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A Lava Tube Lighting Solution for the SCOUT Rover's Visual System

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Abstract

This paper presents a novel lighting solution, designed to enhance the visual system of the SCOUT Rover, a robust and innovative cave exploration robot developed by the German Aerospace Center (DLR) [1]. The new lighting solution, enabling it to effectively illuminate and explore its surroundings in challenging and uncharted environments of Martian and Lunar lava tubes. It also enables efficient simultaneous localization and mapping (SLAM) capabilities due to homogeneous light distribution. A custom free form-lens system for a matrix LED system was developed to adapt the spatial light distribution especially to the lava tube topology. For this purpose, an energy-efficient LED driver circuit for high-power LEDs is realized, includes passive cooling. Future work includes the control of the brightness of the different areas in the picture. As a result, the visual illumination in lava tubes is enhanced, the way for autonomous navigation in future SCOUT Rover missions and is first tested in a Lava Cave in Lanzarote.

Introduction

The low positioning of the Rover's camera close to the ground, presents additional challenges for achieving optimal illumination. COTS lighting solutions fail to provide sufficient illumination quality to capture images at this angle. This shortfall leads to computationally intensive post-processing or artifacts caused by image noise or burned image areas. To address this gap, we developed a customized lighting system, seeing in Fig. 1, specifically designed to meet the operational needs of a rover deployed in such challenging terrains [2][3]. Our design prioritizes energy efficiency, small size and reliability, ensuring the system remains functional even in the harsh conditions characteristic for subterraneous volcanic landscapes. The illumination system is divided into five specialized areas. Each area is described in the next section.

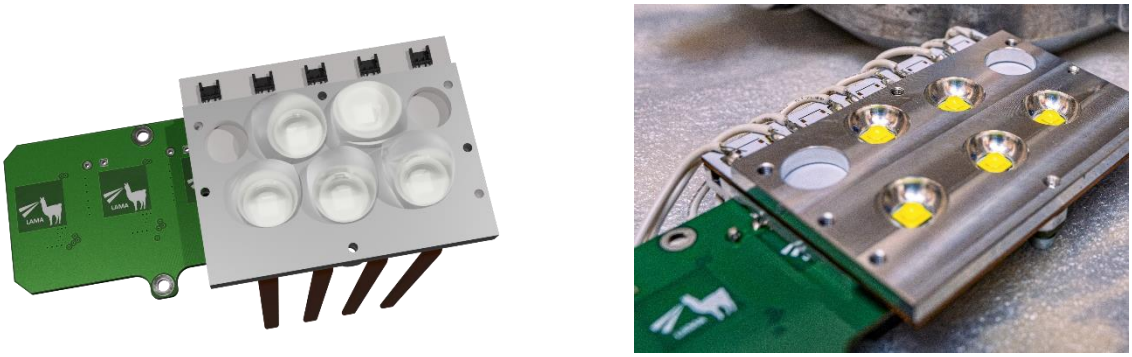

Figure 1: Render of the LAMA lighting sytem (left), Pre assembled LAMA system (right)

LED CAve MAtrix (LAMA)

Consequently, in [2], several specialized lighting zones in the field of view were identified to improve illumination of a lava tube scene: (01 Ground) lights provide targeted lighting directly at ground level in front of the rover; (2 Far/spot light) lighting penetrates deeper into cave environments; (03 Wide) and (04 Wide-Wide) zones extend to the edges of the camera's field of view (FOV), allowing for enhanced peripheral vision. Additionally, (05 Bottom) lighting allows the system to adapt if the rover flips onto its back or needs to investigate pits or downwards steps for traversibility. The different projected areas are shown in figure 2. These zones are enabled by custom free form-lens, a high efficient LED -driver system, including PWM-based brightness control and fault detection. The combination with control system enables quick, energy-efficient adjustments, enhancing illumination across the different areas without compromising power usage. With we tested during an analog-site test mission in Lanzarote [4].

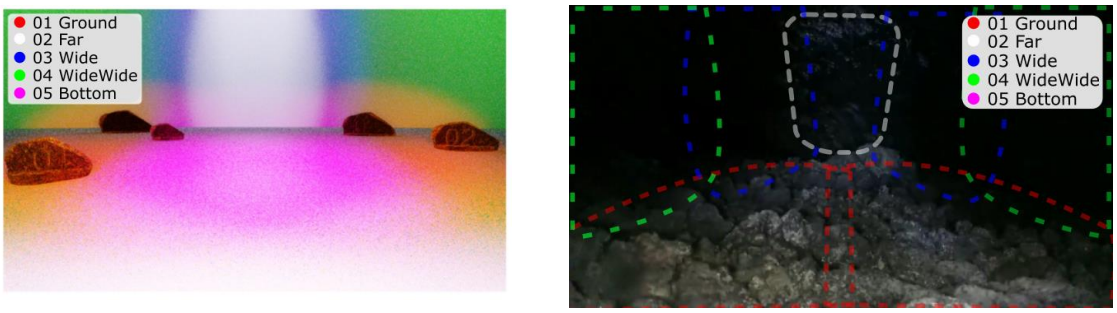

Figure 2: Simulated illumination areas for the LAMA system (left), Picture with the same areas in the real picture using SCOUT's onboard camera (right).

Conclusion

In the presentation, we will provide a detailed overview of the design of the illumination system, along with the rationale behind the development of various lighting zones, illustrating how these configurations offer an optimized solution for SCOUT Rover navigating lava caves. Additionally, we will report on the analog-site mission conducted in Lanzarote, highlighting the successful implementation of the LAMA system.

At the test side in the lava cave, we plan to conduct a comprehensive evaluation of the lighting system in actual field conditions. This involves assessing whether the pre-calculated lighting fields effectively meet operational expectations. For most of the fields in the light system, it was a great success and others will have to be further improved after the field test.

References

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