Flash-LIDAR based Terrain Relative Navigation for Autonomous Precision Lunar Landing

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In recently, lunar exploration is a hot issue in space development. Many country which are interested in space development started to research and development lunar orbiter, lander and rover. By advancement in technology as sensors and on board computer, goal of lunar landing became autonomous precision and safe landing at the interesting location, not just landing somewhere. For precision landing without enough information about landing location, real time sensor data and data processing results have a great effect on navigation during landing phase. In this paper, we focused on terrain relative navigation using flash-LIDAR for lunar landing. During breaking and approach phase in powered descent phase which are available LIDAR(Light Detection And Ranging) sensing, terrain relative navigation can be given more precision current position information to the system. With these results, new guidance and control commands can be generated to approach target point.

The goal of this paper is design and simulation terrain relative navigation based on flash-LIDAR sensor for autonomous precision lunar landing. We defined simple mission and selected available sensor for mission requirements. With this sensor, 3D flash-LIDAR sensor modeling was performed and terrain relative navigation system was designed and simulated.

Terrain relative navigation is the absolute position estimation by comparing terrain measurements from sensor with prepared terrain map. Camera, laser altimeter, or LIDAR systems can be used for terrain relative navigation sensor. But the camera has a limitation for lightning condition and laser altimeter required long time data series. Using LIDAR, terrain measurements can obtain whenever regardless of lightning condition faster than laser altimeter. Thus we considered the LIDAR system – especially flash-LIDAR system – for terrain relative navigation during powered descent phase. Since the outputs of many LIDAR systems used for navigation are a point or a line at a time, scanning is required to get area information and it takes much time. However, the powered descent phase takes just 6 to 7 minutes around, therefore faster sensing could be produced more accurate results. Flash-LIDAR system can generate sensing results for fixed area at a time similar as a camera operation, it is more efficiency and faster for large area scanning.

We designed a terrain relative navigation system using flash-LIDAR system to minimize navigation error during powered descent phase in autonomous lunar landing. Terrain relative navigation algorithm has mainly two parts of terrain mapping for sensing measurements and data filtering for state update and estimation. Filtered output is the final estimated position. Terrain mapping is the process to refine sensor measurements to estimate absolute position in navigation algorithm. From the flash-LIDAR measurement, sensor elevation map is generated. And with generated elevation map, considering motion and angular velocity of a lander, correlation method calculates best estimate position by comparing with prepared terrain map. For state update and propagation, estimated position in terrain mapping process is used with other state measurements as angular velocity and attitude. State variables are estimated in filtering process and estimated states are used again in terrain mapping process.