original panoramic (anamorphic) images, displaced by a baseline, are shown in an anaglyphic layout [6].

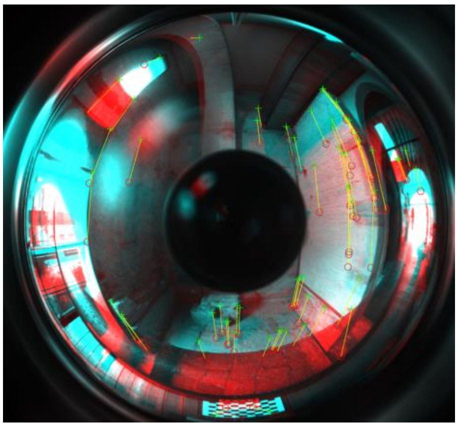

Fig 4: Stereo pair found in panoramic images.

Pack#4: Displaying the cave immersive image. Finally, the last subpackage is the user interface able to show the immersive image obtained by stitching the set of images coming out by the subpackage #2. The immersive image may be display both on a monitor with mouse-based navigation tools or directly by VR glasses, allowing an immersive navigation of the first lunar cave even explored. An example on what we mean is the 3D mesh model reconstruction of the Cueva de Los Siete Lagos (Lanzarote) within the TUBOLAN research framework [7] (see Fig. 5).

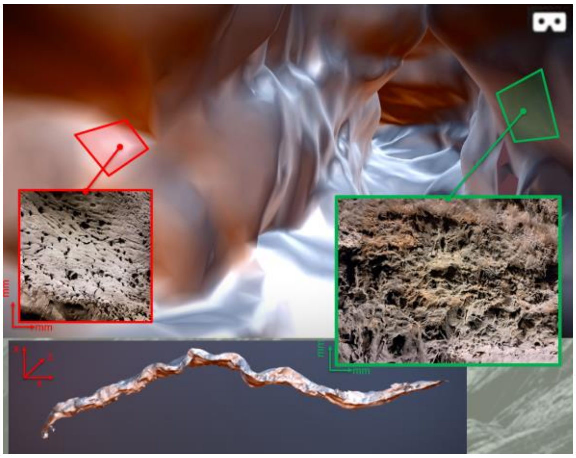

Fig 5: Example of immersive image of a lava tube.

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References: [1] M. Pozzobon et al. (2021), *52th LPSC*, #1886. [2] D. Borrmann et al. (2021), *52th LPSC*, #2073. [3] C. Pernechele et al., (2021), *NESF-ELS* #5. [4] C. Pernechele (2016), *Opt Express*, 24(5), 5014. [5] E. Simioni et al. (2023), *this conference*. [7] E. Simioni et al. (2020), ISPRS XLIII-B3. [8] https://sketchfab.com/3d-models/maguez-cave-lanzarote-75cfc427538547d9b432de3ee8ea5df8.