Paper ID: 84612
oral
student

IAF SPACE SYSTEMS SYMPOSIUM (D1)
D CATEGORY "INFRASTRUCTURE" - Extra Session (8)

Author: Mr. Alessio Derobertis
Politecnico di Milano, Italy

Dr. Toshinori Kuwahara
Tohoku University, Japan
Dr. Paolo paolo_lunghi
Politecnico di Milano, Italy

VISUAL-BASED LUNAR POSITIONING USING A MULTI-STAGE MULTI-HEAD NEURAL NETWORK

Abstract

The Moon has emerged as a central focus in contemporary space exploration, as evidenced by the growing deployment of satellites for both orbital and landing missions. Autonomous navigation poses a significant challenge for these missions, and while various methods have been developed, optical navigation stands out as a promising solution due to its efficacy and suitability for hardware miniaturization, enabling a reduction in required sensors to just a camera. Research, spanning traditional algorithms to machine learning and deep learning, has explored applications from surface proximity to distant approaches. Despite notable advancements, a comprehensive absolute navigation system remains elusive, as existing solutions are often restricted to specific applications such as landings or fly-bys. Moreover, these solutions frequently estimate the state of the spacecraft in relative terms only. This paper introduces an innovative end-to-end deep learning solution for absolute lunar positioning, extracting geospatial information, and expanding the range of altitude constraints. Covering distances from tens to hundreds of kilometers, the proposed approach addresses a wide spectrum of scenarios, providing spacecraft localization in diverse conditions. The algorithm is built on a deep neural network architecture for localization. Taking as input a grayscale picture of the moon's surface, it is trained to output a probability map of the satellite's position through a multi-stage feature extraction process. Initially, the network undertakes the classification of the input image to determine its corresponding region on the moon's surface. Subsequently, the image is aligned with a comprehensive representation of the observed site. This alignment process is allowed by a multi-head architecture, consisting of multiple segmentation autoencoders, to cover the whole surface. The resulting output is finally transformed into position information. What sets this approach apart is its flexibility; localization can be executed from any location around the moon, provided a surface image is available, and position estimation occurs in an absolute reference frame. The network is trained in a fully simulated environment, producing photorealistic images akin to those captured by a flying satellite. Real features are replicated using texture from NASA's LROC mission dataset, while lighting and shadows are simulated in an ephemeris-based scenario to achieve a real-world appearance. This innovative positioning scheme is compared to the current state-of-the-art in optical navigation, and potential applications for miniaturized Moon missions are explored, showcasing the versatility and advancements in absolute navigation methodologies.