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PRECISE POSITION CONTROL FOR THE PINPOINT TOUCHDOWN TO THE ASTEROID SURFACE

Abstract

The asteroid explorer "Hayabusa" succeeded to return to the Earth with an asteroid sample. Japan Aerospace Exploration Agency (JAXA) is now developing the successor of it called "Hayabusa2" which is planned to be launched in 2014. One of the differences of Hayabusa2 from Hayabusa is to make a crater by an "impactor" on the surface of an asteroid. As the optional mission, Hayabusa2 aims to touchdown onto this crater in order to sample the newly exposed material. We call this operation as "pinpoint touchdown" in contrast to "nominal touchdown" as performed by Hayabusa. The radius of the impact crater is predicted to be a few meters. Therefore, the operation of the pinpoint touchdown requires controlling the position of the spacecraft more precisely compared to the nominal touchdown case. In the low altitude (lower than 100 [m]), the presence of the transmission delay time between the spacecraft and the ground station (over 30 minutes) makes it impossible to remote control of the position of a spacecraft from the ground. Therefore, the spacecraft have to control its position autonomously in order to avoid colliding to the asteroid, in the final descent of the touchdown phase. In this autonomous control phase in the low altitude, the six degree-of-freedom (position and attitude) control which controls each degree of freedom independently is performed. This control is based on applying the switching curves and a sliding-mode control scheme, and was verified its robustness in the actual touchdown operation of Hayabusa. Although this control method is robust, it needs a lot of fuel in the case of the pinpoint touchdown due to the severe requirement to the control accuracy. Therefore, we propose to incorporate the Model Predictive Control (MPC) scheme into the six degree-of-freedom control method. The MPC method can explicitly consider constraints in the controller design and can predict future states using dynamical model of the plant. Hence, it is expected that the fuel consumption can be reduced from that of the ordinary six degree-of-freedom control method exploiting the information for the predicted future states. In this paper, we present that the feasibility of MPC method in comparison with the ordinary six degree-of freedom control method in terms of the fuel consumption, touchdown reliability and accuracy.