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A TERRAIN FEATURES LINKED PATH PLANNING METHOD BASED ON POINT CLOUD CARTOGRAPHY FOR COMPLEX LUNAR ENVIRONMENT

Abstract

In the process of lunar exploration and development, harsh environment makes long-term manual operations difficult. Therefore, autonomous lunar robots play an important role. When traveling on complicated lunar surface, autonomous path planning is one of the critical technologies. Unlike the Earth's surface, the lunar terrain under exploration is complex and blanketed with delicate lunar regolith, significantly impacting the mobility of lunar robots. For example, wheels can easily sink into regolith on steep slopes, and motors require more power during ascent, generating more energy consumption. Therefore, taking terrain into considerations is of great importance in lunar exploration. Traditional ground path planning methods that employ gridded maps lead to a great loss of detailed terrain information. These approaches result in a binary terrain classification of grids as passable or impassable based on oversimplified standard, such as slope gradient. These standards fail to account for robots' movement state, such as travel direction. Consequently, feasible paths such as those ascending gentler slopes on hills with asymmetrical gradients, are often improperly classified as impassable by these methods. Moreover, traditional methods prioritize obstacle avoidance and do not have the capability to optimize energy efficiency during pathfinding. To address these deficiencies, a terrain features linked path planning method based on point cloud cartography was presented within this study. Firstly, this advanced method transcends the limitation of conventional grid-based models. It takes advantage of rich details of point cloud data to characterize terrain and employing spline curves to describe proposed paths. The method uses control points as optimization variables, allowing path planning for lunar robots is modeled as a continuous optimization problem. Secondly, feasible pathways are expanded by evaluating terrain obstacles from a multidimensional perspective, including terrain, travel direction and chassis attitude. Subsequently, the model of energy consumption for robots during travel is established precisely based on continuous terrain data and paths. Indicators such as energy consumption, and path curvature are integrated as penalty functions into the overall objective function, enabling a comprehensive optimization of the navigational route. Moreover, heuristic algorithms are used to perform autonomous path planning mission. Simulations and physical validations were conducted in the Simulated Lunar Operations and Robotics Laboratory which equipped with high-fidelity regolith simulant. Compared to traditional methods, a pronounced reduction in energy consumption and a significant contraction of autonomously navigated paths have been observed. This path planning method was confirmed effective in overcoming challenges associated with lunar robot

autonomous path planning mission.