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REMOTE SENSING APPLICATIONS FOR MARS COLONIZATION AND SELF-SUSTAINABLE URBAN DEVELOPMENT.

ABSTRACT

With the imminent goal of sending humans to Mars by 2030, ensuring human resilience and survival on this planet becomes crucial. The objective of this article is to explore the applications and importance of remote sensing techniques in three fundamental areas for human settlement on Mars: landing site identification, Martian minerals mapping, and self-sustaining city planning. The selection of landing sites involves leveraging remote sensing techniques, such as semantic segmentation, deep learning, and image filtering. Additionally, mapping Martian minerals requires the implementation of spectral unmixing and water quantification methodologies to identify areas with significant mineral and water content. Furthermore, remote sensing can support the planning of ecologically oriented cities by providing analysis-ready data layers and facilitating analyses of urban population growth. Overall, the application of remote sensing in Mars exploration is fundamental to ensure the success of current and future missions. As humanity takes this significant leap towards becoming a multiplanet species, further research and development in remote sensing will be important for human exploration on Mars and guarantee a prosperous future for upcoming generations.

KEY WORDS: Mars Colonization, Remote Sensing, Landing, Minerals Mapping, Sustainable Mars City, Image Segmentation, Spectral Unmixing, Deep learning.

INTRODUCTION

Mars has long captivated our imagination, and the possibility of colonizing the Red Planet has been a topic of scientific and public interest for decades. With NASA's goal of sending humans to Mars by 2030, the question of ensuring human resilience and survival in this distant world has become a pressing concern. In this context, remote sensing technologies and data are vital for identifying suitable landing spots, locating, and mapping natural resources, and developing self-sufficient, sustainable cities on Mars's surface. Firstly, traversable, and untraversable areas (primary concern for transportation and landing purposes) can be identified by implementing satellite imagery, deep learning, and image segmentation methodologies. Moreover, spectral unmixing has allowed for the identification of zones with a high presence of hydrated minerals and the creation of Mars water-distribution maps. Lastly, the implementation of ready-to-use cloud platforms like Google Earth Engine and user-friendly applications with satellite imagery will support decision-making for terraforming Mars and developing self-sustainable and ecological cities. By leveraging and applying these technologies in advance, humanity will be better equipped to succeed in this mission, and as a result, we will be able to understand better the challenges and opportunities that colonizing a new world brings.

IDENTIFYING A SUITABLE LANDING SPOT

Selecting an appropriate landing spot is a crucial task to ensure the success of any exploratory space mission. During this complex process, which can take more than 4 years (Golombek, et al. 2012), engineering and scientific requirements are constantly traded off, and several selection criteria are applied. Some of those criteria include land traverse capabilities, rock abundances, elevation, and slope values (Pajola, et al. 2019). For this task, remote sensing techniques/data have been proven to represent surface characteristics accurately (Golombek, et al. 2005), leading to the correct selection of landing places with the maximum scientific return and minimum cost (risk and budget).

Identification of traversable and untraversable areas is a main concern for the transportation of equipment, resources, and human personnel. For this purpose, semantic segmentation with convolutional neural networks, and a deep hierarchy of image filters have been applied using HiRISE imagery (Ono, et al. 2016). As result, in landing sites such as NE Syrtis (Figure 1), terrain classes like craters, rock fields, smooth regolith, and smooth outcrop, have been labeled. Additionally, Golombek et al. (2012) propose an algorithm with HiRISE imagery to estimate rock abundance from shadow segmentation. This algorithm derives the rock height and rock diameter respectively from the shadow length and shadow width. Finally, to determine suitable landing sites based on elevation and slope values, Digital Elevation Maps (DEMs) can be generated from HiRISE images. The process consists of a stereo correlation, generation of a point cloud, and Ortho-projection of the point cloud into a DEM (Ono, et al. 2016). The discussed methodologies and examples given evidence the different satellite imagery, deep learning, and image segmentation applications for selecting suitable landing sites on Mars's surface.

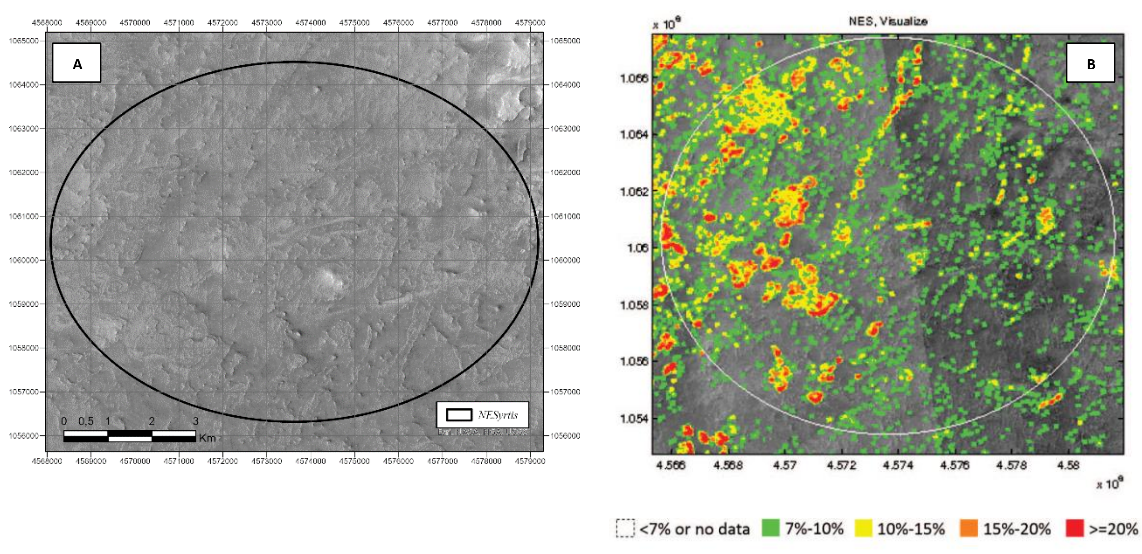

Figure 1. (A) NE Syrtis Map. (B) CFA (rock abundance) map on NE Syrtis. (Ono, et al. 2016)

MAPPING MARTIAN MINERALS

Another fundamental factor in space colonization or exploratory missions is the availability of natural resources. Understanding the geological processes and mapping the minerals present on Mars's surface it's essential not only to characterize past habitable areas in the search of life signs (Keresztury et al. 2016), but also to locate areas with a significative presence of minerals than indicate aqueous phases, including phyllosilicates, carbonates, or sulfates (Paloja, et all. 2019). The identification of the previously mentioned minerals supply information on the water-ice distribution of Mars and helps to determine suitable zones for human settlement with an important presence of this natural resource. Therefore, remote sensing workflows like spectral unmixing and water quantification will effectively support potential future roving and human missions, by minimizing the logistical challenges of sending resources from Earth to Mars and providing the exact location of the water and critical minerals.

This challenge has been addressed with data obtained by different orbiters, including the Mars Express Orbiter, which was launched in 2003 by the European Space Agency, with a visible and near-infrared mapping spectrometer (OMEGA) whose main scientific objective is to obtain global high-resolution photogeology and carry out mineralogical mapping (Chicarro, et al. 2004). Riu, et al. (2022) using the hyperspectral image-cubes of OMEGA, with a range spectral resolution from 1 to 2.5 µm, derived the quantitative composition of hydrated minerals by performing spectral unmixing for Nontronite, Saponite, Kaolinite, Beidellite, Opal, Celadonite, Magnesite, and Lizardite endmembers, based on the MOCCAS spectral library. As result, different zones were identified with a high presence of hydrated minerals, including the Marwth Vallis, Nili Fossae, and Meridiani Planum.

Moreover, based on the study carried out by Riu et al. (2022), A Mars map of H2O content (Figure 2) in wt% stored in hydrated silicates was created, finding that on average the silicates are composed of ~5 wt% of water and regions with >20 wt%. (Rio et al, 2023). In short, remote sensing techniques like spectral unmixing are decisive for mineral and water estimation, which will allow the selection of spots that support human development.

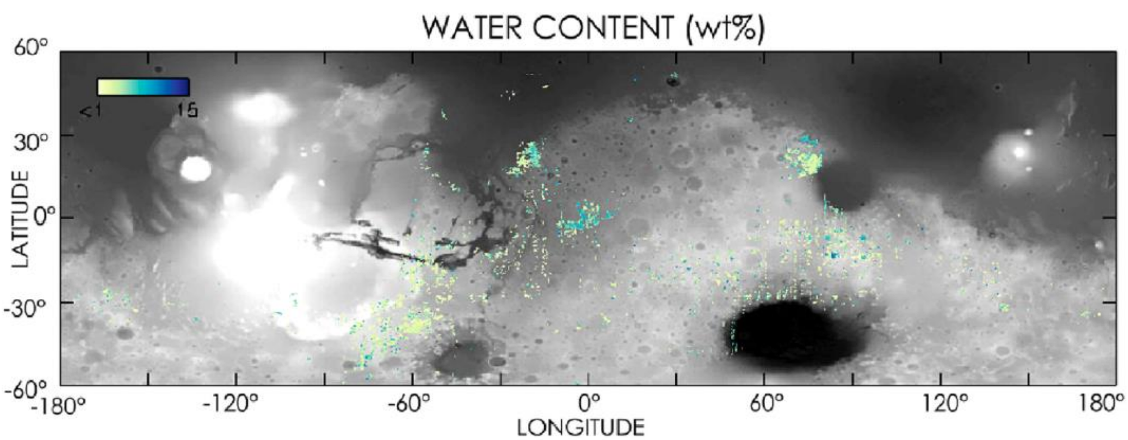

Figure 2. Mars map of H20 content in wt% as stored in hydrated silicates. (Rio et al, 2023)

PLANNING SELF-SUSTAINABLE CITIES

As mentioned in Destinations Mars – The Story of Our Quest to Conquer the Red (May A. 2017, p. 92), landing on Mars is not the final goal, but rather a single step in a long and ongoing process. As a result, long-term Mars colonization missions will have to overcome (eventually) numerous shortcomings, including high radiation levels, and lack of air, water, food, and building materials.

However, the biggest challenge for Martian colonizers will be the lack of freedom due to the Martian hostile environment and high levels of carbon dioxide (May A. 2017, p. 97).

To solve those difficulties, the terraforming process (making an alien planet more Earthlike), has been proposed. (Fogg, M.J. 1998). This includes the design, creation, and development of ecologically oriented cities as on Earth. Considering the previously, remote sensing data/techniques can be implemented to understand Mars' ecological, economic, and social-political needs, with the aim to support planning decisions. Wellmann, et al. (2020) present three ways in which remote sensing will improve Social-Technological-Systems and urban governance on Earth. Ideas that can be implemented on Mars. First, they suggest potentializing the usage of ready-to-use cloud platforms like Google Earth Engine, and the creation of Urban Data Cubes (UDC). Contributing with analysis-ready data layers (aerial/satellite imagery, pre-classified/computed products) which can be used for cooling potential, connectivity, and land use analysis (Lehmann, et al. 2020). Additionally, they consider that the diffusion of Imagery data on user-friendly web applications will promote projects and proposals focused on urban population growth and climate change (Wellmann, et al. 2020), challenges that will be present on a long-term basis on Mars. And finally, they support the linkage between Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) procedures with remote sensing data and knowledge, with the objective of assessing the impacts of environmentally aware policies. By implementing those remote sensing workflows on Mars, cities will be ecologically sustainable, and colonization/terraforming of Mars's surface will be feasible.

CONLUSIONS

In conclusion, after thousands of years of humanity's interest in Mars, we are less than a decade from evidencing the landing of the first humans on the red planet. The available technology seems to show us that now it's possible. However, the preparation and understanding of Mars's nature and phenomena are crucial to secure the success of this mission. In this scenario, remote sensing technologies and data are vital for identifying suitable landing locations, mapping and estimating natural resources availability, and promoting the creation of self-sufficient and sustainable cities. The importance of this mission extends beyond our ability to survive on another planet, as it also offers a unique opportunity to expand our knowledge of the universe and our place within it. In the future, further research and development will be necessary to improve our understanding of Mars and to continue to push the boundaries of human exploration. As we move forward in this endeavor, we must keep in mind the potential risks and challenges while staying focused on our goal: to expand our horizons and build a better future for ourselves and future generations.

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